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Interaction of lexical-semantic and imagery representations.

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Dedication

I dedicate this work to my niece Louise Rachel Jordan (1986-1998). Louise kept my priorities in perspective. It is necessary to come out of the woods to see the landscape, and in our studies of psychology we must not lose sight of humanity. The whole is infinitely greater than the sum of its parts.

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Abstract

We report a series of experiments using a new methodology to investigate the relationships between visual and verbal representations and the process of acquiring new semantic associations. Transfer of associative information between stimulus modalities was investigated by training paired associations between novel pictures and novel words. Our results showed that the transfer of associations is a symbolic process, occurring only when participants are aware of the correspondence between the visual and the verbal items afforded by the name relations. We also obtained evidence to suggest that symbolic associations develop more readily from picture associations than from word associations. We argue that this is evidence that semantic knowledge is grounded in perceptual experience.

Our most striking result, replicated across experiments, is that transfer of associations between modalities only occurs when subjects have specific conscious awareness about the relationships among associations. This should have implications for cognitive theories of symbolic representation. The methods we developed to expose this phenomenon can be extended to examine those implications more thoroughly.

We discuss some of these implications in the terms of competing and complementary cognitive and behavioural theories relating representation to perception and symbols. Dual coding models fit our modality-transfer results more readily than single semantic store models, but neither is well suited for interpreting our awareness results, or for

discussing perceptual grounding of representation. The models of Deacon and Barsalou both focus on systems of distributed representations grounded in perception; the role of awareness in symbol acquisition in their models is discussed and contrasted with theories from the stimulus equivalence tradition of behaviourist research. From these considerations, we argue that implicit associations underpin symbolic associations, but that semantic knowledge is conscious knowledge about the patterns of association which link representations.

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Chapter 1

General Introduction

We are accustomed to using two symbolic systems: pictures and words. Pictures symbolise objects through a direct similarity to the objects that they represent; their meanings are directly accessible and do not have to be learned. Words are arbitrary symbols that acquire meaning only when the relationship between a word and its referent in the world is learned. Word meanings are defined either in relation to objects (or sensory perceptions), or in terms of conceptual relationship with other words. There is a large body of evidence suggesting that there are different processing systems for words and pictures. For example, words are pronounced faster than their correspondent pictures are named (Cattell, 1885; Fraisse, 1967; Glaser & Dungelhoff, 1984; Potter & Faulconer, 1975; Sperber, McCauley, Ragain, & Weil, 1979) whereas pictures are categorised faster than words (Durso & Johnson, 1979; Irwen & Lupker, 1983; Potter & Faulconer, 1975). However, because the experimental evidence is equivocal, there is no consensus about the way that the two symbol systems might interact, nor about how semantic knowledge is accessed by each system. The aim of this thesis is to explore the interaction of lexical semantic and imagery representations, and to attempt to re-evaluate existing models of semantic representation.

This chapter will highlight similarities and differences between picture and word processing and outline how the empirical evidence is accommodated by two different classes of model. The first class posits a common semantic store accessed by both picture and word representations (e.g., Anderson & Bower, 1973; Biggs & Marmurek, 1990; Morton, 1980; Pylyshyn, 1973, 1981; Seymour, 1973, 1979); the second class of model proposes two separate but interacting knowledge systems, one verbal in nature and the other comprising imagery representations of non-verbal experiences (e.g., Barsalou, 1998; Paivio, 1971, 1991; Glaser, 1992; Paivio and Csapo, 1969). Models positing different theories of semantic representation and organisation within the semantic store will also be presented. The experimental aims of this thesis are presented at the end of this chapter.

Picture versus Word processing

Reading-naming difference

Early studies of reading-naming differences relied on chronometric analysis, and tachistoscopic presentation of the words to be read or the pictures to be named. Cattell (1885) was the first to report the difference between the time taken to read a list of nouns and the time taken to name pictures of those items. He presented his subjects with 100 nouns and recorded an average reading time of 25-35 seconds, whereas a corresponding series of 100 line drawings 1 cm wide took an average of 50-60 seconds to be named. This was an especially interesting finding as he had already established that tachistoscopically presented pictures were recognised faster than tachistoscopically presented words. Cattell (1886) came to the conclusion that reading words is such a highly practised skill that the process becomes automatic whereas naming a picture always requires voluntary effort. This conclusion anticipates the influential distinction drawn by Posner and Snyder (1975) between automatic and attentional processes.

The hypothesis that the reading-naming difference was due entirely to reading being an overpractised skill was discredited by Brown (1915). He proposed that, given sufficient training, the time taken to name stimuli should be reduced, whereas training should have little effect on the time taken to read a list of the stimuli names. After 12 days of extensive training the time taken to name the stimuli was still 41% greater than the time taken to read their names, and both the reading time and the naming time showed a decrease in total time taken (17% for the reading and 26% for the naming, cited from Glaser, 1992).

An experiment that elegantly controlled for potential differences in processing times that might underly the reading and naming difference was reported by Fraisse (1967). He presented subjects with the stimulus "O". The identical stimulus was named as "circle" in 615 ms, as "zero" in 514 ms and read as the letter "o" in 453 ms. Fraisse explained the difference in terms of a response conflict when selecting the name of a picture, as the correct answer is determined by the instructions, for example, "name the shape" or "name the number", whereas reading a word has only one possible response.

Glaser (1992) argued that a printed word has a more compatible or automatic access to the internal representation of that word than a picture of the same item. He does not support the hypothesis that the reading-naming difference is due to an efficient grapheme-phoneme translation process. Strong empirical evidence for this view comes from two studies he cited that report similar reading-naming differences when native speakers were reading Chinese ideographs and naming pictures (ideographs are non-phonemic). Potter, So, Von Eckardt, and Feldman (1984) reported differences of 305 ms and Biederman and Tsao (1979) found differences of 266 ms in ideograph versus picture naming experiments.

Priming differences

A priming paradigm that has since been used extensively to investigate semantic association between words was published in 1971 by Meyer and Schvaneveldt. The initial experiment involved a lexical decision task (LDT) in which two letter strings were presented simultaneously. Participants had to press a key designated as "yes" if both strings were words, but to press the "no" key if both strings were nonwords, or if a nonword and a word were presented. The finding pertinent to the semantic representation issue was that "yes" responses were faster when the two words were commonly associated words than when the two words were unassociated. This facilitation effect has come to be known as a priming effect, and the paradigm itself as a priming experiment. There have since been many replications and variations, including studies that have used picture stimuli and both word and picture stimuli, with either simultaneous or successive presentation of the stimulus pairs.

Sperber et al. (1979) used a naming task (their Experiment 3) and found that words were read 120 ms faster than their corresponding pictures were named. They also measured the facilitation produced when the target stimulus was preceded by a related versus unrelated stimulus. A greater priming effect was produced between related picture pairs (31 ms) than between related word pairs (10 ms). Sperber et al. (1979) required participants to name both the target and the preceding item. Bajo (1988) obtained a similar pattern of results when her participants were instructed to look at the preceding item but to respond only to the target item. She reported a mean response of 515 ms for reading words compared with a mean response of 665 ms for naming pictures. However, she reported a greater priming effect for a picture naming task than for a word naming task: a facilitation of 88 ms was produced when a picture was preceded by a related picture compared with a facilitation of 44 ms for related word pairs.

Categorisation differences

The opposite pattern of results occurs when the task is changed from naming to categorisation. Durso and Johnson (1979) asked participants to categorise the target words and target pictures as natural or man-made. Pictures were categorised faster than words (525 ms and 582 ms respectively). In categorisation tasks involving a "yes" or "no" response, pictures have been shown to be categorised faster than words (Potter and Faulconer, 1975). Irwen and Lupker (1983, Experiment 1) gave participants a categorisation task in which they were required to name the category to which the word or picture stimuli belonged. Prior to the experiment, they were familiarised with the category classes for the stimuli, selected from the Battig and Montague (1969) category norms. These included animals, body parts, clothing, furniture, kitchen utensils and vehicles. Word stimuli preceded by an unrelated word were categorised more slowly (1064 ms) than pictures preceded by an unrelated picture (972 ms). However, word stimuli derived the greatest priming effect when they were preceded by a related word (272 ms) compared with a facilitation of 209 ms for pictures preceded by a related picture. It can be concluded from these studies that words and pictures access the semantic system through different pathways, and that pictures have more direct semantic access than their lexical counterparts.

Word-picture interference effects

Further converging evidence for differences in semantic access between pictures and words comes from semantic interference experiments. When participants were asked to name a picture, the presence of a semantically related word slowed down their response time (RT) relative to the presence of a semantically unrelated word, whereas word naming is unaffected by the presence of a semantically related picture (Lupker, 1979). Smith and Magee (1980) reported the opposite pattern of results for a categorisation task. Participants were slower to make decisions about category membership of words in the presence of related pictures relative to the presence of unrelated pictures, but the presence of related words had no effect on the time taken to categorise pictures.

Neuropsychological evidence

There is also neuropsychological evidence that suggests two distinct processing systems for pictures and words. Caramazza (1996) described the performance of patients with optic aphasia. Despite being unable to name items that were visually presented, they were able to correctly mime their function. Similar evidence comes from a patient, J.F, who had a modality specific aphasia; he could mime the correct function of objects that he was unable to name. Beauvois (1982) describes how J.F.'s impairment was bidirectional, in that he had difficulty in picking out a named object from an array. A visual representation of the objects had been maintained but the verbal representations had been lost.

Warrington (1981a) reported patients who had lost "visual" information whilst retaining partial comprehension. When asked for the definition of "pigeon", the response was "I know it is a bird but not which one". The same patient was able to define "bucket" as "a container" but had no notion of the size, weight or typical uses of a bucket. Warrington also reported a double dissociation between the ability to comprehend abstract versus concrete words (see Table 1.1). Warrington (1975) described two patients, E.M. and A.B., with a spoken word deficit. Their ability to perceive words was intact, as measured by their normal performance on a single word repetition task and their above average performances when repeating sentences or strings of words. Their reading ability was fine; they were able to fluently read words that they were unable to comprehend. They were able to express themselves lucidly as illustrated in the following examples. Patient E.M. had a greater difficulty in defining abstract words than concrete words, in contrast with patient A.B. who was able to give succinct and fluent definitions to abstract stimuli (e.g., he defined "supplication" as "making a serious request for help" and "knowledge" as "make oneself mentally familiar with a subject") but had considerable difficulty with concrete words. For example, when asked to define "geese" A.B. replied "An animal - I've forgotten precisely" and to "carrot" he responded "I must have once known" (p.416). A similar dissociative pattern was found by Warrington (1981b) in a pair of patients with a deep phonological dyslexic syndrome. These patients had lost the ability to perform grapheme-phoneme translations and were able to read only by means of entire word recognition, a form of direct semantic access based on a visual vocabulary. Patient K.F. was able to read significantly more concrete words than abstract words, whereas C.A.V. could read abstract words such as "industry" and "humour" but was unable to read concrete words such as "cat" or "salt". Figures for their performances are shown in Table 1.1.

Table 1.1: The percentage of correct word definitions given by patients with focal brain lesions: E.M. and A.B. had specific spoken word deficits and K.F. and C.A.V. had a deep phonological dyslexic syndrome. (taken from Warrington (1981b)

Beauvois (1982) reported several patients with neurological deficits which suggest that separate verbal and perceptual representations must be held in long term memory. An example is offered by the case study of M.P. who had a specific colour aphasia. She had a high IQ score (123), good visual acuity and high verbal abilities, but she was profoundly impaired on her ability to verbally access stored colour representations. What makes this case particularly interesting is that M.P. was able to perceive colours and could perform colour matching tasks involving selecting an identical colour chip from an array. She could also select the object that was an appropriate colour from a series of 5 pictures of the same object, for example, the yellow banana rather than the blue or purple one. Her verbal use of colour words was also intact; for example, she could correctly answer which colour is associated with "envy", or decide that "blush" is best categorised by "red" rather than "yellow" or "brown". She was able to perform at ceiling with verbal naming tasks where the colour of the object does not correspond with its name; for example, when asked to give an alternative name to a variety of ham that has two common names, she was able to report that *Jambon de Paris* is also known as *Jambon blanc.* This particular variety of ham is a distinctive pale pink. However on tasks where she was relying on verbal access to her knowledge of colours, she was unable to give a correct response above chance. For instance, when asked to point to different colours, she pointed to bright blue for pale green, and to yellow when asked to point out the colour of red currant jelly. She selected dark blue as the appropriate colour for a tangerine, and red for the colour of an elephant. She was unaware of her impairment, even when she was correctly able to fill in a sentence requiring the phrase "snow white", but was then unable to report the dominant colour in an imagined alpine skiing scene. Beauvois argues that this evidence suggests not only separate visual and verbal representations for each colour, but also demonstrates that the two systems are interactive.

Semantic Models: Dual Coding versus Common Semantic Store

The data patterns described above have been accounted for by two opposing classes of model. The first hinges on the notion that pictures and words for the same referent share the same semantic representation, but that there are processing differences prior to the activation of this representation by verbal versus perceptual stimuli. The second assumes that verbal and perceptual information are coded in two distinct systems.

Common semantic store models

There are many models that come under this umbrella, but central to all of them is the assumption of a central, abstract, amodal propositional code for long term storage of both verbal and perceptual information. Because of the way we tend to recall only the salient details of an event or of verbal information, and forget many of the unimportant details, it has been proposed that the meaning of a picture or a sentence is abstracted and encoded as a network of propositions. "Proposition" is a concept borrowed from logic and linguistics. It is defined as the smallest unit of knowledge about which a true or false judgement can be made (Anderson, 1990). The propositional network allows for hierarchical organisation of information. The closer two propositions are associated within the network, the more likely they are to serve as effective recall cues for each other (Anderson, 1990). Words derive their meaning through the conceptual propositions in the semantic store; they have no direct access to representations of perceptual or sensory motor experiences. Anderson proposes that propositions are represented as an amalgam of two classes of concept, "argument concepts" and "predicate concepts", which are distinguished in terms of their function. Predicate concepts attract argument concepts and form the relational network in which argument concepts are bound. Concepts can be defined in terms of semantic features, or defining predicates, for example, "a bird has wings" or "a bird is an animal" (Engelkamp & Zimmer, 1994).

Anderson (1974) provides some evidence for the abstraction of meaning and the loss of specific details which he argues is evidence for the propositional nature of semantic memory. His subjects listened to a story and were later tested on a series of critical sentences extracted from the story and asked to identify which sentence from a series of similar sentences was the one that they had actually heard. For example, the story contained the sentence: "The missionary shot the painter", but given a choice between the original sentence and "The painter was shot by the missionary" only 56% of subjects were correct after a delay of 2 minutes. When given the task immediately after hearing it, 99% of the subjects were correct. However, when asked to discriminate between the original sentence and the following "The painter shot the missionary" or "the missionary was shot by the painter" 96% of subjects selected the correct sentence after a delay of 2 minutes and 98% were correct immediately. This illustrates that it is not the words themselves that are recalled, but the meaning behind the words.

Similar evidence, but of a visual nature, comes from Nickerson and Adams (1979) who asked their subjects to sketch an American penny coin. Although most people recalled that it features Abraham Lincoln's head and the date, they performed virtually at chance when deciding which way round the head is facing or whether the words "In God We Trust" or "United States of America" appeared on the same side.

Information from external events or percepts is translated into this propositional code if it is to be stored or used in cognitive operations. The propositional code is not available for conscious inspection. For perceptual or motor information to be made available to language based activities, extensive recoding is required (Glaser, 1992).

To these ends, some models, including Seymour (1973) and Snodgrass (1984), contain specific storage and processing systems for perceptual and for verbal information. Seymour's model (shown in Figure 1.1) contains an adaptation of Morton's logogen model (1969, 1970).

In this model, the iconogen system contains prototypical or canonical representations of everyday objects and motor programs for practised actions. The logogen system contains morphemic representations of all the words within an individual's lexicon, together with their syntactic, phonemic and orthographic properties. Differences between the response rate for pictures and words have been accounted for by assuming that words activate phonemic information prior to activating semantic information, but pictures activate the semantic system first, and that pictures have access to more elaborate visual codes than do words (Nelson, Reed, & McEvoy; 1977). A slightly different adaptation was proposed by Te Linde (1982) who suggested that word stimuli might be able to bypass the phonemic processor and directly access the semantic store.

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Figure 1.1: Seymour's (1973) model of a central abstract semantic code. Taken from Glaser (1992).

This is not an implausible suggestion, since deep dyslexics are able to access semantic information from a written word when they have lost the ability to read that word. For example, a patient shown the word "peach" says "apricot" (Hinton & Shallice, 1991). This shows that the mapping between the visual form of the word and its semantic representation must be preserved because the error is dependent on the probe word (in this example the word "peach"). However, this route would still be slower than the direct route available to pictures. If it is assumed that a word can be processed in parallel by the phonemic and the semantic systems, then this model can account for the word interference in the picture naming task reported by Lupker (1979). A feature common to all variations of this model is that words can be named without recourse to semantic activation, whereas pictures must be identified via the semantic store before they can be named.

Much support for a common semantic store comes from the picture-word priming literature. It has been argued (Sperber, McCauley Ragain, & Weil, 1979) that a prediction of this model would be cross modal priming. If pictures of related concepts can prime the naming of target words as well as other pictures, or if a related word preceding the presentation of a target picture can facilitate naming that picture, then this would indicate a common semantic representation for both words and pictures. Sperber et al. reported semantic priming for mixed picture and word pairs, an 8 ms priming effect for pictures priming words, and a 10 ms priming effect for words priming picture targets. The effects were quite small, but comparable with a facilitation of 10 ms in a word-word condition, and 31 ms in the picture-picture condition. Similar results were reported by Carr, McCauley, Sperber, and Parmelee, (1982, supra threshold condition) with a 24 ms effect for pictures priming words and a 29 ms for words priming pictures in a naming task. Durso and Johnson (1979) failed to produce a picture-word priming effect in a naming task but found a larger priming effect for picture-word pairs than for word-picture pairs in a categorisation task (110 ms and 83 ms respectively). These results were also taken to support the notion of a common semantic store. Since then, many other researchers have reported a cross modal priming effect between pictures and words and vice versa (Bajo & Canas, 1989; La Heij, Dirkx & Kramer, 1990; Irwen & Lupker, 1984; Kroll & Potter, 1984; Vanderwart, 1984, (word-pictures only); Bajo, 1988; Biggs & Marmurek, 1990).

Biggs and Marmurek (1990) proposed that the facilitation that occurs in naming the second of two items is a function of an overlap in processing. This can occur in the initial visual analysis, the phonemic processing or response, or the common semantic system. They proposed a variant of the single semantic store model. They assume different initial processing systems for pictures and words, but with both systems accessing a single semantic store (illustrated in Figure 1.2). Words are processed initially through a lexical system compatible with Morton's (1980) logogen model, which accesses a rule governed phonemic processor allowing spelling to sound translation and access to a lexicon which accommodates whole word recognition.

This would present two routes for pronouncing a written word, which accommodates the previously reported failure of categorically related word primes to facilitate word naming (Huttenlocher & Kubicek, 1983; Lupker, 1984). This model can accommodate the failure of picture-word priming, because naming a picture and naming a word do not necessarily have processing in common. Picture naming can only occur after semantic analysis has occurred, whereas a word can be named without accessing the semantic store. Biggs and Marmurek (1990) shared many of the assumptions of Snodgrass (1984). Processing within the model is described in terms of depth of processing. The first level is the processing of physical information, then prototypical information about that word or picture is processed. The deepest level is amodal propositional analysis in the common semantic store. It is not assumed that the verbal and the visual analysis systems have access to the same conceptual representations; abstract concepts are only accessible to the verbal system.

Biggs and Marmurek make no assumption that equivalent facilitation is produced in all areas of overlap, but where there are two or more overlapping processes the effects are additive. This model predicts that facilitation depends both on the physical form of the stimuli and on the semantic relationship between the prime and the target stimulus.

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Figure 1.2: Biggs and Marmurek's (1990) processing overlap model of picture and word naming and categorisation. Taken from Biggs and Marmurek (1990 p 84).

Dual coding models

The most frequently cited dual coding model is that of Paivio (1971, 1986, 1991). This model is based on the premise that cognition consists of the activity of two specialised symbolic systems (see Figure 1.3 for an illustration). They are both derived from experience, but they are differentially equipped to deal with different types of representation. The verbal system processes language-based information, the imagery system processes non-verbal representations of perceptual, affective and behavioural knowledge. Although these two systems are assumed to be structurally and functionally independent within the theory, functional interconnectivity occurs with experience, meaning that a word can elicit its referential image and an image can elicit a name. This interconnectivity does away with the need for a dedicated transfer system with its mediating interlingua of propositional representations. Paivio (1986) argued that models postulating a common semantic store are unparsimonious and lead to an infinite regress of mediating interlingua. Within the two systems, Paivio proposes hierarchically arranged modality specific units. He refers to the representational units within the verbal system as logogens, a term he borrowed from Morton's logogen model. Although Paivio (1986) did not necessarily accept all of the features of Morton's (1979) revised model, the distinct auditory and visual units for both input and output are particularly applicable for Paivio's model.

Within the imagery system, Paivio proposed "imagens" as the basic representational units. They are analogous to the logogens of the verbal system, in that they are capable of representing different sensory aspects of non-verbal behaviour. Paivio (1986) is at pains to point out that imagens are the components from which a mental image is generated; they are not available to conscious inspection in their stored state. Neither store is conceived as containing fixed entities corresponding to static objects or words; they are the units from which a complete representation is constructed. There are functional differences in the way that material is processed within the two systems. The imagery system is suited to synchronous organisation and integrative processing of memory traces, and is conceived as having a parallel processing system. The verbal system is specialised for sequential and temporal processing tasks, and like language has a linear processing function.

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Figure 1.3: Schematic depiction of the structure of verbal and non-verbal symbolic systems, showing the representational units and their referential (between system) and their associative (within system) interconnections as well as connections to input and output systems. The referentially unconnected units correspond to abstract-word logogens and "nameless" imagens respectively. (from Paivio, 1986, p. 67)

The conceptual implications of the peg word mnemonic technique for recalling a list of items in sequence formed the basis of Paivio's empirical questions about the mechanisms of cognitive processes. The technique consists of learning twenty memory peg words that rhyme with the numbers: "one-run", "two-zoo", "three-tree", et cetera. Each item to be recalled is imagined in an interactive relation with the number peg word. Thus, the first item is visualised as running or held by somebody running; the second is related to an animal in the zoo. On recall, the image associated with the number of the item to be recalled is retrieved along with its associated compound image, from which the target item can be readily retrieved. In an investigation designed to determine whether the imageability of the peg noun was the critical factor for its value as a retrieval cue, Paivio, Smythe, and Yuille (1968, cited by Paivio, 1991) carried out a series of experiments using a paired associates learning paradigm. The imageability of the words to be recalled and of the peg words were manipulated, as were other factors that correlated with a good recall performance such as frequency and verbal associative meaningfulness (the number of words that are readily produced by a given word in a free association task). By holding the values of imageability constant and varying the verbal associative meaningfulness values of the stimuli, and vice versa, they were able to establish that imagery of the peg stimulus was the most strongly related to the recall of the stimuli pairs, and to a lesser extent the imageability of the paired associate. Associative meaningfulness had no effect when imageability was held constant.

Epstein, Rock, and Zuckerman (1960) showed that picture pairs are more readily learned when they have a meaningful association, such as a picture of a hand and a bowl, but that subjects perform even better if they are instructed to integrate the images (for instance, a hand in the bowl). Paivio proposed that a compound image generated from the paired associates would be the most effective in terms of the number of correct responses on a cued recall task. The mechanism he posited for this was that the retrieval cue, (one of the original pictures) would activate the compound image allowing retrieval of the target item.

Paivio's dual coding model predicts that concrete words are highly imageable and should, therefore, have a good representation in both visual and verbal memory. In an experiment carried out by Paivio and Yuille (1969 cited by Paivio 1991), the effects of instructing subjects to use imagery during a verbal paired associate learning task were investigated. Not only did they find that this instruction produced significantly better recall, but their results indicated that concrete cue words produced the most effective retrieval cues.

Many participants in paired associate learning tasks have reported constructing an integrated image of the two items during the task. Participants who have been instructed to use this technique showed an improvement in their recall performance (Paivio, 1971). For example, given the word pair "elephant-ambulance", participants might construct an image of an elephant riding on top of an ambulance. Because concrete words are more imageable than abstract words, the data were interpreted as further support for the dual coding model.

Paivio drew on the work of Begg (1972, 1973, cited by Paivio, 1991) to build a more complete view of the structural organisation of imagery. Begg investigated the possibility that enhanced retrieval of paired associates when following imagery instructions is linked to a process of redintegration. Redintigration is defined by a comparison of cued and free recall: integration is inferred only if items are recalled better in a cued recall task than in a free recall task. Low imageability abstract pairs appear to be remembered as two separate items. When subjects generated integrated images of two concrete items their recall was better than in trials in which they generated independent images. Paivio assimilated this integration-reintegration hypothesis into his account of the effects of imagery in associative recall tasks.

Paivio (1971) predicted that if the key to the retrieval process was imageability, pictures as retrieval cues should be superior to words because pictures arouse images directly, whereas even the most imageable words have an indirect link with their images. Paivio (1991) provides evidence supporting this view from the experiments of Paivio and Dilley (1968) and Paivio and Yarmey (1966), in which pictures used as retrieval cues were superior to highly imageable words for both picture and word associates. This picture superiority effect lends support to the notion that non-verbal imagery is a mediating mechanism in associative learning, but it does not exclude the possibility that the concreteness of the items made it easier to discriminate between the stimulus members of the paired associates list. Additional evidence came from the subjects' reports of the strategies that they used. Questionnaires were used to determine to what extent subjects had used imagery, verbal or other strategies while they were learning the paired associates. There was a strong correlation between the recall scores and imagery. Verbal strategies, although often reported, did not show the same relationship to performance on the recall task.

Dual coding and image modality

Paivio's work originally focused on visual imagery because, he claimed, that visual experience was the dominant modality for most objects and events. In the imagery experiments described above, there was an implicit assumption that imagery is modality specific. To investigate this further, Paivio & Okovita (1971) tested congenitally blind participants on a paired associate learning (PAL) task. Words that have a high visual imagery rating would be effectively abstract to a congenitally blind person, whereas words with a high acoustic imagery rating might prove to be more concrete for the blind. The data from two PAL tasks provided a neat demonstration of this. In the first experiment, blind subjects derived no advantage from the condition of word pairs that had a high visual imagery value but a low auditory value, but they recalled significantly more pairs in the second condition comprising word pairs that had both a high auditory imagery rating and a high visual imagery rating. For the second condition, there was no significant difference in the numbers of pairs recalled between the blind and the sighted subjects. A second experiment added weight to the conclusion that imagery-concreteness is modality specific. In this experiment, blind participants recalled significantly more when the word pairs had a high auditory imagery value and a low visual imagery value compared with the condition in which the word pairs had a low auditory imagery value and a high visual imagery value. Sighted participants showed the opposite pattern, with enhanced performance for the pairs that had a high visual imagery and a low auditory imagery rating compared with those pairs with a high auditory and a low visual rating.

Paivio's original explanation for the advantage of concrete words over abstract words was based on the construction of a compound cue that was later redintegrated by the probe word during recall. Paivio assumes that this is a function of spatial representation in visual imagery. If spatial representation is assumed to be visual then it is difficult to explain the advantage the blind participants had in the high auditory imagery conditions. Paivio suggests that a blind person's ability to represent space might be based on exploratory activities and non-visual sensory contact with the environment. He suggests that if words evoke images of sounds they might somehow become integrated into this non-visual representation of space. This appears to be an unnecessarily elaborate explanation, as it is not difficult to imagine that two sounds could become integrated as a compound and then later redintegrated. We are accustomed to hearing many sounds at once and yet being able to attend to only one in the array; for example, when listening to an orchestra we can hear the whole composite or we can attend only to the string section or the percussion.

Verbal system

Paivio assumes that verbal processes are better suited than the integrated imagery processes for tasks that require sequential processing. This assumption is based on the sequential structure of language. Csapo and Paivio (1969, cited by Paivio, 1991) presented a series of tasks to subjects that required them to remember either the sequential order in which stimuli were presented or only the items presented. The ease with which verbal or imagery processing could occur was manipulated. Visual imagery processing was tested by briefly presenting the stimuli at a rate so fast that subjects had no time to name picture stimuli, although words could be read. Verbal processing was favoured by a slower rate of presentation. As predicted, at the faster rate of presentation recall of the sequence of presentation was worse for pictures than for words while the total number of items recalled was better for picture than for word stimuli.

On the basis of available neuropsychological data, Paivio (1991) theorised that the structures responsible for imagery are distributed throughought the brain, with different imagery related tasks being performed in different regions of the brain. He argued that both hemispheres must contain structures for referential processes as most people can identify objects presented in either the left or the right visual field, as can split brain patients. However, some imagery tasks, specifically mental transformations, are carried out more efficiently by the right hemisphere than the left hemisphere, while for tasks involving imaging letters or words there is evidence from Farah (1984) that the left hemisphere is dominant. Paivio proposes that the left hemisphere is dominant for carrying out the referential processing required in generating mental images, naming objects or describing images. Right hemisphere functions of imagery would include associative processes and non-verbal transformations.

Predictions of dual coding

The dual coding model predicts facilitation for related items in the same stimulus class. There are also two possible patterns of spreading association between the two representational systems accommodated by this model. The first alternative is that a given stimulus causes a general activation of associative links within its processing system and only specific representations are activated in the other system via the referential links. In the second pattern, there would be a general parallel spread of activation in both systems (Paivio, 1986). Because relationships within the two systems are not necessarily identical, there is no prediction that the same degree of association exists between two concepts represented in the visual system and representations of those same concepts in the verbal system. The dual coding model predicts that word targets with a representation only in the word system will derive less benefit from prior activation than picture targets that have both a visual and a verbal representation (Te Linde, 1982).

Paivio proposed that the effects of the two coding systems were additive. Evidence for this was produced by Paivio and Csapo (1973, reprinted in Paivio, 1991 Chapter 5) who demonstrated that subjects recalled approximately twice as many words when they were instructed to make an image for each word, compared with when they were instructed to pronounce the words. In addition, when subjects were told to name pictures their performance was similar to their recall for the imaged words condition.

Single semantic store versus dual coding

Anderson & Bower (1973) claimed that a problem with Paivio's dual coding theory is that it is "unclear exactly what is meant by an image" (p.230). They argue that if an image generated from a sentence is conceived as a perceptual description containing arbitrarily abstract concepts of the information contained in that sentence (e.g., it's a picture of a kind man helping a frightened dog), then there is little or no difference between the formalism of propositional representations and the imagery hypothesis. More recently Anderson (1984, cited by Anderson, 1990) modified his propositional theory to include multiple representations. He proposed that imagery representations are used to encode spatial information. Network structures of propositions alone give an inadequate account of the way that knowledge appears to be represented. However, if propositions are bound together with spatial representations to form schemas, co-occurrence relations can be encoded. A schema represents knowledge about how features tend to go together. For example, a schema for a house would contain information about the overall shape, information about the usual structural features such as doors and windows, and propositional information about the function of a house. Paivio (1991) argued that propositional approaches only have sufficient power to account for the empirical data with frequent recourse to *post hoc* assumptions. He feels that it would be unreasonable to abandon a dual coding approach unless a model was put forward that readily accommodated both positive and negative findings. He pointed out that the propositional account put forward by Anderson, which distinguished between perceptual and linguistic propositions, is merely a conceptual variant of the dual coding model.

Empirical tests of dual coding versus single semantic store models

Single store models assume that all semantic knowledge is stored within a common semantic store accessed by both verbal and visual processing systems. Although it is possible that there might be a different time course for picture and word processing prior to activating the store, once activated the time course to response should be equal. Dual coding assumes that verbal information is stored within the verbal system and non-verbal information is stored in the imagery system. The empirical question of what information is accessed more readily by different types of stimuli bears directly on the issue of where different types of information are stored. Thus, an advantage for picture stimuli over word stimuli in a categorisation task is interpreted as meaning that categorisation requires non-verbal knowledge. The faster decision times are interpreted as an indication that within system processing has occurred.

Te Linde (1982) proposed a test of the merits of the two model types by comparing the performance of picture and word stimuli on two tasks. The first task was dependent on verbal information (association judgement). The second was dependent on non-verbal information (size judgement). Both tasks required participants to make a "yes-no" key-press response about pairs of simultaneously presented stimuli. For the size judgement task, participants had to decide whether the two items were of a similar size in real life, and in the association task participants were asked to decide whether the items were associates of each other. The single semantic store model predicts an effect of stimuli, with different access rates for pictures and words, but no interaction with the type of decision required. Dual coding models predict that there will be an interaction between the stimuli and the task decision dependent on where the information required resides - in the verbal or the non verbal system. Associative information may be stored in either system depending on whether an association was acquired through verbal contiguity or perceptual experience. The dual coding model predicts a slower decision latency for mixed pairs (picture-word, word-picture) than same type pairs because items would require conversion to the same code type (either verbal or image).

The results obtained (presented in Table 1.2) showed a significant interaction between stimulus type and decision task. Decisions about the size of the stimuli were faster for picture stimuli than for words, whilst decisions about association were faster for word pairs than for picture pairs. Te Linde (1982) argues that these results support the predictions of the dual coding model and cannot be accommodated by single semantic store models. However, the dual coding prediction of longer processing latencies for mixed pairs than for same stimulus pairs was not supported.

Table 1.2: Mean "Yes-No" response times (in seconds) for Picture-Picture, Picture-Word and Word-Word pairs for decisions of association and size decisions. (Taken from Te Linde, 1982, Experiment 2)

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Te Linde put forward two possible modifications of dual coding to accommodate his results. The first posited associative links between the two processing systems in addition to the referential links (e.g., the verbal representation of "mouse" might be directly associated with the visual representation of "cheese"). This would eliminate the requirement for converting the stimuli to a common representation (image or word). The alternative modification introduced a third amodal representation system in which the processing of those tasks that show no difference between pictures and words might occur.

It has been argued that cross modal (picture-word, word-picture) semantic priming is evidence for a common semantic store (Bajo, 1988; Carr et al., 1982). Common store models also predict a common phonetic code for pictures and words, although it is assumed that pictures have to be semantically processed before they can access their phonological code, whereas words have direct access. Dual coding models can support cross modal priming via its referential and modality specific associative links. However, Bajo and Canas (1989) argue that the dual coding model predicts a reduction in cross modal semantic priming effects compared to within modality priming effects. To test their prediction, they used naming tasks with either semantically related primes or phonetically related (rhyming) primes. For the semantically related primes, their results showed equal priming effects for both word and picture primes, although the picture-word naming difference was maintained. Picture targets were named more slowly than word targets, but derived a greater facilitation from a related prime. The phonetically related picture and word primes had an equivalent effect for picture naming, but the picture primes produced less facilitation than the word primes for the word naming task (see Table 1.3. for figures).

Bajo and Canas interpreted these data as support for common semantic and common phonetic stores, on the grounds that there was no reduction in facilitation for cross modality priming. Their argument appears to be based on an assumption that a priming effect is produced at each step in the process. However, if the priming effect results only from the associative links rather than from the referential links, then the pattern described above might be the one predicted by a dual coding model, since a phonetically related priming effect would result from an association within the lexical system.

An important difference between words and pictures is the specificity of the representations they evoke: a word has one possible name whereas a picture might have more than one name. If the wrong name is selected there would be no phonetic similarity between the prime and the target. There were no experimental procedures to ensure that the subjects were actually naming the prime. Lupker (1979) failed to show any interference effects on a word reading task when a semantically related picture was simultaneously presented, whereas there was an interference effect from a related word when the picture had to be named. It is possible that picture processing does not necessarily result in a name being generated, in the same way that word processing does not necessarily result in semantic activation.

This might be dependent on the task: experiments that have failed to produce priming of a word by a related picture (e.g., Durso & Johnson, 1979; Irwen & Lupker, 1984; Sperber et al., 1979) used procedures that do not require semantic processing, whereas those employing procedures that require semantic access have obtained significant picture-word priming effects (Bajo, 1988; Bajo & Canas, 1989; Guenther, Klatzky, & Putnam, 1980).

Biggs and Marmurek (1990) claimed that the set of predictions implicit in their model would distinguish between their single semantic code model and a dual coding model. Their model predicts that facilitation may not always occur for word targets in a naming task, since words may not receive semantic processing prior to being read aloud, whereas picture targets should benefit from both picture and word primes. Semantic activation will occur for a prime word either before or after it has been vocalised, but as long as this occurs before the target picture is presented, there will be facilitation. Picture primes activate the semantic system prior to being labelled.

Dual coding models predict that there should be facilitation for related items in the same stimulus class (word-word or picture-picture). If general activation is assumed in both the verbal and the non-verbal systems, then there should be no interaction between the modality of the prime and the modality of the target, and so equivalent priming effects should be produced by both word and picture targets.

Table 1.3: Mean response latency (in ms.) as a function of the type of relationship (semantic or phonetic) relatedness, prime modality and target modality. From Bajo and Canas (1989, p. 111)

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To test these predictions, a naming experiment was performed. Because Biggs and Marmurek (1990) assumed that priming occurs as a function of processing overlap occurring in any of the processing systems, participants were required to name both the prime and the target stimuli. The following types of stimulus pairs were employed, so that the priming effects for all combinations of picture and word pairs at different loci could be investigated. The different sources of facilitation predicted for different pair types are shown in Table 1.4. Categorically related pairs were used in one condition with the prediction that both word and picture primes would cause semantic activation and facilitate the naming of target pictures, but that there would be no facilitation for word targets from either prime modality since words may be named prior to semantic activation. A repeated pairs condition was included, with the prediction that priming would occur during the initial visual analysis for the same modality pairs, but additional semantic priming would only occur for picture targets. An additional synonymous condition was developed: pairs of similar drawings representing synonymous pairs such as blouse and shirt were constructed in such a way that both possible labels could be applied to either drawing. Because of the physical similarity between the synonymous pictures, this model predicts some facilitation at both the visual processing level and the semantic analysis level. If this were true, then the largest priming effect could be expected between the synonymous picture-picture pairs, whereas word-word pairs and picture-word pairs have little or no processing overlap in the synonymous condition so facilitation would not be expected. An unrelated baseline control condition was included.

The results were not clear enough to reject either the single store or dual coding model, although the results were interpreted as supporting their processing overlap hypothesis. Picture naming was facilitated by the prior naming of an identical, synonymous or related picture, and by the prior naming of a synonymous word. Picture targets had greater facilitation from synonymous word primes than from the repeated word primes.

Table 1.4: Sources of facilitation predicted by the processing overlap model, and mean facilitation (in ms) reported for target naming latencies as a function of relationship presentation class in Experiments 1 & 2 (Biggs & Marmurek, 1990, compiled from Tables 1, 2, & 3)

This led Biggs and Marmurek (1990) to suggest that repetition of a response is not the source of facilitation in picture naming. It was also interpreted as evidence that naming a word does not automatically terminate further semantic processing of that word.

There was no evidence that prior naming of a related word prime facilitated naming a picture. Word targets were primed only by the prior naming of an identical word, although this effect was not strong (it failed to reach significance in Experiment 2). Failure to produce related word priming led them to assume that 'semantic' priming effects reported in earlier publications resulted from an associative relationship between paired items rather than a semantically mediated facilitation.

Biggs and Marmurek (1990) concluded that their experiments give further support to the existence of a common semantic system. They also concluded that word naming precedes semantic access, whereas picture naming follows semantic access. Articulating a name does not terminate word processing; semantic activation will still proceed. This experiment does not cast any light on whether picture processing will ultimately result in lexical activation, or on whether associations between lexical items will necessarily be activated.

" It remains to be determined whether a picture processed in a non-lexical way will facilitate the naming of a subsequent related picture" (Biggs & Marmurek, 1990, p. 96-97). One of the aims of this thesis is to examine the influence of non-lexical picture information associations on their lexical referents. To try to ensure that pictures were processed in a non-lexical manner, participants were presented with novel items for which they had no ready label.

Semantic Representation

The models discussed above are concerned largely with the locus of semantic information and the relationship between lexical and perceptual representations. Other models have focused on the nature of semantic representations.

Hierarchical model of semantic memory

Collins and Quillian's (1970) hierarchical model of semantic memory, and its later adaptation by Collins and Loftus (1975), have proved very influential in shaping researchers' conceptions of the organisation of semantic memory (e.g., Besner, Chapnik-Smith, & MacLeod, 1990; Fischler 1977a; Glaser & Glaser, 1989; Meyer & Schvaneveldt, 1971; Shelton & Martin 1992; Williams 1996).

This was developed from Quillian's (1967, 1969) computational model in which semantic memory was seen as having a hierarchical organisation, similar to Linnaeus' taxonomy of plants and animals. Collins and Quillian referred to the nouns in their model as superset or superordinate category names, to which properties are attached. This allowed information to be stored in a logical and economical fashion. Facts that relate to all birds in general, for example, "has feathers" and "can fly", are not necessarily replicated at the level of each exemplar but are stored as properties of the category 'bird' at a higher level in the organisational structure (see Figure 1.4 for an illustration). Embedded in this model were the assumptions that there are different types of links between concepts such as superordinate and subordinate "is-a" links, modifier links both conjunctive and disjunctive, and another form of link that allowed for verb relations to be specified between concepts. In this form, the links themselves have conceptual properties. It follows that, to determine the truth of a sentence such as "A canary has wings", an inference must be drawn from the two facts that a canary is a bird and birds have wings, rather than just accessing the properties relating to the concept "canary".

This assumption led to the following predictions: When making a decision about the truth of a statement, the more inferential steps that are required along a path of "is-a" links, the longer the decision time will be. Decisions that require access to the subordinate properties of a given superordinate node should take an equal amount of time to process. For example, the truth of the statement "A fish has gills" should be confirmed in the same amount of time as the statement "A fish has scales"; whereas the statement "A shark is an animal" would take longer because more inferential steps are required before a decision can be made. Participants were presented with a series of sentences, and the results supported the predictions. There was also a pattern of facilitation that supported the notion of "is-a" paths. If the sentence "A canary has a beak" was preceded by the sentence "A canary has wings" a faster response was obtained than if it was preceded by the sentence " A canary is yellow".

Figure 1.4: Model of Hierarchical Memory taken from Collins and Loftus (1975).

Two potential mechanisms were proposed to explain this facilitation. One relied on the metaphor of the electric maps in the Paris underground, in which a button is pressed to indicate the station to which one wishes to travel and the path of least electrical resistance lights up, indicating the shortest route. The other, which was to prove the enduring model, was that of spreading activation. This was inspired by Pavlov (1927 cited by Collins & Quillian). In this model a sentence such as "A canary can fly" would cause a spread of activation from the nodes representing the categories "fly" and "canary". The node "fly" might have pointers to other nodes such as "insect", "airplane", and "wings" as well as to "bird". As activation spreads to each adjoining node, it is tagged, until a node that has already been tagged is reached and an intersection is found that creates a path between the two starting nodes. In this example, the intersection would occur when the activation spread from the node "canary" to "bird" and found that it had been tagged by the activation spreading from the node "wings". This model allows for facilitation to occur off the direct path between the two starting nodes, whereas the subway model only permits facilitation along the direct route. For this reason, the spreading activation model supported an explanation of associative priming. An assumption of Quillian's models not illustrated here is that links are equally central to the core meaning of a given concept, and that by means of numbering them it is possible to indicate their definitive value to that concept. It is also assumed that the value of any pair of links between two concepts can be different; for example, the link between "swan" and "bird" might be more salient to the meaning of the concept "swan" than the corresponding link between "bird" and "swan" is to the meaning concept of "bird", in which "swan" is an exemplar of the concept "bird".

The semantic network approach successfully models inferential processing -- it allows access to knowledge that has not been explicitly acquired, such as learning a paired association between two concepts. It also models the way in which people are able to generate an apparently unlimited amount of knowledge from one concept. In this model, the meaning of any concept is the overall pattern activated by that concept node.

Quillian's original models were developed using computer terminology. Collins and Loftus (1975) aimed to extend the models by translating them into "quasi-neurological terms" (p 411), adding a set of local processing assumptions and a set of global assumptions about the structure of memory and memory processes.

Local processing assumptions

Collins and Loftus' (1975) local processing assumptions were as follows: The activation tags are source specific, traceable back to the node in which the activation originated. The spread of activation decreases as it spreads through the network. The gradient of the decrease is inversely proportional to the accessibility and strength of the links in a path. Only one concept can be actively processed at any one time, reflecting humans' central processing limitations, but the duration of activation released from any one node is related to the duration of continuous processing of that concept. Hence activation can only start out from one node at a given time, but, once started, activation spreads in parallel through the network. Activation decreases over time and can be interrupted by a competing activity. These last two assumptions, combined, place a limitation on the amount of activation that can be generated by using more than one prime. Collins and Loftus also introduced an assumption that an intersection requires a threshold activation level to produce firing, which will then cause an evaluation of that intersection path between the two start nodes.

Global memory assumptions

These assumptions are based on the notion that the semantic network is separate from lexical memory. Each name node in the lexicon is connected to one or more concept nodes in the semantic network. The semantic network Collins and Loftus (1975) propose is organised along lines of semantic similarity. The more closely two concepts are related, the more properties they will have in common, the greater the number of links they will have via these common properties, and the greater the total activation they can propagate to each other. For example, "lemon" will be more closely linked to other fruits than to the properties sour or yellow. Because there would be only one link (albeit a close one) between the node for the concept of "lemon" and one colour or taste concept, the total activation between related fruit-concepts, particularly other citrus fruits, would be greater. This model predicts an inverse relationship between typicality and the time taken to make a category decision about a given category instance. Experimental results (Rosch, 1973; Rips et al., 1974) show this to be the case; the more typical an instance the faster it can be categorised.

Empirical evidence supporting hierarchical models of memory comes from double dissociations reported by Warrington (1981a). She described a patient, V.E.R., who had an infarction of the front temporo-parietal region of the left hemisphere following a stroke, leaving her with a dense spoken word comprehension deficit. For example, she was unable to follow simple instructions such as "close your eyes". She was also unable to reliably point out one of a pair of common objects. When her abilities were closely scrutinised, it appeared that she was not performing significantly above chance when identifying human artefacts (63% correct, chance = 50%) but performed significantly above chance when pointing out animals or flowers (83%, and 96 % correct respectively). These findings contrast precisely with the abilities of J.B.R., a 24 year old graduate who made a partial recovery from a herpes encephalopathy. He was severely amnesic, but was left with an average IQ, and his linguistic skills were relatively intact. He had a severely impoverished comprehension vocabulary, but the loss appeared to be confined to plants and animals. When given an identification task, he got 18% of the living objects correct and 76% of the human artefacts correct. Warrington argues that this pattern of dissociation is evidence that semantic memory is categorically organised, since deficits peculiar to one category can occur.

The distinction between semantic and lexical memory allows for a spread of activation to occur either through the lexicon (words beginning with "M" for example), or through activation of related concepts in the semantic network. Loftus and Collins (1975) suggest that activation can also spread between the lexical network to the semantic network and vice versa. This model is compatible with Paivio's dual coding theory if it is assumed that the semantic network is composed of perceptually based imagens.

Multidimensional semantic space

Rips, Shoben, and Smith (1973) investigated the notion of semantic distance and constructed sets of related word meanings represented in terms of a multidimensional semantic space in which salient functional features are scalar. They obtained semantic similarity ratings for a set of 12 birds and 12 mammals by asking participants to indicate the degree of relatedness on a 4 point scale between a standard word and each of set of comparison words. Each item in each list was presented as a comparison word. Participants were then required to indicate the degree of relatedness between "bird" and then "animal" and the comparison words in the bird set and between "mammal" and "animal" in the mammal set. Another group of participants rated each of the bird and mammal items in terms of typicality for the categories of bird, mammal and animal. The data obtained were analysed using Carroll and Chang's (1970) INDSCAL program (cited from Rips et al.) which gives a general solution of instances in *n* dimensions. The salience of dimensions is taken into account by weighting the distances along the axis, stretching the more salient ones and shrinking less salient ones. The orientation of axes within the space is determined by this procedure. The solutions that they obtained containing only 2 dimensions are illustrated in Figure 1.5. Rips et al. suggest that for the set of birds the horizontal axis appears to order the birds in terms of size and the vertical axis in terms of predatory relations, with game birds at the top of the axis and predators at the bottom. The solution for mammals could also be interpreted in terms of size along the horizontal axis and in terms of degrees of domesticity along the vertical axis.

In a series of experiments Rips, Shoben, and Smith (1973) were able to demonstrate a correlation between reaction times and the derived semantic distances in several chronometric tasks. In Rips et al.'s first experiment, participants were asked to respond true or false to a series of sentences, all of which were of the structure of "An S is a P"; for example, "A sheep is an animal". Their results showed a subset effect for mammals, demonstrated by a faster reaction time for statements combining items from the mammals list and animal than for mammal, whereas items from the birds list

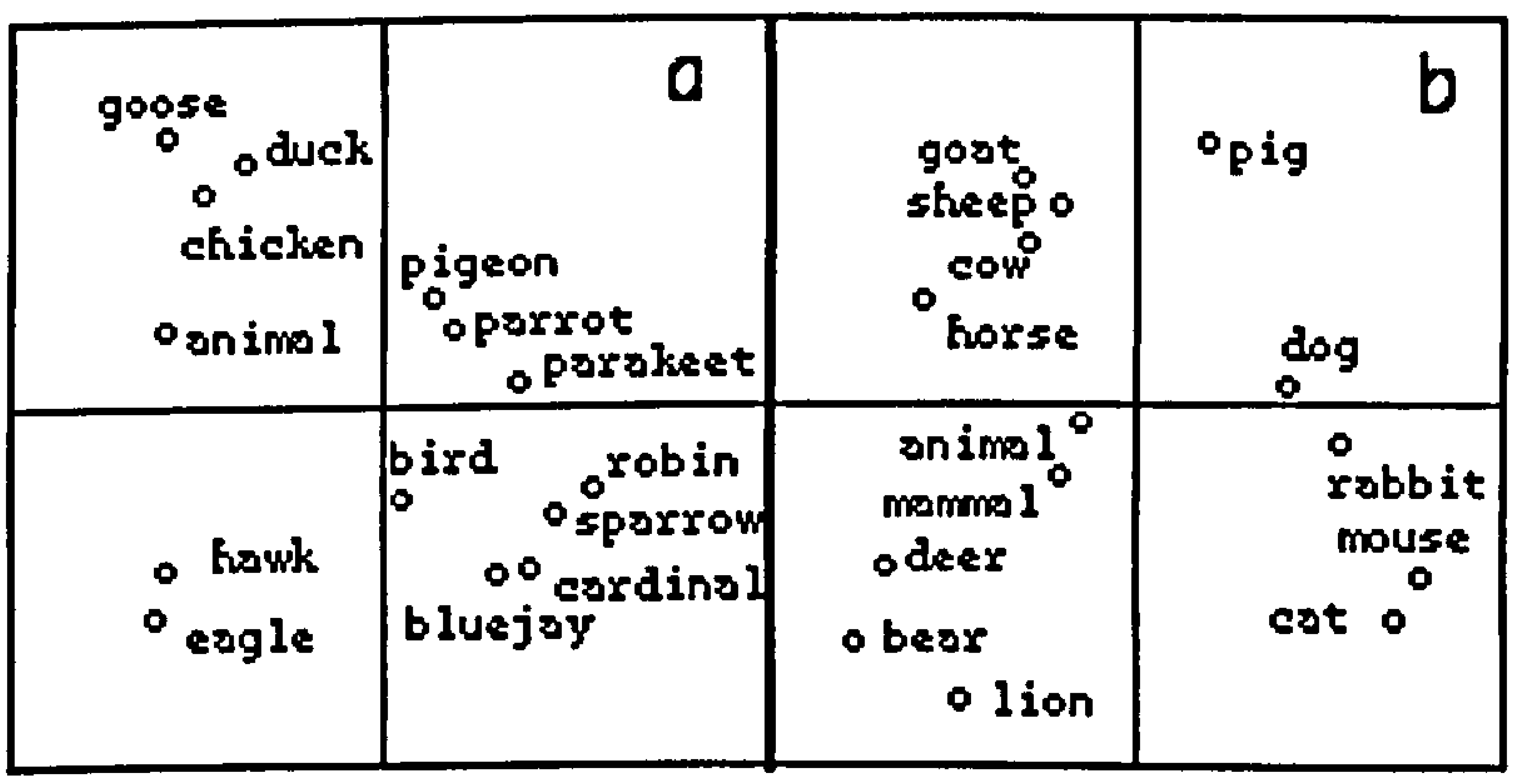

Figure 1.5: Represents a two dimensional scaling solution for birds shown in (a) and for animals shown in (b) (taken from Rips, Shoben, & Smith, 1973; p10).

produced a faster reaction time for those statements combining bird compared with animal. The subset effect was only obtained where the rated semantic distance was greater between an instance and its immediate superordinate than to its higher level superordinate. A further experiment used a categorisation task in which participants had to indicate whether two words belonged to the same category or to different categories. A significant correlation was demonstrated between the latency of decision and the derived distance between the items.

Rips et al. proposed the following theoretical mechanism to explain their data. They assumed that all functional features (those features which define or characterise an instance or a category) are treated as continuous variables. They proposed that categorisation tasks involve a two stage comparison process, in which the first stage determines the degree of overlap between the shared features of a given instance and those of its category, and the second stage discriminates between characteristic features and defining features. The second stage is required if the first stage does not provide information about which specific features are similar. This model predicts that the time taken to respond "false" will be faster if the two words are unrelated pairs than related, because the decision can be made after the first stage of processing, since unrelated pairs would show a low degree of functional feature similarity. The results of their Experiment 1 support this prediction.

Collins and Loftus (1975) argued that any feature model is representable in a network model if each of the features is represented by a node in the network. They argued that of the two models a network model is the more powerful, because it allows for inferential processes and for feature embedding, whereas it is not obvious how Rips et al's model could handle this. Collins and Loftus (1975) reject Rips et al.'s (1973) assumptions of defining features and characteristic features on the grounds that people are often unaware of which features are the defining properties of a given category.

Also, they doubt that a person would choose the same defining property across time, or whether there would be agreement between different individuals in determining between a characteristic and a defining property. By excluding the use of categorical links in their decision making model, Rips et al. are suggesting that people ignore the superordinate information available to them. Loftus (1973) performed a categorisation experiment demonstrating that the category name has a greater priming effect on the category instance than vice versa. These results would not be predicted by Rips et al's feature comparison model.

Distributed representation

A different approach to semantic representation has come out of neuronally inspired computer models; these have come to be known as connectionist models. Their starting point was considerations of what is known about the functioning and organisation of the brain. The cortex of the brain is arranged so that large regions can operate in parallel, both within and between regions. Sequential connections between cortical regions are present, but each individual area is highly parallel in its organisation. The advantage of a parallel architecture is that simultaneous processing can occur, allowing greater efficiency in both speed of processing and co-ordination of output. Parallel processing allows retrieval of an item from a partial description, or from a description of its relationship to other items when these retrieval cues are unanticipated. This basic human ability is particularly hard to implement on a conventional digital computer (a Von Neumann machine). Von Neumann machines locate stored information by using a local memory address, and it is hard to discover the address from an arbitrary subset of the contents of a given entry. Their operational design is based on the idea of a powerful, sequential, central processor operating on the passive contents of memory. This is similar to spatial metaphors of memory, such as a warehouse with specific memories stored in specific locations. In contrast, connectionist models employ a large interconnected set of simple processors, which interact in parallel via hard wired connections, a computational architecture analogous to that of the neuronal structure of the brain.

A particularly exciting property of parallel machines is that they do not assume that each item or concept in memory is represented by an individual processing unit, as in the network model put forward by Collins and Loftus (1975) described above. Items can be represented as patterns of activation across the processing units. The idea that a given pattern of activity represents a specific item is referred to as distributed representation (Anderson & Hinton, 1989). The proposal that memories are distributed across a functional area of the brain was put forward by Lashley (1950). He concluded from his neurological research on rats that memories do not reside in one specific cell, but that when an area is activated, the pattern of activation spreads across that whole cortical area. An advantage of distributed representation is that it is economical in terms of the number of representations that can be stored by a given set of processing units; the same neurones may be active in numerous different patterns of activation. Associations between distributed representations can be produced by modifying the strengths of the connections or the activation thresholds of the processing units; the pattern of activity corresponding to one item can cause a pattern of activation that corresponds with another. An argument put forward against imagery by Anderson and Bower (1973) posited that the concept of imagery "in the brain" is not scientifically viable, because it leads to a photograph or videotape metaphor, suggesting that sensations once recorded can be rerun. Interpretations of this type of memory require an homunculus to view them. Also, the storage of such perceptual memories would require an impossibly large amount of storage and retrieval capabilities. In contrast, the distributed representational memory system proposes that recall occurs by means of a reactivation of the pattern encoded at the time of the initial sensory experience. Additional storage neurones are not required for each new memory, and the processing mechanisms for comprehending the pattern of activation are the same as those employed during the original perceptual processing.

Tulving's episodic/semantic distinction

Tulving (1972, 1984) felt the need to redefine the concept of memory to draw a distinction between semantic memory and episodic memory. He had strong objections to the way that studies of language and cognitive processing had claimed to be entering the domain of memory research by virtue of the term "semantic memory", borrowed from Quillian's model of semantic memory. Episodic memory is, he suggests, a temporally ordered store of discrete events. These encodings refer to personal memories of past events, autobiographical memories; they are important for establishing an individual's personal identity. Semantic memory is the memory that is necessary for language to be employed. It is a store of knowledge about meanings of words and symbols and the relations between them. It contains the rules and algorithms for the manipulation of words and symbols necessary for language comprehension and production, and for inferential and deductive processing. It is tightly organised according to conceptual relations between entries. For information to enter semantic memory, it has to be comprehended, whereas the sensation of a stimulus is sufficient for it to enter episodic memory.

Similarities between episodic and semantic memory

Episodic and semantic memory are propositional representations, which Tulving contrasts with systems of procedural memory concerned with learning skills and procedures. Tulving states that propositional memories have a truth value, can be contemplated internally, can be communicated to others without relying on demonstration, and can be acquired through a single perceptual or thought experience, whereas the procedural acquisition of skills generally requires repeated practice.

Differences between episodic and semantic memory

Tulving claims that differences between the two systems can be observed in the type of information that is encoded, the way in which it is processed or "operated on", and the applications of the memories.

The facts and concepts in semantic memory are conceptually organised and are well suited to inferential processes, but they have no direct access to personal experience or the temporal order of their acquisition. Information enters semantic memory through language and referential events. It is accessed automatically in a manner that is more dependent on the organisation of the information within the system than the nature of the retrieval cue.

In contrast, the "base unit" of episodic memory is an event or an episode. People tend to use the word "remember" when talking about episodic information, and "know" when recalling semantic information. The sensation of a stimulus is all that is required for an event to be encoded. Although a temporal organisation of this system is proposed, with the sequence in which events occur in relation to each other being recorded, it is envisaged as only a very loose organisation. The veridicality of a belief held in episodic memory is independent of the beliefs of others. Although problems relating to the temporal order of events can be solved, this system has a very limited inferential processing capacity. Operations of episodic memory are thought to be more context dependent than those of semantic memory, though Tulving does not rule out the possibility that the encoding operations of semantic memory are context dependent. It is suggested that retrieval operations in the episodic system can result in the information being changed as it is recoded. Tulving suggests that information accessed from episodic memory is interpreted in terms of semantic knowledge, a "synergistic" combination of information.

Assumptions of Tulving's episodic and semantic memory systems

Tulving is of the opinion that episodic memory develops after semantic memory. This opinion is diametrically opposed to Paivio's assumption that the patterns of association within the imagery and the verbal system are acquired through experience. Although many researchers employ the terms episodic and semantic when classifying experimental tasks or types of information stored, this does not mean that they share Tulving's proposed functional distinctions between the two systems. He proposed that, though the two systems interact closely, each system can operate independently of the other. He presented a series of dissociations between episodically related words and semantically related words in various episodic recognition tasks. For example, faster reaction times were recorded for words that were related episodically than for words that were related semantically in an episodic recognition task, but when the same words were presented in an LDT there was no effect of the type of relation on the RT (McKoon & Ratcliff, 1979). Further support for Tulving's distinction comes from neuropsychological dissociations in amnesic patients able to recognise famous faces but unable to recall personal details (Schacter, Wang, Tulving, & Freedman, 1979). This assertion was not supported by Baddeley (1984,1986) who conceded that it is a useful heuristic, but found no evidence that these are two functionally independent memory systems. He suggested that the differences cited by Tulving can be explained in terms of differences of difficulty in the processing tasks. Baddeley took the view that semantic and episodic memory emphasise different aspects of the same memory system. He interpreted the evidence from the amnesia literature as support for a procedural / declarative dichotomy but not for a semantic/episodic division within the propositional memory system. He argued that the semantic memory tasks given to amnesics tend to test semantic material that is overlearned and had been encoded years previously, while typically the episodic tasks rely on testing the amnesic's memory for recently presented materials.

Tulving also throws open the question of the status of lexical memory. He suggests that although it makes intuitive sense to see lexical memory as part of the semantic network (e.g., Collins & Loftus, 1975) or as another form of propositional memory (Kintsch, 1980), it is equally plausible that lexical memory is a form of procedural memory with a functional role in transmitting information to episodic memory and expressing episodic and semantic knowledge.

The Symbol Grounding Problem

Both the dual coding and the single semantic store models are reliant on symbolic representation of concepts. Both classes of model suggest that the most important elements of a conceptual system are the connections between concepts; that the organisation of concepts within the system is crucial to the way that meanings are learned and to the efficacy of different recall cues. Within a system, the meaning of a given concept is defined in terms of its relation to other concepts. For example, apple could be defined as "a fruit, small spherical red, et cetera". The problem is: how are each of these terminal concepts defined? From where do they get their meaning? Red might be further defined in terms of hue and intensity, but what distinguishes the symbol for the concept of "red" when it is referring to an apple, compared with the colour of someone's hair (Barsalou, 1991; Ellis, 1994b)? At some point, these "terminal" concepts must be grounded in something that gives them their meaning. Harnad (1990) refers to this problem as the "symbol grounding problem".

Wittgenstein (1953) illustrated this problem with the following example. Someone sent out to a store gives the storekeeper a shopping list that says "five red apples". The store keeper then opens the drawer labelled "apples", looks up the word "red" on a table and finds a colour sample which he then uses to match the apples in the drawer with. He takes out each apple in turn, reciting the series of cardinal numbers until he has reached the number five and there are five apples on the counter. Wittgenstein supposes that this is how one operates with words, but it poses several questions: How did the storekeeper know where to look up the colour red? What does the word "five" mean? What is a number? This example demonstrates, according to Wittgenstein, how the notion of word meaning creates a fog which makes the study of the phenomena of language impossible. To get a clearer view it is necessary, he suggests, to study it in primitive kinds of application.

Harnad (1990) proposed that perceptual memories provide the conceptual grounding: the red that is recalled when one recalls the concept apple is the same red as was originally perceived. A word can be described in terms of other words, or a concept in terms of other concepts, but ultimately these must be grounded in terms of a perceptual experience.

Is there a perceptual/conceptual overlap?

New category exemplars are learned more easily if they have a strong family resemblance to other category members. The more features held in common with other category members, the stronger the family resemblance, especially when those features are not common to items belonging to other categories. Features include conceptual, functional and physical attributes. Structural similarity is also a major determinate of the ease in which new category exemplars are learned. The more prototypical the structure of an item, the higher its structural typicality for a given category. Both family resemblance and structural typicality influence the ease with which new exemplars are classified after they have been learned, and the order in which items are generated in a production task. Structural typicality is also a reliable predictor of the degree of facilitation that will be produced in a priming task (Rosch, Simpson, & Scott Miller 1976). In an experiment in which participants had to learn and categorise new stimulus sets, Rosch et al. (1976) were anxious to avoid stimuli that had discrete nameable attributes, so they used sets of random dot patterns. The properties of typicality held for this stimulus set. This suggests that it is raw physical attributes that are encoded as the semantic features on which similarity decisions are based, rather than on similarity based on the number of links to shared concept nodes, as proposed by Collins and Loftus (1975). Further evidence for this view comes from a priming experiment which Rosch et al. employed the random dot stimuli used by Rosch et al. (1976). Participants had to decide whether pairs of stimuli were the identical or different. The stimulus pairs were either preceded by the category name that they had learned earlier, or by a warning signal. When the prime was a category name, at least one of the stimuli was always a member of that category. Facilitation was recorded when the identical pairs were highly typical of their category set, and inhibition was produced when the stimulus pairs were atypical examples of their class. Rosch (1975) reported a similar effect when using colour categories. She explained these results in terms of "constructive memory". The category name causes a prototype to be generated, and this causes expectations about the stimuli that follow. Rosch's findings demonstrate that a noun category can be defined in terms of a set of perceptual features that cannot be verbally defined.

A study that investigated the semantic aspects of perceptual similarity was carried out by Schreuder, Flores d'Arcais, and De Glazenborg (1984). Word pairs were selected to be related by perceptual similarity (e.g., ball-apple), conceptual similarity (apple - banana), or both conceptual and perceptual similarities (apple-cherry). Perceptual information was defined as relating to the physical attributes of a particular class of objects. For the purposes of their experiment, conceptually related items were defined as those belonging to the same semantic category, avoiding pairs that were physically similar in the conceptually related condition.

Each pair was presented as prime and target in an LDT and in a pronunciation task. A significant priming effect of 26 ms. was produced by the conceptually related pairs compared with the conceptually unrelated pairs in the LDT. The perceptually related pairs produced a facilitation of 15 ms compared to perceptually dissimilar pairs. This effect approached significance ($p = .053$). The effects appeared to be additive; a priming effect of 50 ms was produced when the pairs were both conceptually and perceptually related. However, given Rosch's (1975) findings about typicality, this might be because these word pairs are more typical of their category class than the pairs with only a conceptual relationship.

In Schreuder et al.'s naming paradigm there was a significant priming effect produced by the perceptually similar pairs, but not by the conceptually similar pairs. The priming effect for the conceptual and perceptual pairs was almost equal to that of the perceptual only pairs. The results were interpreted as evidence that both perceptual and conceptual information is encoded in semantic memory. It was also proposed that perceptual information is accessed earlier than conceptual information, as evidenced by the priming in the pronunciation task. Although Schreuder et al. claim independent effects of conceptual and perceptual information, the evidence they produced is not that strong. On the other hand, the evidence that perceptual information is encoded in semantic memory is very strong. Some of the perceptually similar pairs had relatively few perceptual features in common; for example, "cupboard-toaster", "saucepan -pipe", "finger-French bread", "banjo-tennis racket".

Further evidence for the imaginal nature of semantic memory appears in the data obtained by Wheeldon and Monsell (1994). They found that the time taken to name a picture is increased if a conceptually similar word had previously been elicited. For example, if the word "bee" had been elicited by the description "It buzzes around and makes honey", then a picture of a fly was named more slowly than if previous trials had elicited unrelated words. This seems to suggest that the perceptual features shared by the distractor and the picture were activated by the verbal description. Some of their stimuli were structurally similar; for example, "shark" and "whale" or "teapot" and "kettle", and others were functionally similar such as "torch" and "lamp" or "cigarette" and "pipe". It appears from this that the contents of the non-verbal system are not limited to visual or other perceptual information, but also contain action-based information.

The idea that semantic information comprises motor information is not new, and models that accommodate it have been proposed as variations for both single semantic store (Engelkamp & Zimmer, 1994) and variations of dual coding models in which conceptual representation is a product of perceptual representation (Barsalou, 1998).

Summary

- Any model of the interaction between lexical semantic and imagery representations must be able to accommodate the following differences between picture and word processing.

- Reading words becomes an automatic process, whereas naming a picture always requires voluntary effort.

- A printed word has a more compatible or automatic access to the internal representation of that word than a picture of the same item.

- When a naming task is employed, words are read faster than their corresponding pictures are named. However, a greater priming effect is produced between related picture pairs than between related word pairs.

- The opposite pattern of results occurs when the task is changed from naming to categorisation: word stimuli are categorised more slowly than picture stimuli. The priming effect produced between related picture pairs is less than the priming produced between related word pairs when the task involves categorisation.

- The presence of a semantically related word slows down the time taken to name a picture, but the presence of a semantically related picture has no effect on the time taken to name a word.

- Decisions about category membership of words are slower in the presence of categorically related pictures, but the presence of related words has no effect on the time taken to categorise pictures.

- Neuropsychological evidence shows double dissociations between concrete and abstract knowledge, and between visual and verbal representations.

- Two classes of model have been put forward to explain the differences between picture and word processing.

- One proposes separate processing mechanisms for the two symbolic forms but a common semantic store accessible to both pictures and words. Information within this store is represented as abstract, amodal propositions organised hierarchically. Concepts are represented in terms of semantic features, or by the pattern of their relation to other concepts.

- The other class of model proposes two separate, specialised, symbolic systems: the imagery system and the verbal system. These systems are functionally independent, but interconnectivity between the systems develops through experience allowing referential links between imagery and word representations. The imagery system is assumed to have parallel processing, and to be best suited for synchronous organisation and storage of non verbal information. The verbal system is assumed to have a linear processing function and to be specialised for sequential and temporal processing tasks.

- Various models of how semantic information might be organised within a semantic store have been proposed. Hierarchical models of semantics have been very influential, and predictions made by these models have been supported by many studies measuring semantic priming. Models proposing spreading activation and hierarchical organisation of information can be incorporated into both single semantic store models and dual processing models. This is also true of models proposing semantics as multidimensional representations of the most salient features. Distributed representation provides an economical means of representing perceptual information, and lends itself as a possible mechanism for the imagery system of dual coding models. It is harder to integrate distributed representations into single store models.

- Paivio and Tulving present diametrically opposed arguments about the development of episodic and semantic memory. Paivio argues that the referential associations between and within the two processing systems are acquired through experience. Tulving argues that the development of semantic memory precedes the development of episodic memory.

- Models that assume propositions or semantic features run into the symbol grounding problem. They offer no explanation of how the terminal concepts acquire their meaning.

- Definitions of semantic memory that refer only to conceptual knowledge are too narrow. Semantic memory must include perceptual information.

Aims of Thesis

The objectives of this thesis are to examine the interaction of verbal and imagery representations. The experimental aims are to determine 1) whether associations that are encoded visually (picture pairs) are automatically available to the verbal system once the names of the pictures are established; 2) whether verbal associations are automatically available to the visual system once picture names have been learned; 3) whether the order of learning the name relation (picture-word association) affects the ease with which information is transferred between the systems; 4) whether there is any evidence that semantic information primarily resides in the imagery system.

Single semantic store models predict that the order in which information is presented will not determine the ease with which information is available to the other processing system. For example, the speed and accuracy of cued recall should not be different if the names for associated picture pairs are learned before or after the picture pairings are learned. If all the information is stored as propositional representations in a single semantic store, the order in which the information was learned should make no difference.

Dual coding models predict that the order in which information is acquired will have an effect on the time taken to identify the stimuli. If the names of two associated pictures are learned prior to an association between the pictures, then the associates can be processed both by the visual and the imagery systems.

The relationship between perceptual and verbal representations could be explained by one of these (non exclusive) hypotheses:

Hypothesis 1

Semantic associations arise from verbal experience and remain within the verbal system. Word collocations underpin the semantic system. Verbal experience and visual experience are unrelated.

Hypothesis 2

Words that have been infrequently associated might still have strong semantic association if their perceptual referents are closely associated. Semantic association can arise from associated perceptual experience. For example, if a visual association exists between two items and then the names of those items are learned the existing perceptual association would create a corresponding verbal association.

Hypothesis 3

Semantic associations between words arise if items are automatically named when they are presented contiguously, thus creating verbal associations. For example, if items that have names become perceptually associated, a correspondent name association will also arise.

Chapter 2*

Are Picture Associations Verbally Mediated?

This chapter describes an experiment attempting to examine the relationship between the verbal and the visual (specifically picture) processing systems. An attempt was made to gather empirical evidence to answer the question "Are picture associations verbally mediated?"

In Chapter 1, we evaluated two classes of model for symbolic and perceptual representation: single semantic store models and the dual coding model. It was noted that single semantic store models have evolved so that each new generation of model can accommodate experimental findings that proved to be problematic to previous ones. Most semantic models now propose a three code system. The surface forms of pictures and words are processed by two different systems, but the conceptual content of both pictures and words is processed by a common semantic system (Biggs & Marmurek, 1990; Kroll & Potter, 1984; Seymour, 1973); all conceptual associations are mediated by the common semantic store. Dual coding proposes that conceptual associations will occur within the picture / word processing (iconogen / logogen) systems. By determining whether picture associations can be created without word associations, we should be able to distinguish between the two models.

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* *Acknowledgement*

This experiment was run with the collaboration of two third year undergraduates from the School of Psychology, Bangor. Caroline Bond and Jonathan Williams collected the data for one condition each and presented these for their honours projects.

That question is methodologically difficult; the two systems are intimately enmeshed. There is little previous research to provide a framework for comparing word and picture processing. One major methodological problem is to devise tasks and materials for visual and verbal processing that are equally difficult. Another, especially subtle, problem is to control for participants' idiosyncratic personal histories of association and exposure to real-world words and objects. We discuss these problems in the context of previous research. The experiments of Kroll and Potter are particularly relevant; we discuss the methodological merits and shortcomings of their research.

The rationale for the experimental methodology decided upon is explained. The experiment was only partially successful; an examination of weaknesses in our design is presented. Sufficient evidence was obtained to conclude that picture associations are not verbally mediated.

Pictures and Words Interact in Cognition

The influence of a verbal label on a perceived object has long been known to have an effect on the later recall of that object. Carmichael, Hogan, and Walter's (1932) classic experiment with ambiguous figures showed that a precise verbal label applied to an ambiguous figure will affect the way that it is later reproduced. For example, a line drawing of a diamond inside a square labelled "curtains", when it is presented, is likely to be reproduced so that it resembles curtains, with the straight lines of the diamond transformed to curves, whereas the same shape labelled "diamond inside a square" is likely to be reproduced as a geometric figure. The verbal label appears to affect the perceptual encoding.

Perceptual similarities and family resemblances are the basis of category class inclusion (Rosch & Mervis, 1975). A word labels a class, not a unique item; to name an object is to categorise it. For example, "chair" refers not only to the chair that I am sitting on, but to all chairs. A word does not embody a specific feature set; it refers to a network of overlapping features. Children who have not yet learned the names of objects will sort them correctly into basic level categories on the basis of perceptual similarities (Rosch, Mervis, Gray, Johnson, & Boyes Braen, 1976).

If verbal labels influence the level of perceptual encoding and the amount of perceptual detail that is recalled, then it is likely that the composition of semantic memory is influenced by relations between items of verbal information. Tulving (1984) developed this idea in his model of semantic memory.

Further support for this notion comes from Jörg and Hörmann (1978). They showed that the generality or specificity of a given verbal label was a determinant of accuracy when deciding whether test pictures were identical to those that had been studied earlier. The picture stimuli presented were described either at a general level, for example, "the knife is next to the fish", or at a more specific level, for example, "the flounder is next to the bread knife". They assumed that the verbal labels affected depth of processing during the study phase. They concluded that the verbal labels had "induced conceptual demarcations for perceptual processing" (p. 453). The verbal labels had affected the depth of processing of subsequently presented pictures.

There is much evidence that verbal processing influences the way that pictures are processed and encoded. To determine whether picture associations can occur without verbal mediation it is necessary to find some means of controlling for the influence of the verbal processing system.

Picture and Word Processing in Semantic Associations

The dual coding and single semantic store models differ fundamentally in their accounts of semantic associations.

In dual coding terms, meaning is based on two distinct type of link: links within a system, and links between the two systems. For example, the representations for "boy" and "girl" might involve an associative structure comprising four elementary representations, two verbal and two imaginal and their interconnections at the referential (image-word, word-image) and associative (image-image, word-word) levels. "Which components are most strongly connected presumably depends on the nature of prior experience" (Paivio, 1971). If dual coding is correct, cross and within modality associations can have different strengths.

In contrast, common semantic store models predict equivalent strengths for picture associations and word associations representing the same conceptual association. It follows that there must be equivalent facilitative effects across and within the two surface forms, and equivalent interference effects between and within the two surface forms (Snodgrass, 1984).

Comparing Conceptually Related Pictures and Words

Potter and Kroll (1984) carried out a series of experiments designed to measure the strengths of picture associations and word associations representing the same conceptual association. They presented subjects with two tasks: a lexical decision task and an object decision task analogous to the lexical decision task. The stimulus sets used in each task were equivalent; the words in the lexical decision task were the names of the objects that appeared in the object decision task. The non-objects were line drawings of closed figures, created by tracing parts of drawings and regularising the resulting figures. To control for extraneous conceptual associations each of the pictures selected had only one name. If lexical and object decisions rely on the same conceptual representations, the two tasks should be influenced by the same experimental manipulations.

Potter and Kroll (1984) established that the response times to the words and the pictures in their tasks were similar. Objects were recognised faster than words (35 ms and 24 ms respectively), but the difference was not significant. They inferred from this that objects are not necessarily named as part of the recognition process. If naming was necessary prior to object recognition, it could be predicted that object recognition would take some

200 - 300 ms longer than word recognition (Cattell, 1886; Potter & Faulconer, 1975; Smith & Magee, 1980).

They found similar frequency effects for words and pictures (according to Kucera & Francis', 1967, frequency norms). This could be accounted for either by a common, amodal code, or because of similar frequencies of the names and appearances of different objects. It remains to be demonstrated whether words gain in functional frequency when their referents are seen or vice versa.

An adaptation of the tasks was used to measure priming effects. Participants had to make a decision about two simultaneously presented stimulus pairs. They were asked to respond "yes" if both stimuli were real words or real objects, and "no" if one or both stimuli were nonwords or non-objects. Priming was produced both for picture pairs (49 ms) and for word pairs (18 ms), but there was a significantly greater priming effect for the picture pairs than for the word pairs.

An analysis of the negative responses showed that when a real word was displayed above a nonword, the latency of response was significantly longer than when a nonword was displayed above a real word. This pattern was not found for picture pairs. The difference in response times when a real object was displayed above a non-object, compared with a non-object displayed above a real object, was not significant. This was interpreted as possible evidence that words are processed serially, whereas pictures are processed in parallel.

Potter and Kroll (1984) added a more stringent test by presenting the two types of symbol pairs in mixed blocks. When a mixed object/lexical decision task was presented, there was an overall increase in reaction time compared with that obtained in their Experiment 1. The common semantic code hypothesis predicts that mixed presentation should have no effect on the processing of either stimulus modality.

A variation of their mixed stimulus block experiment was carried out by Potter and Kroll

(1984) to examine the effects of repetition within and across surface forms. The rationale for this was that, if both pictures and words accessed a common conceptual store, repetition effects across surface forms could be predicted. The results showed a significant effect of repetition (average of 25 ms) within form, but there was substantially less repetition priming across surface forms. A small but significant priming effect was obtained when words were preceded by their picture referent, but no significant facilitation was produced for pictures preceded by their names. Potter and Kroll speculated that the pictures activated a conceptual representation, priming word recognition, but that presentation of the name did not activate the conceptual store.

The results of Kroll and Potter's (1984) experiments established that priming has a form specific component in addition to its established sensitivity to conceptual relations between items. Evidence that priming is affected by conceptual relations can be seen in semantic priming experiments (Guenther, Klatzky, & Putnam, 1980; Hines, Czerwinski, Sawyer, & Dwyer, 1986; La Heij, Dirkx, & Kramer, 1990; Lupker, 1984; Lupker, 1988; Meyer & Schvaneveldt, 1971; Williams, 1996). Overall their results did not provide unambiguous support for either common semantic store or dual coding models.

To summarise, Kroll and Potter (1984) developed an object decision task that taps conceptual associations without requiring objects to be named. Variants of this task can be used to produce priming effects for both picture pairs and word pairs.

Methodological Decisions

Rationale for employing novel stimuli

Evidence from interference tasks strongly suggests that associations between a word and a picture are automatically activated. For instance, the presence of a related picture slows the time taken to categorise a word (Smith & Magee, 1980), and the presence of a related word slows down the time taken to name a picture (Lupker, 1979).

Paivio (1971) assumed that the strength of associative links is dependent on the nature of prior experience. Existing patterns of association are likely to be idiosyncratic, and hard to control for. Different participants are likely to have learned different patterns of associations and to have different associative strengths between items reflecting their different experiences.

Kroll and Potter (1984) found similar effects of familiarity between associated pictures and associated words; these effects could be the result of a transfer of functionality or of experience with objects in the world.

It was therefore deemed necessary to provide participants with new associations in a controlled manner.

Dagenbach, Horst, and Carr (1990) reported that it is much easier to add a new word (and its meaning) to semantic memory than it is to create a link between two previously unrelated words already established in semantic memory. They proposed that the cause of this difference might be spreading activation along existing connections having a dampening effect on the new association.

Training associations between novel stimuli would be an appropriate means of controlling participant's prior experience, and would eliminate any problems relating to pre-existing associations. It would also reduce the possibility of lexical processing automatically priming existing relationships between two pictures, or of imagery based associations automatically facilitating the processing of two words.

It was hoped that by manipulating the sequence of exposure to information it would be possible to map the availability of associative information across the two processing systems.

For these reasons, it was decided to train participants with novel word associations or novel picture associations, and with associations between the novel words and the novel pictures.

Design of the experimental task

It has been widely assumed that the size of the priming effect produced between two related items is a measure of the strength of associations between those items (Carr, McCauley, Sperber, & Parmelee, 1982; McKoon and Ratcliff, 1992).

McKoon and Ratcliff (1979; 1976, cited in Ratcliff & McKoon, 1978) demonstrated that priming effects can be produced by new associations between words. Their participants were taught a series of word associations between previously unrelated words (e.g. city-grass). Immediately after learning the paired associates, participants were given a lexical decision task. A priming effect of 45 ms was produced.

Greater priming effects between recently associated items were produced when participants were asked to decide whether the target words had appeared in the study list, compared with having to decide on the lexical status of the letter strings. This item recognition task increased the priming effects from 45 ms to 150 ms using the same stimulus pairs and presentation procedure.

It was decided that priming would be a suitable tool for investigating the structure of recently learned verbal information; for this reason, variations on the lexical decision tasks were employed. It was also decided to employ an item recognition task to measure the strength of association between items.

Carr et al (1982) demonstrated that larger priming effects are achieved when the prime is displayed at supra threshold levels. They found that the mean identification threshold for picture primes was 45 ms, that for word primes 65 ms. They calculated their supra threshold duration by adding 450 ms to the full threshold duration for each item. On these grounds it was decided that a prime exposure time of 500 ms should be sufficient to obtain an associative priming effect.

In an experiment that required a response to both prime and target, Guenther, Klatzky, and Putnam (1980) found an increase in the reaction time to the target when the prime was a picture. They explained this as a function of a post-iconic perceptual memory that is maintained for a fixed time period. The picture prime is maintained in the visual short term memory, inhibiting the response time to the second stimulus. This inhibitory period was overcome by Bajo and Canas (1989). They presented all their primes for a period of 1000 ms with an inter stimulus interval (ISI) of 50 ms before the target was shown. They demonstrated word-word priming, picture-picture priming and cross modal (picture-word and word-picture) priming. In order to create an adequate interval to prevent any interference produced by post-iconic memory, it was decided to have a SOA (Stimulus Onset Asynchrony) of 1000 ms. Since the prime duration had been set at 500 ms, the ISI was 500 ms.

Bajo (1988) and Kroll (1990) demonstrated that presenting blocks of mixed classes of prime-target relations (for example picture-picture and word-word) increased the response latency, but reduced the size of the priming effect, compared with blocks of a single prime-target class. It was therefore decided to present the decision tasks separately to measure trained associations versus cross modality priming.

Experimental Aims

The primary aim of these experiments is to determine whether patterns of association established between two pictures can be mediated without verbal processing. A secondary question is whether, once an association is established in one symbol modality (e.g. picture association), the information is transferable to another symbol modality (e.g. word association). For example, if two objects are associated by contiguous exposure, will the names for these objects also become associated? Further questions are whether picture associations require previously associated words, and whether visual associations require perceptual experience?

These questions are of theoretical relevance; answers to them would provide evidence for deciding between the different models of the relations between picture processing and verbal processing. Dual coding theory could accommodate independent patterns of association within and between the verbal and the non-verbal system. Patterns of association established in one symbolic modality are accessible to the other via referential links, but the strength of these associations may be different. Single semantic store models predict that once an association exists between two concepts, it can be accessed by either picture or word processing systems regardless of the modality through which the association was acquired. The strength of a conceptual association must be equal for picture pairs and word pairs.

Further questions arise from the novel nature of our stimuli:

1. Can a verbal association arise if there are no names available for the items at the time they are associated?

2. If visual associations are established before names have been learned for the associated items, when names are learned will these be associated because of the existing visual association?

3. If associations are learned between two novel words, does this create a corresponding association between their picture referents?

4. If so, do the names of the referents need to be established before the word association is learned?

Pilot Study 1

This pilot study was carried out to establish whether priming could be produced between recently associated novel word pairs and novel picture pairs. Training tasks designed to teach participants paired associations between novel pictures or between novel words were tested. An object decision task was used to measure the strength of associations established between the novel picture pairs, and a lexical decision task was employed to measure the strength of association between the novel word pairs. These decision tasks required participants to decide whether the target stimulus had appeared during the training phase, presenting targets after associated or unassociated priming stimuli.

Method

Participants

Twelve postgraduate students from the School of Psychology, University of Wales, Bangor were recruited. Four of the participants were male, eight female. Subjects were not informed about the experimental aims until they had completed the experimental trials.

Stimuli

Verbal stimuli

A set of 58 three letter novel words were created, all were of a consonant-vowel-consonant structure, and none were words in the English language (the list of these stimuli is presented in Appendix 2.1). All the words were presented on a computer screen in Chicago 24 point. Four of these words were selected for the training phase during which they were presented as two pairs embedded in simple phrases; for example, "Lof above Jiz" and "Gub right of Nas". The stimuli were presented in this way in an attempt to add some meaning in the form of positional information. Twenty phrases were constructed, in which each word appeared as the first noun, with its associated word as the second noun (see Appendix 2.1). The remaining 54 novel words were employed as foils in the priming task. For the priming task three blocks of 16 word pairs and a practice block of 8 word pairs were constructed comprising an equal number of the following combinations: an associated word pair, a previously associated word followed by a novel word, a novel word paired with a previously associated word, and a pair of novel words. All of the novel words in this task appeared only once in the entire experiment.

Visual stimuli

A set of 58 distinct visual stimuli, each composed of randomly filled squares on a 5 x 5 matrix, was created (see Figure 2.1 for examples). Each picture was 2.8 cm square. Four visual stimuli were arbitrarily selected for the training phase. During the training phase these four stimuli were presented as two pairs. Each pair was presented randomly, in any of two out of three corners of a square stimulus field (top right, bottom left, and bottom right of a computer screen). The remaining 54 stimuli were used as foils during the visual priming task (an example of these is given in Appendix 2.2).

A practice block of 8 visual pairs and three experimental blocks of 16 pairs each were constructed. Each experimental block contained four of the following prime target pairs: trained picture associates, an associated picture (from the training phase) paired with a novel picture, a novel stimulus picture and an associated picture, and pairs of novel stimuli. Each novel stimulus was presented only once in the entire experiment. The practice block comprised two of each of the pair types.

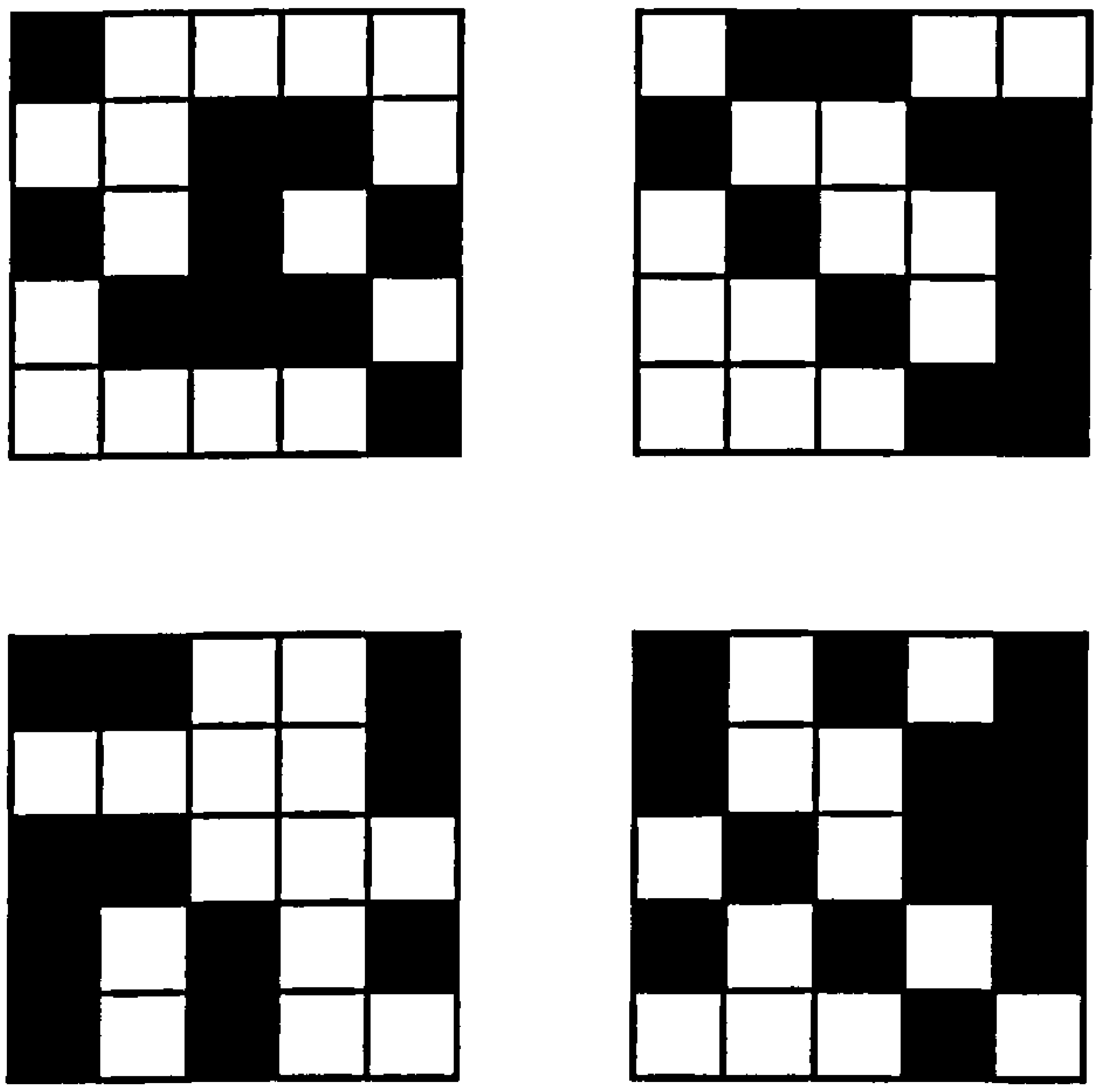


Figure 2.1: The stimulus pairs for the visual association training and visual priming task.

Apparatus

The experiment was generated using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993) and run on a Macintosh IIvx computer using an 18" black and white Radius monitor. The Macintosh keyboard was used for subjects' responses, and the built-in Macintosh (screen refresh cycle) timer was used for recording the response times (in increments of 16.6 ms.).

Design

Participants were presented with two tasks in this experiment, a verbal task and a visual task. Each task consisted of a training phase and a testing phase. The order of presentation was counterbalanced; half of the subjects completed the visual task first and half the verbal task first. During each of the training phases, participants studied associations between two pairs of novel stimuli. During the testing phase, participants were given either a lexical decision task or an object decision task. The stimuli that had appeared in the training phase were presented either preceded by a novel stimulus or by their associated stimulus. An equal number of novel targets were also presented, preceded by novel stimuli or by the stimuli from the association task. A within subjects design was employed for analysing each of the two tasks. A comparison was made between the response time to target stimuli when preceded by an associated prime (primed associated targets) compared with when those targets were preceded by an unrelated prime (unprimed associated targets). The dependent variable was the latency of response to the target stimulus in each trial.

Procedure

Participants were run individually on all tasks. The task that participants undertook first (visual association + priming, or verbal association + priming) was determined by the order in which they arrived in the testing room.

Verbal Task

Verbal association training task.

Each participant was seated in front of the monitor on which the following instructions were displayed:

> Welcome. This part of the experiment lasts for approximately ten minutes. Your task is to study sentences that describe a new physical world. In this world there are four objects which interact. You will see 80 sentences, one after another, which describe the ways in which these objects interact. Your job is simply to read aloud each sentence as it is presented, and to try and figure out the possible relationships in this world from the set of sentences that describe it. If you have any questions ask the experimenter now. Otherwise press the "/" key when you are ready to begin.

Pressing the "/" key started the training trials. Each trial commenced with a fixation mark (*) displayed in the centre of the screen for 500 ms. This was replaced by one of the stimulus association phrases (e.g., "Gub abutting Nas"), which remained on view for 4000 ms. After 500 ms a visual mask, comprising a row of "XXXXXXXXXXXXXXX", was displayed for a further 500 ms. After an inter-trial interval (ITI) of 1000 ms, the next trial was presented. This continued until all 80 training phrases had been displayed.

Verbal priming task

This task was presented immediately after verbal association training. At the start of the task the following instructions were displayed on the monitor:

> Welcome. This part of the experiment lasts approximately five minutes. There are 8 practice trials and 48 experimental trials. On each trial you will see a * then a three-letter "word", then another three-letter "word". Your task is to judge if the second "word" was one of the original four that you studied in your earlier observations of the sentences which described the new physical world. If it was, then press the "/" key. If it wasn't, then press the "z" key. Make your responses as quickly as possible while still trying to be accurate. If you have any questions ask the experimenter now. Otherwise, press the "/" key when you are ready to begin.

Eight practice trials were followed by a short break, during which participants could ask any questions about the procedure, before commencing the 48 experimental trials. Each trial started with a fixation mark (*) displayed for 1000 ms, followed by the prime word which remained on view for 500 ms. After an ISI of 500 ms the target word was displayed. The target remained on view until a response key was pressed.

Visual Task:

Visual association training

The training started with the following instructions displayed on the monitor.

> Welcome. This part of the experiment lasts approximately ten minutes. Your task is to observe events in a simple new physical world. In this world there are four objects which interact. You will see 80 events, one after another. In each of these events two object interact. Your job is simply to study each event, to try to recognise the detailed shape of each of the four objects, and to try and figure out the possible relations between them. If you have any questions ask the experimenter now. Otherwise press the"/" key when you are ready to begin.

After the instructions, the 80 training trials were presented in a random order. The two picture pairs were presented in an equal number of trials. Each trial consisted of a picture displayed for 3000 ms, with a second picture appearing on the screen 1000 ms after the onset of the first picture. The second picture was displayed for 3000 ms. Each picture was displayed in one of three positions within a stimulus field that occupied the centre of the screen. The three possible positions were the two lower quadrants and the upper right quadrant. The distance between the pictures was approximately 1 cm. Following an interval of 500 ms the entire stimulus field was occupied by a chequered visual mask that remained on the screen for 500 ms. After an ITI of 1000 ms the next trial started, until all the trials had been run.

Visual priming test

This task was presented immediately after the visual association training. These instructions were displayed on the screen:

> This part of the experiment lasts approximately five minutes. There are 8 practice trials and 48 experimental trials. On each trial you will see a "*" then a picture,

then another picture. Your task is to judge if the second picture was one of the original four that you studied, in your earlier observations of the new physical world. If it was, then press the "/" key. If it wasn't, then press the "z" key. Make your responses as quickly as possible while still trying to be accurate. If you have any questions ask the experimenter now. Otherwise press the "/" key when you are ready to begin.

After the instructions, there were 8 practice trials followed by a break, during which the experimenter answered any questions participants had about the procedure. Then the experimental trials were presented. Each trial started with a fixation mark (*) displayed for 1000 ms, followed by a prime that had a duration of 500 ms. After an ISI of 500 ms, the target appeared and remained on display until a response was recorded. The latency of response from the onset of the target was recorded by the computer.

Results for Pilot Study 1

The dependent variable was latency of response (measured in ms; increments of 16.6 ms "ticks") to the target stimulus. There were four within subject conditions in each task formed by the different combinations of stimulus pairs. The two pairs of novel stimuli that had been previously associated during the training phase will be referred to as the associated words or the associated pictures. The other stimuli, shown only once during the entire experiment, will be referred to as the *novel words* or the *novel pictures*. A priming effect was calculated for each task, that is, the comparison between the response times to primed associated targets (an associated target preceded by its paired associate from the training task) and unprimed associated targets (an associated target preceded by a novel stimulus). The alpha level for all of the following analyses was set at .05.

Verbal Priming

The data from one participant were excluded because she failed to make any correct responses in the unprimed associated target condition.

The mean reaction times and standard deviations for each condition of prime-target pairs are shown in Table 2.1. A one way repeated measures ANOVA showed a significant difference between the four conditions ($F = 3.025$, $df = 3,10$, $p = .045$). The ANOVA table is given in Appendix 2.3. Planned means comparisons showed a significant priming effect ($F = 5.51$; $df = 1,10$; $p = .026$).

Table 2.1: Mean reaction (+ SD) for the verbal and the visual decision tasks using associated novel stimuli

Stimulus Form	n	Prime - Target Pairs			
		nov - nov	ass - nov	nov - ass	ass - ass
Verbal	11	577.6	541.7	602	549.2
		(83.3)	(86.1)	(109.9)	(100.7)
Picture	11	805.8	704	806.1	725. 1
		(146.6)	(100.6)	(174.1)	(141.2)

Note: nov = novel stimulus, ass = associated stimulus

The reaction times to the different target types (novel word targets and associated word targets) were compared using planned means comparisons. The difference was not significant.

Picture Priming

The data from one subject were excluded because she used only one finger for the responses due to boredom. She reported that she had no idea whether she had seen the stimuli before, because she had only studied the top left corner of the pictures during the training phase.

The mean reaction times and standard deviations for each condition are shown in Table 2.1. A one way repeated measures ANOVA showed a significant difference between the four conditions ($F = 3.26$; $df = 3,10$; $p = .035$). The ANOVA table is presented in Appendix 2.4. Planned means comparisons showed a significant priming effect ($F = 4.49$; $df = 1,10$; $p = .042$). Means comparisons between the target types (associated pictures compared with the novel pictures) showed no significant difference in the reaction times.

Picture Stimuli versus Word Stimuli

A repeated measures ANOVA was carried out to compare the mean response latency for the picture targets (737.5 ms; $SD = 125$) compared with the word targets (563.4 ms; $SD = 86$). The response to the word targets was significantly faster than to picture words ($F = 74.5$; $df = 1, 9$; $p < .0001$). The ANOVA table is shown in Appendix 2.5.

Discussion

This pilot experiment established that a priming effect could be produced between novel picture associates and between novel word associates after paired associative training. This supports the hypothesis that picture associations can occur without being verbally mediated. The pattern of results we obtained was not the same as that of Kroll and Potter (1984) who found that pictures were recognised faster than words. However, Kroll and Potter used pictures of very familiar objects, our study used pictures with an unfamiliar format that had only been studied for a relatively short period. The training task was deemed to be adequate to establish paired associate learning between the novel stimuli. The priming task appeared to be a sufficiently sensitive measure of associations.

Pilot Study 2

Experimental Aims

This pilot study was carried out to discover whether cross modal priming could be produced after participants had been taught the name relation (picture-word, word-picture) between the stimuli that were presented in the paired association training tasks. Pilot Study 1 established that a priming effect could be produced between two recently associated novel picture stimuli and between recently associated novel words. A vocabulary training task (picture-word, word-picture associations) was introduced in this study. A vocabulary test task was also included to measure how well participants could recall the names for the novel pictures. The order in which the vocabulary training was introduced was manipulated across conditions (see Figure 2.2 for an illustration of the training and testing sequence for each condition). This Pilot Study 2 tested participants for cross modality priming: participants trained in the picture association task were tested with the verbal priming task; participants trained in the word association task were tested with the visual priming task.

Single semantic store models predict that priming effects will not be affected by the order in which associations are established (e.g., word association training after vocabulary training vs. vocabulary training after word association training). No difference would be predicted between cross modal picture priming after word association training and cross modal word priming after picture association training, since the model proposes that these associations have a common conceptual association.

Dual coding models predict that larger priming effects might be produced when the vocabulary training occurs before the paired association training. For example, picture associates could produce larger cross modal priming effects if they were named prior to their association because both a verbal and a non verbal association could be formed during the training phase. Cross modal priming is supported by dualcoding models via referential links; because of this, there is a prediction that the response latency will be slower for the cross modal decision tasks than for the associative decision tasks employed in Pilot Study 1.

Participants

Twenty four participants volunteered to take part in this study. They were all university psychology graduates, either employed as research assistants or postgraduate students at the University of Wales, Bangor. Participants were not aware of the experimental aims until they were debriefed at the end of the experiment. None of the participants had taken part in Pilot Study 1.

Stimuli

The picture stimuli and verbal stimuli were the same as those employed in the first pilot study. The words and pictures that were employed in the trained association tasks were arbitrarily paired to form four picture-word pairs for the vocabulary training task (shown in Figure 2.3). These pairs were arranged in 2 blocks; in the first block the picture appeared first, and in the second block the word appeared first. These pairs were further blocked into two pairs of pairs for the trained associations.

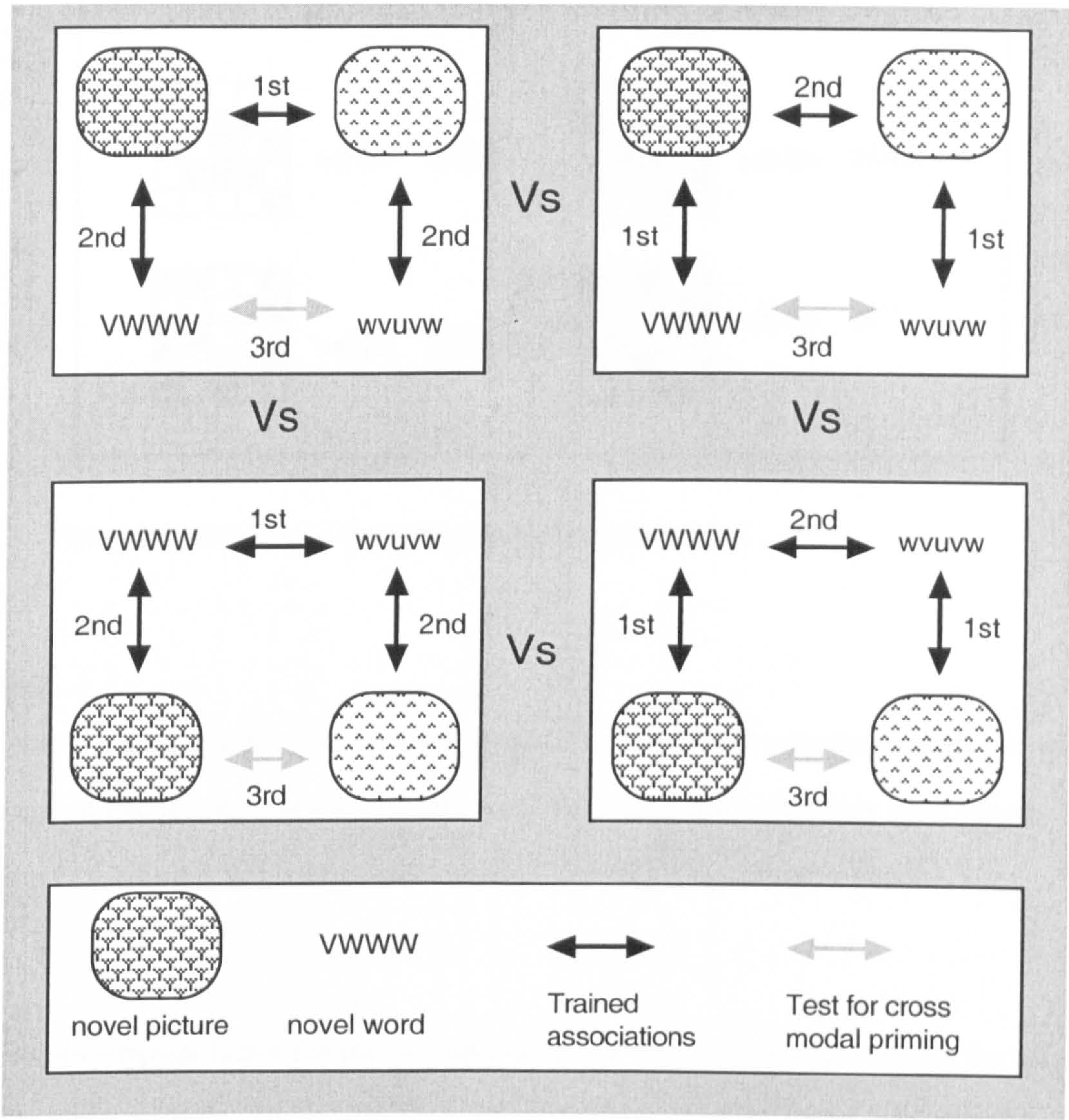


Figure 2.2: An illustration of the four different training and testing sequences in Pilot Study 2.

Apparatus

This experiment was generated using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993). It was run on a Macintosh IIvx computer using an 18" black and white Radius monitor. The Macintosh keyboard was used for subjects' responses, and the built-in Macintosh (screen refresh cycle) timer was used for recording the response times (in increments of 16.6 ms.).

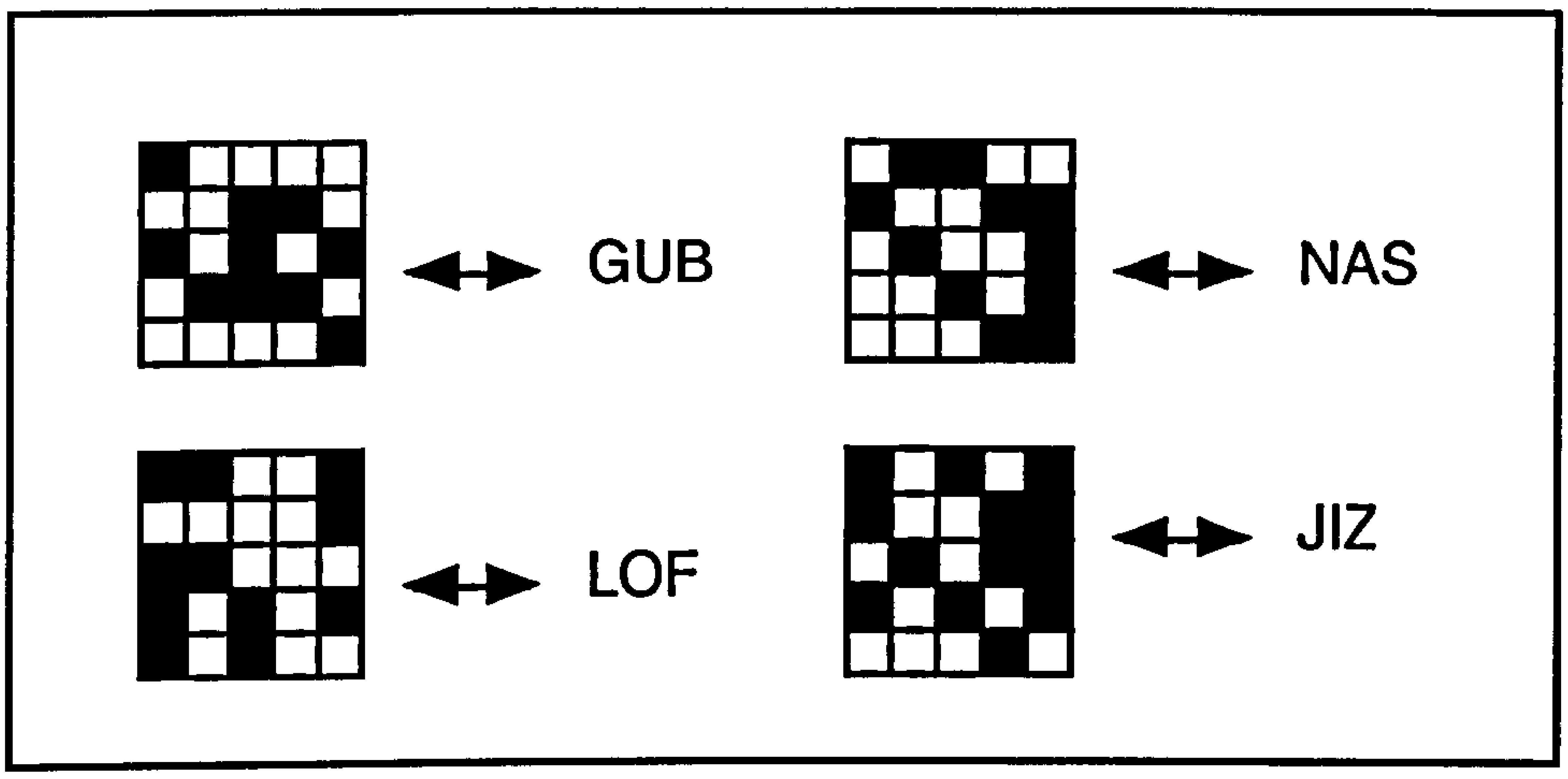


Figure 2.3: Stimulus pairs for the vocabulary training task.

Design

This was a mixed design. The between subjects manipulation was the sequence in which the training and testing tasks were presented. Four different conditions were tested. The sequence of training and testing tasks for each condition is shown in Table 2.2.

The within subjects factor for the decision tasks was the relationship between the prime and the target stimuli. There were four different types of prime target pair (novel-novel, associated-novel, novel-associated, associated- associated). Associated stimuli were those that appeared in the trained association and vocabulary task, novel stimuli only appeared once in the entire experiment. The dependent variable for the decision tasks was response time to the target measured in ms (increments of 16.6 ms "ticks"). The dependent variable for the vocabulary test task was number of correct responses recorded. To control for possible interference effects caused by the additional tasks, the sequence of tasks presented was arranged with an intervening task between training and related test tasks (between the association training task and the priming task and between the vocabulary training task and the vocabulary test task).

Table 2.2: Sequence of training and test tasks for each condition in Pilot 2

Condition	1st task	2nd task	3rd task	4th task
1	vocabulary training	picture association	vocabulary test	word priming task
2	vocabulary training	word association	vocabulary test	picture priming task
3	picture association	vocabulary training	word decision task	vocabulary test
4	word association	vocabulary training	picture decisioı task	vocabulary test

Procedure

The paired association training and the decision tasks were identical in procedure to Pilot Study 1. Two new tasks (vocabulary training and vocabulary test) were introduced in this pilot study. Each participant was run individually.

Vocabulary training task

The participant was seated in front of the monitor and the following instructions were displayed:

> Welcome. This part of the experiment lasts approximately 10 minutes. You will be introduced to a series of objects and word labels that are part of a new physical world. Your task is simply to learn the name of each of these objects. Please read aloud the name of each object as you study its detailed shape. If you have any questions before you start, ask the experimenter now. When you are ready to begin press key "/".

There were 40 picture-word trials and 40 word-picture trials, in each of which each of the four pairs appeared 10 times. Picture-word trials started with the presentation of a picture to the right of centre in the stimulus field; after 1000 ms the name of the picture was displayed on the left of the stimulus field. The two stimuli remained on view together for a further 3000 ms. The stimuli were replaced by a chequered visual mask which filled the stimulus field for 500 ms. There was a minimum ITI of 500 ms. Word-picture trials commenced with the word displayed to the left of the stimulus field, after 1000 ms the picture appeared on the right; the stimuli were displayed together for a further 3000 ms, followed by the visual mask for 500 ms. The trials were presented in a random order.

Vocabulary test task.

A vocabulary test task was presented to test whether participants could recall the picture-word name associations studied in the vocabulary training task. This test task commenced with the following instructions:

> This part of the experiment is designed to test how well you have learned the names for the new shapes that you have just been shown. You will see 56 trials, including 8 practice trials. Each trial is made up of one word and four pictures. Your task is to read each name that will be displayed, to match it to the right shape, then to press the number key that corresponds to the number displayed with that shape. You will be told when you have made the correct response. If your choice is not correct you will hear a beep sound. This part of the experiment is not measuring your reaction time, so take your time and respond as accurately as possible. If you have any questions please ask the experimenter now. When you are ready to begin press key " / ".

Each trial comprised a stimulus array of 5 squares arranged in a cross appearing in the centre of the screen (see Figure 2.4 for an illustration). In the centre square one of the names of the associated novel pictures was displayed in Chicago 24 point. The four pictures from the vocabulary training task were displayed, one in each of the outer boxes. The outside squares were numbered 1 - 4 in a clockwise direction starting from the top. Each square was approximately 5 cm in size.

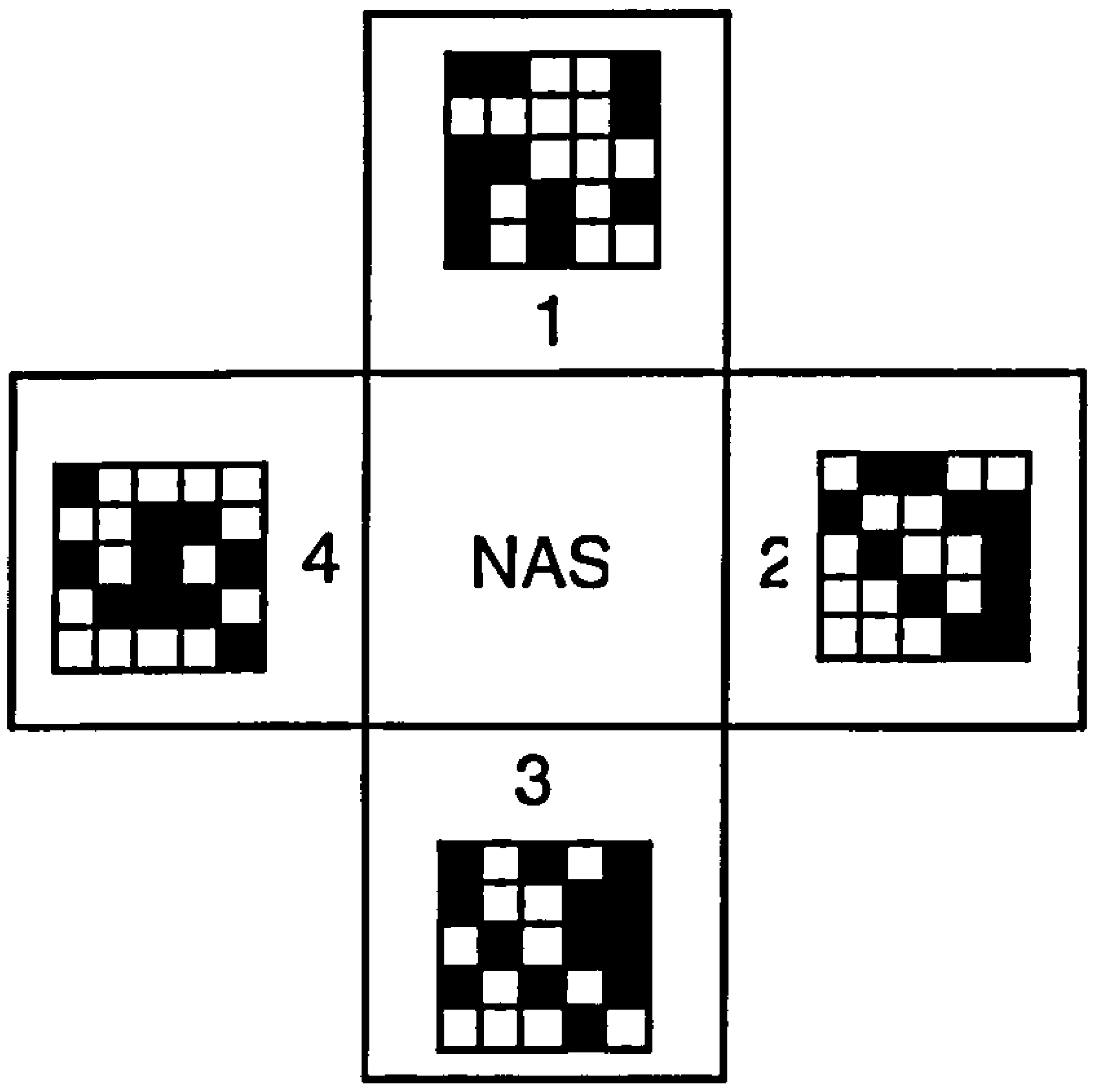


Figure 2.4: The stimulus array for the vocabulary test task.

The participant's task was to read the name and select the appropriate picture by pressing the number on the keyboard corresponding to the box in which that picture was displayed. If participants selected the right key, the word "correct" was displayed in the centre of the screen for 1000 ms. If the wrong key was selected, a beep sounded ("incorrect beep" from the Macintosh sound control panel). The stimuli remained on the screen until the correct button had been pressed. The first key press for each trial was recorded on the computer, as was the number of the square in which the correct picture appeared. There were 8 practice trials and 48 experimental trials. The position of the pictures was randomised between trials to prevent participants responding to each name according to a number, or a location, rather than selecting the picture.

Results for Pilot Study 2

The dependent variable for the vocabulary test task was number of correct responses (excluding the practice trials). The percentage of correct responses in the vocabulary task for each individual are shown in Table 2.4

The dependent variable for the cross stimulus modality decision tasks was latency of response to the target word measured in ms (increments of 16.6 ms "ticks"). Incorrect responses were excluded from the analysis, as were all responses that exceeded three standard deviations of an individual's mean response time.

The mean reaction times and standard deviations for each condition are shown in Table 2.3. The priming effect for each condition was analysed separately using a one way repeated measures ANOVA. The difference between the response time to the associated prime-target pairs was compared with the response times to those targets when they were preceded by an unrelated prime. In all of the following analyses the alpha level was set at .05.

Analysis of Condition 1

(*vocabulary training, picture association, vocabulary test, word priming*)

A one factor repeated measures ANOVA showed no significant cross modal priming effects. The analysis was repeated excluding data from the participant who scored < 95% correct in the vocabulary test. The difference in reaction time to the primed and the unprimed targets was not significant. The ANOVA table for these analyses are shown in appendices 2.6a and 2.6b.

The mean reaction time to the novel word targets (627.5 ms, *SD* = 121.7) was compared with the reaction time to the associated target words (words presented in the vocabulary training task; 585.4 ms, *SD* = 145.6). A two factor repeated measures ANOVA was employed; the first factor was target type (novel or associated), the second factor was prime type (novel or associated). Responses to the associated word targets were significantly faster than to the novel targets ($F = 9.26$; $df = 1,5$; $p = .029$). The effect of prime type was not significant, nor was there an interaction between target and prime type. The ANOVA table for this analysis is shown in Appendix 2.6c.

Table 2.3: The mean response times (in ms) for each condition to the previously trained target stimuli when preceded by an unrelated prime and by the previously associated prime (standard deviations are shown in parentheses)

Condition	*n*	Unrelated prime	Associated prime
Condition 1 *(vocabulary training, picture association, vocabulary test, word priming)*	6	591.9 (118.4)	578.8 (180.3)
Condition 2 *(vocabulary training, word association, vocabulary test, picture priming)*	6	1083.3 (438.5)	917.4 (248.2)
Condition 3 *(picture association, vocabulary training, word priming, vocabulary test)*	6	563.7 (77.6)	572.6 (67.8)
Condition 4 *(word association, vocabulary training, picture priming, vocabulary test)*	6	788.7 (128.9)	812 .5 (221.6)

Analysis of Condition 2

(vocabulary training, word association, vocabulary test, picture priming)

A one factor repeated measures ANOVA was performed on the response times to the primed and the unprimed target pictures (shown in Table 2.3). No significant priming effect was found. The ANOVA table is shown in Appendix 2.7a. The analysis was repeated excluding data sets for those subjects who scored less than 95% in the vocabulary test. No significant priming effect was found. The ANOVA table for this analysis is shown in Appendix 2.7b.

A two factor repeated measures ANOVA was carried out; the factors were target type (novel or previously associated) and prime type (novel or previously associated) to compare the mean response times to the novel targets (878.6 ms, *SD* = 210.1) and associated targets (1000.4 ms, *SD* = 350.6). The difference did not prove to be significant. There was no main effect of prime type, and there was no interaction between prime type and target type. The ANOVA table for this analysis is presented in Appendix 2.7 c.

Analysis of Condition 3

(picture association, vocabulary training, word priming, vocabulary test)

A one way repeated measures ANOVA was conducted to compare the mean reaction time to the primed and the unprimed target words. The means are presented in Table 2.3. There was no significant difference. The ANOVA table is shown in Appendix 2.8a. The analysis was repeated excluding data from participants who scored less than 95% correct in the vocabulary test. There was no evidence of a priming effect. The ANOVA table is shown in Appendix 2.8b.

A two way repeated measures ANOVA was carried out to compare the reaction times to the novel target words (601 ms, *SD* = 116) and the associated target words (568 ms, *SD* = 69.6). The difference was not significant. The second factor was prime type, and this had no significant effect). There was no interaction between target type and prime type. The ANOVA table is presented in Appendix 2.8c.

Analysis of Condition 4

(*word association, vocabulary training, picture priming, vocabulary test*)

A one way repeated measures ANOVA was carried out on the reaction times to the primed and the unprimed target pictures. The means and standard deviations are given in Table 2.3. There was no effect of prime type. The analysis was repeated excluding data from those participants whose scores on the vocabulary test were less than 95%. There was no evidence of a priming effect. The ANOVA tables for these analyses are shown in Appendices 2.9a and 2.9b.

The mean reaction time to the pictures that had been previously associated with words during the vocabulary task (800.6 ms, *SD* = 173.3) was compared with the reaction time to the novel pictures (779 ms, *SD* = 122.2). A two factor repeated measures ANOVA was carried out: the two factors were target type (novel and associated) and prime type (novel and associated). There was no significant difference in the reaction times to the two target types. Nor was there a significant effect of prime type. There was no interaction. The ANOVA table for this analysis is given in Appendix 2.9c.

Because no priming effects were produced, no comparisons were made between the conditions.

Inspection of the individual data shown in Table 2.4 reveals a very mixed pattern of results with approximately half the participants producing slower responses to the primed targets than the unprimed targets, and approximately half producing faster responses. Only two participants produced similar response times.

Table 2.4: Individual mean response times (in ms) for the priming tests and % of correct responses vocabulary test (excluding practice trials)

Condition	Subject	Vocabulary Test score	Priming Test	
			Unrelated	Associated
Condition 1	1	100	740.1	625.7
(*vocabulary training,*	2	93.8	630.8	561.0
picture priming)	3	100	406.1	423.7
	4	100	652.8	387.7
	5	100	618.1	894.1
	6	100	504.0	580.7
Condition 2	1	95.8	778.5	838.4
(*vocabulary training,*	2	95.8	1198.7	1122.8
word association,	3	95.8	707.7	636.1
vocabulary test,	4	100	675.4	681.5
picture priming)	5	91.7	1763.0	1268.3
	6	97.9	1376.3	957.5
Condition 3	1	93.8	475.0	509.2
(*picture association,*	2	100	651.5	592.9
vocabulary training, word	3	100	480.4	493.4
priming, vocabulary test)	4	100	572.3	554.2
	5	87.5	552.8	610.8
	6	85.4	649.9	674.9
Condition 4	1	100	690.1	578.5
(*word association,*	2	93.8	833.5	705.6
vocabulary training, picture	3	72.9	572.3	616.6
priming, vocabulary test)	4	97.9	886.2	884.9
	5	54.2	866.6	926.6
	6	97.9	883.4	1162.8

Discussion

This pilot study failed to produce any evidence of cross modal priming. A weakness in the design was that no checks were made to ensure that associative priming had been established after the paired association training or that it had been maintained after the vocabulary learning phase. It is possible that the addition of another set of associations (a word or a picture linked to each of the original four stimuli) might have weakened the strength of the original paired association. It was determined that the next experiment would include tests to establish at what point the paired associations failed to produce a priming effect. If associative priming effects were produced, and maintained, between the original paired stimuli, then a failure to produce cross modality priming would suggest that associative information is not automatically transferable.

Experiment 1

The aim of this experiment was to establish whether transfer of novel conceptual information could occur across stimulus modalities. A cross modality priming task was employed to look for evidence of cross modal associations derived from within modality associations. Pilot Study 2 failed to establish priming. It was not clear whether this was because patterns of association are not transferable across stimulus modalities, or because the original associations were not strong enough. Experiment 1 included two additional measures of associative priming. The first was to demonstrate that sufficiently strong associations had been produced after the training task. The second was to check whether the vocabulary task had interfered with the original associative pairs because participants had failed to learn the paired associations, or whether the strength of the original paired associations was diminished by learning a second set of associations involving the same stimuli.

Procedural Changes

Some changes to the procedure were made with the intention of enhancing any priming effects.

Meyer and Schvaneveldt (1976) demonstrated that degrading a word target slowed the response latency by up to 100 ms but increased the facilitation of a related prime from a mean of 55 ms in the intact target condition to 146 ms in the degraded target condition. Sperber, McCauley, Ragain, and Weil (1979) demonstrated that larger priming effects were produced in a picture naming task when the target was degraded than when it was intact (112 ms and 51 ms respectively) although the response latency to the degraded targets increased significantly (from 783 ms to 973 ms). They also found a similar pattern for degraded word targets.

It was decided that the targets in the following experiment would be degraded to enhance any priming effect that might be produced.

Carr et al, (1982) found evidence that a larger priming effect was produced in a naming task when the duration of the prime is above the identification threshold. They found that the mean identification threshold for their familiar pictures was 45 ms and for their word stimuli was 64 ms. In their above threshold condition the picture primes were displayed for 500 ms and word primes for 540 ms. They found that the mean latency (across conditions) for naming pictures was 665 ms and for words was 569 ms. They propose that a small SOA could result in the target and the prime competing for processing capacity when the task requires the prime to be named.

Because the stimuli in our experiment were not highly familiar, it is possible that they would have higher thresholds, and since the cross modality priming is mediated by naming, it was decided to increase the duration of the prime to 1000 ms.

Method

Participants

Thirty five participants were recruited from the University of Wales, Bangor School of Psychology undergraduate subject pool. There were 15 men and 20 women, with a mean age of 21.2 years. Due to time restrictions, and the failure of some volunteers to keep their appointments, 16 subjects took part in Condition 1, and 19 subjects participated in Condition 2. Three participants were later excluded from Condition 2; this was due to their poor performance on the vocabulary task. Participants were informed that they were taking part in a learning and memory experiment, but the experimental aims were not explained until after they had completed all phases of the experiment.

Design

This experiment had two between subjects conditions; participants in Condition 1 studied associations between novel pictures, participants in Condition 2 studied associations between novel words. Participants were given two training tasks and four testing tasks. The order in which these tasks were presented is shown in Table 2.5.

Participants were given the first associative priming task immediately after associative training to determine whether associations between the stimuli had been sufficiently learned. The second associative priming task, presented after the vocabulary training task, was included to determine whether there had been any decay in associative strength during vocabulary training. This was followed by the cross modal priming (decision) task that measured any transfer of association across stimulus modalities. The last task was the vocabulary test task to measure participants' recall of the picture-word associations.

The decision tasks were all repeated measures; response times to the primed and the unprimed targets were compared. The dependent variable for the vocabulary test task was number of correct responses.

Table 2.5: The sequence of tasks presented to participants in Conditions 1 and 2

Task	Condition 1	Task	Condition 2
1st	Training associations between novel pictures	1st	Training associations between novel words
2nd	First picture priming test	2nd	First word priming test
3rd	Vocabulary training (a novel word paired with each of the novel pictures)	3rd	Vocabulary training (a novel picture paired with each of the novel words)
4th	Second picture priming test	4th	Second word priming test
5th	Word priming task	5th	Picture priming task
6th	Vocabulary test	6th	Vocabulary test

Stimuli

The same novel word stimuli and novel picture stimuli employed in Pilot Studies 1 and 2 were used in this experiment. The stimulus pairs selected for the association training tasks in Pilot Studies 1 and 2 were used in this experiment. The stimulus blocks for the decision tasks were also taken from the Pilot Studies.

Apparatus

The experiments were generated using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993) and were run on a Macintosh LC computer with a 14" Apple colour monitor. The Macintosh keyboard was used for subjects' responses, and the built-in Macintosh (screen refresh cycle) timer was used for recording the response latencies (in increments of 16.6 ms.).

Procedure

Prior to commencing the experiment, each participant was informed that he/she was about to take part in a computer generated memory and learning experiment. Each participant was run individually. The following tasks were then presented on the computer.

1. Novel association training.

Participants in Condition 1 started the experiment with the picture association task. Participants in Condition 2 started with the word association training task. The procedure for these tasks was identical to that described in Pilot Study 1. Each training task comprised 80 trials, each of which showed an association between two pairs of novel stimuli.

2. First associative priming task.

Participants in Condition 1 were presented with the picture priming task, and Condition 2 participants the word priming task. There were 8 practice trials and 48 experimental trials. The procedure was the same as for Pilot Study 1 with the following exception: the prime was displayed for 1000 ms. The target was degraded (setting .09 on the Psyscope stimulus attributes template).

3. Vocabulary training task.

The vocabulary training was presented to participants in both Condition 1 and Condition 2. The procedure was the same as described in Pilot Study 2. Four word-picture pairs appeared over 80 trials. Each pair appeared an equal number of times, in half of the trials the word appeared first and in the other half the picture appeared first. The trials were presented in random order.

4. Second associative priming task.

This was a repeat of the first priming task. Participants in Condition 1 performed the picture priming task, and participants in Condition 2 performed the word priming task.

5. Third priming task (cross stimulus form).

The next task was identical in procedure to the first associative priming task; but participants in Condition 1 (trained in picture associations) were tested with the word priming task, and participants in Condition 2 (trained in word associations) were tested with the word priming task. As before, there were 8 practice trials and 48 experimental trials.

6. Vocabulary test task

For participants in both conditions the last task was the vocabulary test. The procedure for this task was identical to that used in Pilot Study 2.

Results of Experiment 1

The data recorded for the decision tasks were the response latencies to the target stimuli (in ms; increments of 16.6 ms "ticks"). Responses over 1200 ms were excluded as they were not considered to be automatic; response times less than 400 ms were also excluded because they were considered to be accidental. Incorrect responses were also excluded. The number of correct responses in the vocabulary test was calculated for each participant. A performance criterion of 90% correct responses for the vocabulary test task resulted in three participants being excluded from Condition 2. The alpha level was set at 0.05 in all of the following analyses.

The mean response times and standard deviations in all the decision tasks for both conditions are presented in Table 2.6. A one factor repeated ANOVA was employed to analyse each of the priming experiments. The difference in response times to the unprimed associated target and the primed associated target was compared to determine whether there was a significant priming effect. Conditions 1 and 2 were analysed separately.

Table 2.6: Mean response times (+ SD) to target stimuli after associated and unrelated primes, in each of the three priming tasks.

Task	Condition 1 (*trained picture associations*)		Condition 2 (*trained word associations*)	
	unrelated	associated	unrelated	associated
Priming 1	787	719*	653	659
associative priming	(150)	(129)	(113)	(105)
Priming 2	752	700*	628	617
associative priming	(135)	(96)	(79)	(65)
Priming 3	656	595*	866	859
cross stimulus modality	(134)	(92)	(142)	(126)

Note: * difference is significant

Analysis of priming Task 1

A significant picture priming effect of 68 ms was produced in Condition 1 ($F = 8.673$; $df = 1,15$ $p = .01$). In Condition 2 the response time to the primed associated targets was 6 ms. slower than to the unprimed targets. This difference was not significant. The ANOVA tables for these analyses are shown in Appendices 2.10 and 2.11 respectively.

Analysis of associative priming Task 2

A significant picture priming effect of 52 ms ($F = 4.834$; $df = 1,15$; $p = .044$) was produced in Condition 1. The picture priming effect had been maintained after studying the vocabulary learning task. There was no evidence of a word priming effect in Condition 2. The primed associated targets were recognised 9 ms faster than the unprimed associated targets, this difference was not significant. The ANOVA tables for these analyses are given in Appendices 2.12 and 2.13 respectively.

Analysis of cross modality priming Task 3

A cross modality priming effect was produced in Condition 1. A significant facilitation of 61 ms was produced when the target words were preceded by an associated prime ($F = 8.28$; $df = 1,15$; $p = .0115$). In Condition 2, the response time to the primed target pictures was 7 ms faster than to the unprimed associated pictures. There was no evidence of a cross modality priming effect. The ANOVA tables for these analyses are presented in Appendices 2.14 and 2.15 respectively.

Comparison of priming effects between tasks

A graph showing the priming effects produced in Condition 1 for each of the three decision tasks is illustrated in Figure 2.5. The reaction times for Condition 2 are illustrated in Figure 2.6.

To determine whether the priming effects produced in each task were significantly different a two way repeated measures ANOVA was performed.

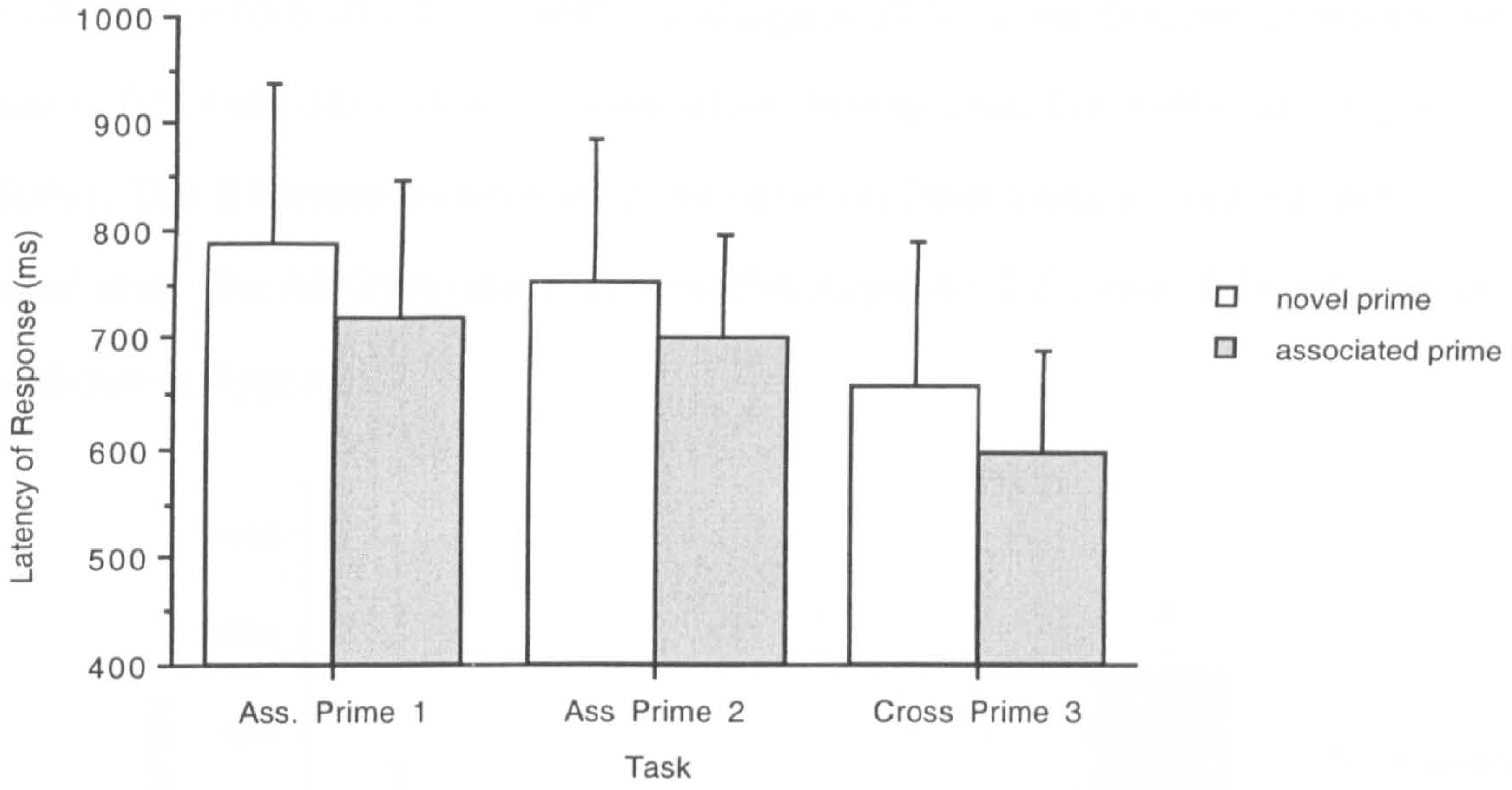


Figure 2.5: Priming effects (+ SD) produced by Condition 1 for each of the decision tasks (associative priming Task 1 and 2 and cross modality priming test).

In Condition 1 there was a main effect of task ($F = 34.07$; $df = 2,30$; $p < .0001$) and a main effect of prime type ($F = 9.17$; $df = 1,15$; $p = .009$), but there was no evidence that the difference in priming effects produced by each task was significant. There was no interaction between task and prime type. Planned means comparisons showed that there was no difference between the mean response time to Associative Priming Task 1 (752 ms, $SD = 142$) and Associative Priming Task 2 (726 ms, $SD = 118$). The mean response time of 625 ms ($SD = 117$) to the word stimuli in the cross modal priming task was significantly different to the mean response times to both Associative Priming Task 1 ($F = 61.3$; $df = 1$, $p < .0001$) and Associative Priming Task 2 ($F = 38.2$; $df = 1$, $p < .0001$). The ANOVA table for this calculation is given in Appendix 2.16).

For Condition 2, there was a significant main effect of task ($F = 51.9$, $df = 2,30$; $p < .0001$). There was no main effect of prime type. There was no interaction between prime type and task. Simple main effects showed that the mean response time to the picture targets in the Cross Modal Priming Task (862 ms, $SD = 131.9$) was significantly slower than the response times to the word targets in Associative Priming Task 1 (655.8 ms; *SD*

= 106.9) ($F = 65.6$; $df = 1$, $p < .0001$), and significantly slower than the mean response time of 622.4 ms ($SD = 71.4$) for Associative Priming Task 2 ($F = 88.6$; $df = 1$, $p < .0001$). The difference between the Associative Decision Tasks 1 and 2 was not significant. The ANOVA table is presented in Appendix 2.17; mean RTs for all tasks areshown in Appendix 2.18

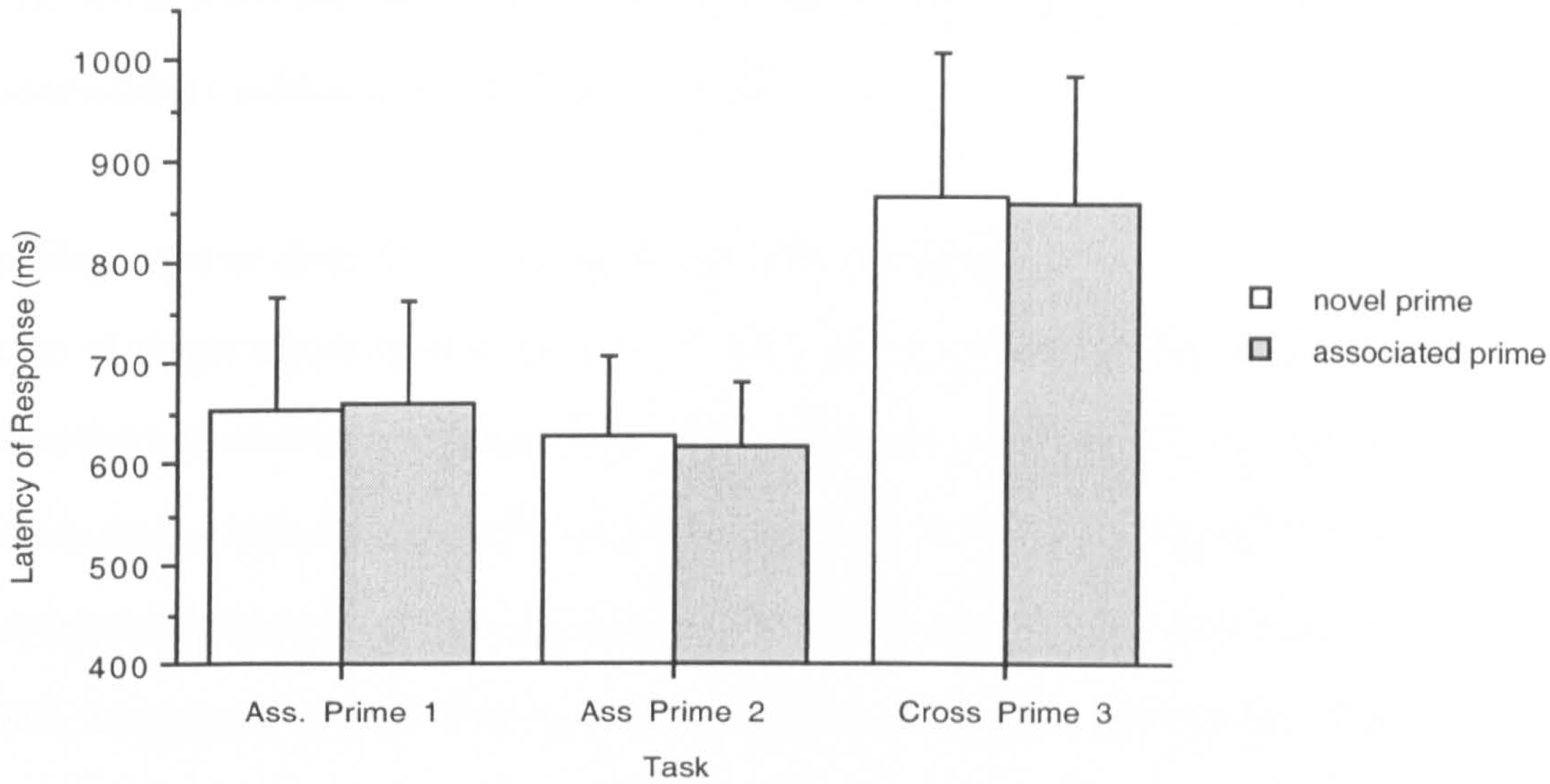


Figure 2.6: Response times (+ SD) to the target following an associated prime and an unrelated prime in each of tasks (associative priming task 1 and 2 and cross modality priming test) for Condition 2.

Discussion

Picture Association without Verbal Mediation

The results of Pilot Study 1 and the Associative Decision Tasks in Experiment 1 are a clear demonstration that picture association can occur without verbal mediation. Participants studied contiguously presented picture pairs. The pictures were of a very abstract nature, randomly filled squares on a matrix that had no resemblance to objects in the real world, and so did not invoke a naming response. It is improbable that the participants named the squares and then subvocally created an association between the names. The association between the pictures was strong enough to produce a corresponding word priming effect after names for each picture had been taught to the participants. This provides evidence that the representation for the picture association is accessible to the lexical system. We conclude that word associations are not dependent on a history of direct association. Because Experiment 1 failed to establish associations between the novel word stimuli, there was no evidence produced to determine whether picture associations could also be verbally mediated.

Dual Coding versus Single Semantic Store Interpretations

A prediction of single semantic store models is that conceptually mediated associations will produce the same facilitation regardless of the modality in which they are tested. These models propose that the surface form of pictures and of words are processed in separate systems and thus do not necessarily process information at the same rate (Te Linde, 1982; Snodgrass, 1984). The data from Condition 1 fit these predictions. The priming effect produced between the associated words in the cross modality task was equivalent to the priming effects produced between the associated pictures. The overall response time to the picture stimuli was slower than the response time to the words. Single semantic store models also predict that the order in which the associative information is acquired will have no difference on the resulting strength of associations, because all the information is translated into an amodal propositional code. The failure of Pilot 2 to produce any priming effects means that there is no evidence with which to evaluate this prediction. Methodological improvements in our subsequent experiments (see later chapters) make them more suitable for testing the predictions of competing theoretical models.

The dual coding model can also accommodate these patterns of results. In a dual coding model, the association between the pictures resides in the iconogen system. The lexical system has access to this association via the referential links. Because the locus of association is the same for both tasks, then the same facilitative effects would be predicted. The dual coding model proposes different processing systems with entirely different mechanisms, and so the different response times recorded for picture and word stimuli are in keeping with the predictions of the model. Dual coding allows different associative strengths to be established in each symbol processing system for the same conceptual pairs. However, no comparisons between the processing systems could be made because of the failure of Pilot Study 2 and Condition 2 of Experiment 1 to produce word associations.

Perceptual Basis of Conception

If picture associations can be mediated purely on the basis of perceptual experience, this is evidence for the perceptual grounding of conception. Stronger evidence comes from the availability of this perceptual information to the verbal system. The failure to create associations between novel words that had no meaning or perceptual referent is in keeping with the theories of perceptual grounding put forward by Barsalou (1998).

Are Novel Word Associations Verbally Mediated?

Dagenbach et al. (1990) posited that associative priming might require a meaningful relationship between the prime and the target. It is possible that the phrases in the verbal training did not constitute a meaningful relationship. Associations between the abstract novel pictures were established, and this was sufficient to mediate a verbal association. This would suggest that there is something inherently meaningful in a picture (however abstract that picture might be) that is not present in a novel letter string.

Jörg and Hörmann (1978) claimed words are more than object labels. They claimed that the level of specificity of the verbal label results in a qualitatively different form of processing, not a quantitative change in the number of features that are encoded from the picture array. This is an important phenomenon: it seems that a word is a product of cognition -- a qualitatively different representation of reality than that of perception and sensation (Vygotsky, 1934/1986). If this is true, presenting participants with meaningless letter strings to associate does not constitute a verbal task.

Paivio (1971) suggested that associations between concrete words are stronger because of a redintegration process which forms a compound image combining two items. In contrast, abstract word pairs are less memorable because they are encoded as two separate items. According to Paivio, the novel words employed in this experiment would be encoded as separate items, and would thus be less memorable. On this basis, it would be expected that participants in Pilot Study 2 would perform better in Condition 2 (word-picture associations learned prior to word-word associations) than in Condition 4 (word-word associations learned prior to picture-word associations). The data show a trend in this direction: there was a faster response following the primed target compared with the unprimed target in Condition 2, whereas the response to the primed target was slower than to the unprimed target in Condition 4. Inspection of participants' mean response times in Condition 2 showed that four of the six participants produced faster reaction times to the primed targets compared with the unprimed targets, whereas only two of the six participants in Condition 4 showed any evidence of a priming effect. As these differences failed to reach significance, further evidence must be obtained before any conclusions can be drawn.

The overall pattern of our data is consistent with previous research. For example, Carr et al. (1982), and Sperber et al. (1979) both showed that the latency of response to picture targets was greater than for word targets when a naming task was employed, although the priming effects were greater for the picture targets than for the word targets. Durso and Johnson (1979) also found much larger priming effects between related pictures than between related words (200 ms and 28 ms respectively).

It is possible that a verbal association was produced in Experiment 1 but was not sufficiently strong to produce a priming effect. More likely, any pattern was masked by the wide individual differences produced. Carr et al (1982) found more priming for picture targets than for word targets regardless of the type of prime (54 ms and 23 ms respectively). Pictures seemed more susceptible to priming than words did.

Methodological Weaknesses

It appears that contiguous exposure to novel word stimuli is insufficient to establish associative word priming. It is also possible that the training procedure was too passive; there was no means of ensuring that participants attended to the monitor after they had pressed the button to start the trials.

A problem with the vocabulary test task was that the program required that participants press the correct response button before the display disappeared from the screen. This in effect turned the test task into a further training task with feedback. It is very possible that the scores obtained on the vocabulary test task are not representative of participants' ability to recall the picture-word pairs. This might explain the failure to produce priming in Pilot Study 2: participants had not learned the picture-word associations sufficiently well to effect a transfer of associations across stimulus modality.

Conclusion

This experiment demonstrated that picture associations can be established without verbal mediation, and once established are available to the lexical system.

Summary

- The experimental aim was to answer the question "Are picture associations verbally mediated?"
- Evidence was presented to show that verbal processing influences the way that pictures are processed and encoded. To determine whether picture associations can occur without verbal mediation it was necessary to find some means of controlling for the influence of the verbal processing system.
- Participants were presented with novel picture and novel word stimuli.
- Paired Associations were trained between the new stimuli.
- This reduced the possibility of automatic lexical processing priming the relationship between two pictures, and of imagery based associations automatically facilitating the processing of two words.
- Pilot Study 1 demonstrated associative priming effects following exposure to contiguous presentations of pairs of novel words and novel pictures.
- Pilot Study 2 introduced picture-word association training following the paired associate training. There was no evidence of cross modal priming.
- Experiment 1 produced associative priming between novel pictures without verbal mediation and demonstrated a cross modal word priming effect.
- Experiment 1 failed to produce associative priming between novel words.
- Insufficient evidence was obtained to distinguish between the predictions of single semantic store and dual coding models.
- It is important for theoretical reasons to determine why Experiment 1 failed to produce associations between the novel words.

Chapter 3

Transfer of Associations Between Pictures and Words: Can Word Associations Produce Corresponding Picture Associations?

Introduction

In Chapter 2, we established that patterns of association between novel pictures are available to the verbal system. In this chapter we aim to establish whether patterns of association between novel words are transferable to the visual system: Can corresponding picture associations be produced from associated words?

In Experiment 1 (Chapter 2) a transfer of associative information was demonstrated from picture stimuli to their corresponding names, but we failed to produce transfer from novel word to novel picture associations. The experiments described in this chapter aim to explore this issue more fully. In Experiment 1, the names of the stimuli (picture <-> word associations) were not given until after the novel associations had been trained. The experiments described in this chapter are designed to replicate the results of Experiment 1 and to extend the design so that the role of the name relation (picture <-> word) can be investigated. Does the order in which the name relation is learned make any difference to the transfer of associative information between stimulus modalities? For example, if name relations are learned before the novel word associations are presented, does a corresponding picture association arise more readily than if the name relations are taught after the novel word associations are presented?

The experiments in this chapter are also intended to allow us to test two hypotheses arising from the results of Experiment 1 (Chapter 2): Hypothesis 1 (H_1) is that novel picture associations are learned more readily than novel word associations. Hypothesis 2 (H_2) is that associations are formed more readily between novel words which are the names of novel pictures than between novel words which have no pre-existent picture referents.

Word associations have long been thought to hold the key to the organisation of semantic memory (Clark, 1970; Collins & Loftus, 1975; Fischler, 1977a). Data that shed light on the means through which word associations are acquired might contribute to our understanding of the nature of semantic memory and to our ability to evaluate the contrasting predictions of dual coding and single store models of semantic memory.

Overview of Experiments

Two experiments are described in this chapter: the first (Experiment 2) proved unsuccessful. Experiment 3 was designed to overcome the problems identified in the training and testing procedures of Experiment 2. Similarities were identified between the methodologies of Experiment 2 and the matching to sample paradigm that has been employed successfully in many behaviourist studies of language. The matching to sample paradigm has been particularly useful in exploring *stimulus equivalence.* This phenomenon is closely linked with symbolic representation, a link which has been extensively exploited in behaviourist studies of the status of associations that exist between words and picture referents. A short review of this research literature is provided later in this chapter, and the differences between the research questions explored by behaviourists and the experimental aims of this thesis are presented. The methodology of Experiment 3 draws heavily on behaviourist techniques to explore a key aspect of cognitive processes: the interaction between lexical semantics and imagery representations. The results of Experiment 3 are consistent with the conclusions of Experiment 1. An exploratory analysis of Experiment 3's post experimental interviews leads us to consider the role of conscious processing during the acquisition of symbolic relations.

Semantic Memory

Dual coding proposes separate systems for verbal and perceptual material, hence the advantage conferred to concrete words over abstract words. A concrete word has two representations: a representation within the verbal system, in which associations with other verbal representations are encoded, and a representation within the visual system, in which associations with other visual representations are encoded. In addition to the associations within each system, referential links between the systems are proposed by dual coding theorists, so that perceptual associations encoded within the perceptual system are available to the verbal system, and vice versa. Because it is assumed that these processing systems are functionally independent, there is no prediction that comparable operations within each system should take comparable times (te Linde, 1982; Snodgrass, 1984).

Those single semantic store models that permit associations between words at a purely lexical level assume these associations to be devoid of any semantic content; all semantic representations are amodal and stored as propositions (Biggs & Marmurmek, 1990; Seymour, 1973; Snodgrass, 1984). It might be supposed that novel word associations would be achieved more readily than novel picture associations, since they can be related at a purely lexical level. The results of Experiment 1 did not show this pattern – associations between novel pictures, but not between novel words, were achieved after contiguous exposure. The priming paradigm employed in Experiment 1 has been held to be a measure of semantic priming because of its sensitivity to conceptual relations between related items, and therefore might not be a sensitive measure of associations devoid of conceptual content. Single semantic store models predict that order of acquisition will not have an effect on retrieval processes, since semantic knowledge is stored as propositional representations in these models. For example, when two novel pictures are associated, the strength of any corresponding word associations should not depend on whether the names for the pictures were learned before or after the pictures were associated. The experiments described in this chapter aimed to test this prediction by manipulating the order in which name relations were introduced when participants learned associations between novel pictures.

Why Might Word Associations Arise More Readily from Picture Associations than from Verbal Contiguity?

Experiment 1 (Chapter 2) demonstrated that patterns of association established by contiguous presentations of novel pictures can result in corresponding word associations without explicit training. A priming effect was achieved between the associated novel pictures and between the names of these pictures. It was concluded that the picture association mediated the association between the picture names. This was a demonstration of word associations grounded in a direct perceptual experience. It is improbable that this word association resulted from subvocally naming the pictures during the paired associate training task, since the names for the pictures were not presented until after the picture association training task. Nor had the participants ever seen (or heard) the names of the pictures presented together.

Because the picture stimuli in Condition 1 (Experiment 1) were abstract, the priming effects demonstrated cannot be accounted for by semantic similarity dependent on overlap of semantic features (such as "back" or "legs"). The relations between the matrices forming the picture stimuli were arbitrary; the association could only be derived from the simultaneous presentation of the novel picture stimuli during the training task. We contend that the priming produced between the corresponding novel words reflected a semantic relationship based on the episodic memories created during the picture association training task.

Condition 2 of Experiment 1 failed to produce priming effects between the novel word pairs after the associative training task. The novel word pairs were contiguously presented embedded in a series of simple phrases. This suggests that contiguity may not be enough to produce priming effects.

In their original priming study, Meyer and Schvaneveldt (1971) proposed that the facilitation recorded between related words such as "doctor and nurse" or "bread and butter" reflected the organisation of semantic memory: semantically related items were stored in the same location, activated by spreading activation. Further evidence that semantic associations between stimuli enhance priming effects comes from Ratcliff and McKoon (1978). They showed that, after extensive study of a series of sentences, priming effects were produced between words that had appeared in the same sentence. Greater priming effects were produced between words that were from the same proposition than from other words in the same sentence, regardless of the physical proximity of the words within that sentence (measured in terms of the number of intervening words in that sentence). This suggests that the priming effect is semantically mediated, rather than the result of mere contiguity. It also appears that the closer the relationship the greater the priming effect produced.

Word Associations: Accidents of Contiguity or Semantic Similarity?

Wundt (cited in Fishler, 1977 a) distinguished between two types of word association. He referred to associations based in semantic or logical relationships as "inner associations", and to associations arising from contiguity or speech habits as "outer associations". Fischler (1977 a) attempted to determine whether the priming effect produced by associated words in a lexical decision task (LDT) arose from semantic properties of the words or from "accidents of contiguity" (p. 335). He demonstrated a priming effect between word pairs that shared an underlying semantic similarity but were not free associates of each other. For example, Fischler hypothesised that "wife" and "nurse" might be related through the common semantic attributes of "human" and "female". The priming effect he produced between his semantically related word pairs was similar to the priming effect he observed between free associates obtained from a normative list of free associations (84 ms and 99ms respectively). Fischler concluded that priming results from a facilitation of semantic processing, but his experiment did not exclude the possibility that facilitation in LDT could be caused by accidental association of two items rather than an underlying relationship. Fischler also observed that there was a possibility that the facilitation effect could ultimately be derived from episodic memory.

It is unlikely that passive exposure to phrases containing pairs of nonwords was sufficient to establish a semantic relationship. However, we cannot exclude the possibility that an association reflecting the co-occurrence of the novel words had been produced. An LDT might not be an appropriate measure of word associations created between novel words devoid of semantic content. It was decided to use a different test task to try to establish whether word associations based in co-occurrence might create corresponding associations between their picture referents. If the pattern of results obtained replicated those of Experiment 1, this would add to the weight of evidence supporting dual coding and also the perceptual grounding of symbolic material.

Perceptual Symbol Grounding

In recent years there has been a resurgence of the idea that cognition is intrinsically perceptual (Barsalou, 1999; Glaser, 1992; Goldstone & Barsalou, 1998; Pani, 1996). The assumption that cognition and perception share the same processing systems provides a parsimonious solution to the symbol grounding problem: how does a symbol refer to a perceptual state? If symbolic functioning is abstract and amodal, how can a symbol be understood in the absence of its physical referent? This problem was introduced in Chapter 1.

Perceptual and Linguistic Symbols

Barsalou (1999; Goldstone & Barsalou, 1998) proposed an account of how the brain could implement a conceptual system using sensory motor mechanisms. It assumes that a perceptual symbol is a record of a subset of a perceptual state arising in the sensory-motor system. Perceptual states, including introspective states, cause patterns of neural activity within the brain; subsets of these neural states are extracted and stored in long term memory. Perceptual symbols are modal and analogical; on recall they are represented in the same areas of the brain activated by the original perceptual state. For example, the perceptual symbols for colour are represented in the same areas of the brain that are involved in perceiving colour. This account overcomes both the symbol grounding problem and the related problem of transduction – the process whereby perceptual states are mapped onto amodal symbols.

Barsalou (1999) proposes that because perceptual symbols are patterns of neural association they will change with experience. A perceptual symbol behaves as an attractor in a connectionist network; it changes as the network changes. Barsalou proposes that perceptual symbols are not stored in isolation, but are organised in a way that allows the cognitive system to construct a simulation of an object or an event. He gives the example of the way that the perceptual symbols acquired from studying a car might be stored. When someone looks at a car their attention will focus on different parts of the car, the wheels, the doors, the windows, et cetera. The perceptual symbols for these parts will become spatially integrated, possibly using an object-centred frame. Further experience with the car, the front elevations, the interior, the sound of the engine will also become integrated into the same framework. Barsalou refers to this framework as a simulator. A simulator will allow someone to anticipate how the car would look from another viewpoint, or to simulate that car in its absence. Simulators form the basis of concepts and categories in Barsalou's model. New information and associations can be added to simulators.

Barsalou (1999) proposed that simulators for linguistic symbols develop in the same way as simulators for perceptual symbols. He suggests that linguistic symbols develop alongside their associated perceptual symbols. A linguistic symbol is not an amodal symbol. A linguistic symbol is the schematic memory of the perception of a written or spoken word. The perceptual experiences that form each linguistic symbol are integrated to form simulators. These produce simulations that allow the surface forms of these words to be recognised and reproduced. As the word simulators develop they become associated with the simulators for the entities to which they refer, and to other properties, for example, "red". The simulator for a concept might contain a large number of simulators for words, linked to produce a semantic field that is mapped onto the underlying conceptual field. Barsalou (1999) posits "Once simulators for words become linked to simulators for concepts, they can control simulations. On recognising a word, the cognitive system activates the simulator for the associated concept to simulate a possible referent" (p. 592).

This account suggests not only that associations between novel pictures will produce associations between their names, but also that associations between words can result in new conceptual associations. This allows the prediction that associations between novel words can produce associations between their corresponding novel pictures. However, because this account suggests that simulators for words are mapped onto simulators for concepts, it is possible that the sequence in which novel words and novel pictures are introduced might have an effect on how readily an association between novel pictures might be derived from a novel word association. Experiment 2 aims to address this question by manipulating the sequence in which associations between novel words and associations between those novel words and novel pictures are introduced.

Barsalou (1999) examines the implication of his theory for language development in infants. He suggests that infants have developed the capacity to simulate their perceptual experiences of the world long before they use language. This conceptual knowledge then supports the acquisition of language; new words are attached to the relevant simulators. Some new words may generate a new simulator or a new aspect of an existing one, but more often new words are mapped onto existing simulators.

Barsalou's (1999) theory suggests that patterns of verbal association will be stronger if they are linked as components of a perceptual simulation. This leads to the prediction that associations between novel words that are grounded in a perceptual association will be stronger than an association between two perceptual symbols representing the surface forms of two novel words. This model can also support picture associations emerging from corresponding word. It could be predicted from this that associations between novel pictures will emerge more readily from word associations if the words are associated with picture referents before associations between the words are learned.

Like Paivio's (1971; 1986; 1991) structural-functional dual coding theory, Barsalou's (1999) perceptual symbol theory suggests that there will be an advantage in learning corresponding picture-word associations prior to learning novel word associations. This is because corresponding patterns of activation can then arise between the perceptual symbols. Perceptual symbols theory also seems to suggest that novel words which are mapped onto existing perceptual associations can produce stronger associations amongst themselves, since they might be incorporated into an existing conceptual simulator (that specifies the association between the perceptual symbols). Both dual coding and perceptual symbol systems accommodate most of the results of Experiment 1 (which used an LDT to demonstrate a priming effect between novel words when they were related via an association between their picture referents). They do not particularly predict the failure to produce word associations by repeated contiguous exposure (Condition 2). However, if the priming task produces facilitation between semantically related items, and semantic relations are defined by the link between the word and its perceptual representation, then these results might be predicted.

Methodological Decisions

A new methodology was introduced for the experiments described in this chapter. A comparison of the numbers of correct associates selected for the experimental versus control stimuli provided a measure of transitively derived associations that was not dependent on semantic priming. If the pattern of results obtained in Experiment 1 was replicated, it could be concluded that the differences observed in the participants' abilities to learn picture associations compared with word associations were not the result of an experimental artefact. The novel word stimuli used in Experiment 1 were replaced by longer novel words because it was possible that they were too phonetically or orthographically similar to existing words. Evett and Humphreys (1981) showed that if a novel word is similar to an existing word it can cause activation of its existing lexical neighbours. They showed that the facilitation produced by an orthographically similar prime produced the same facilitation as the legal prime. For example, in their word recognition test there was no difference in the facilitation produced by the legal prime word "smite" in priming the target "SMILE", compared with the nonword prime "smife". It was decided that the training tasks in Experiment 1 were too passive. The procedure for the training trials was altered in both Experiments 2 and 3. Participants were required to actively attend to the display, and to select the associate for the target stimulus presented in each trial. Feedback was given on each trial, so that participants knew when they had made a mistake and what the correct response should have been. In Experiment 3, a criterion of learning was introduced: the training trials continued until participants had produced 16 consecutive correct responses. The test task was a variant of the training trials, with number of correct responses as the dependent variable. To test between the predictions of dual coding and single store models, the number of conditions was increased so that name relations (picture-word associations) could be introduced either before or after novel picture or novel word associations were presented.

It was decided that the results of Experiment 1 required replication, but with a task that would measure patterns of association resulting from contiguity. In order to assess the predictions of single semantic store models versus dual coding models the design needed to be extended. Comparisons were required between conditions in which the name (picture-word) associations had been established before the trained novel associations (word-word or picture-picture), and conditions in which the novel associations were trained in the absence of a name or a picture referent.

Experiment 2

Method

Participants

A total of 110 volunteers were recruited from two participant panels: those from the psychology undergraduate panel received a course credit, and those from the community panel were paid £3.00. No attempt was made to balance the number of males (42) and females (66) participating. Their age range was approximately 16 - 45. Participants were allocated to one of six conditions on a pseudorandom basis, determined by the order in which they arrived.

Stimuli and apparatus

Eight abstract picture stimuli were selected for the experimental tasks from the corpus of picture stimuli generated for Experiment 1 (Chapter 2). Each picture was composed of randomly filled squares in a five by five grid matrix. An additional four picture stimuli comprised of four circles with different infill patterns, were generated for the filler tasks. Twelve novel word stimuli were generated; each consisted of seven letters and conformed to a consonant vowel pattern, for example, *doxovan.* Eight of the novel words were randomly selected for the experimental trials (four for the paired association training task and four for controls in the association test task); the remaining four were allocated to the filler tasks.

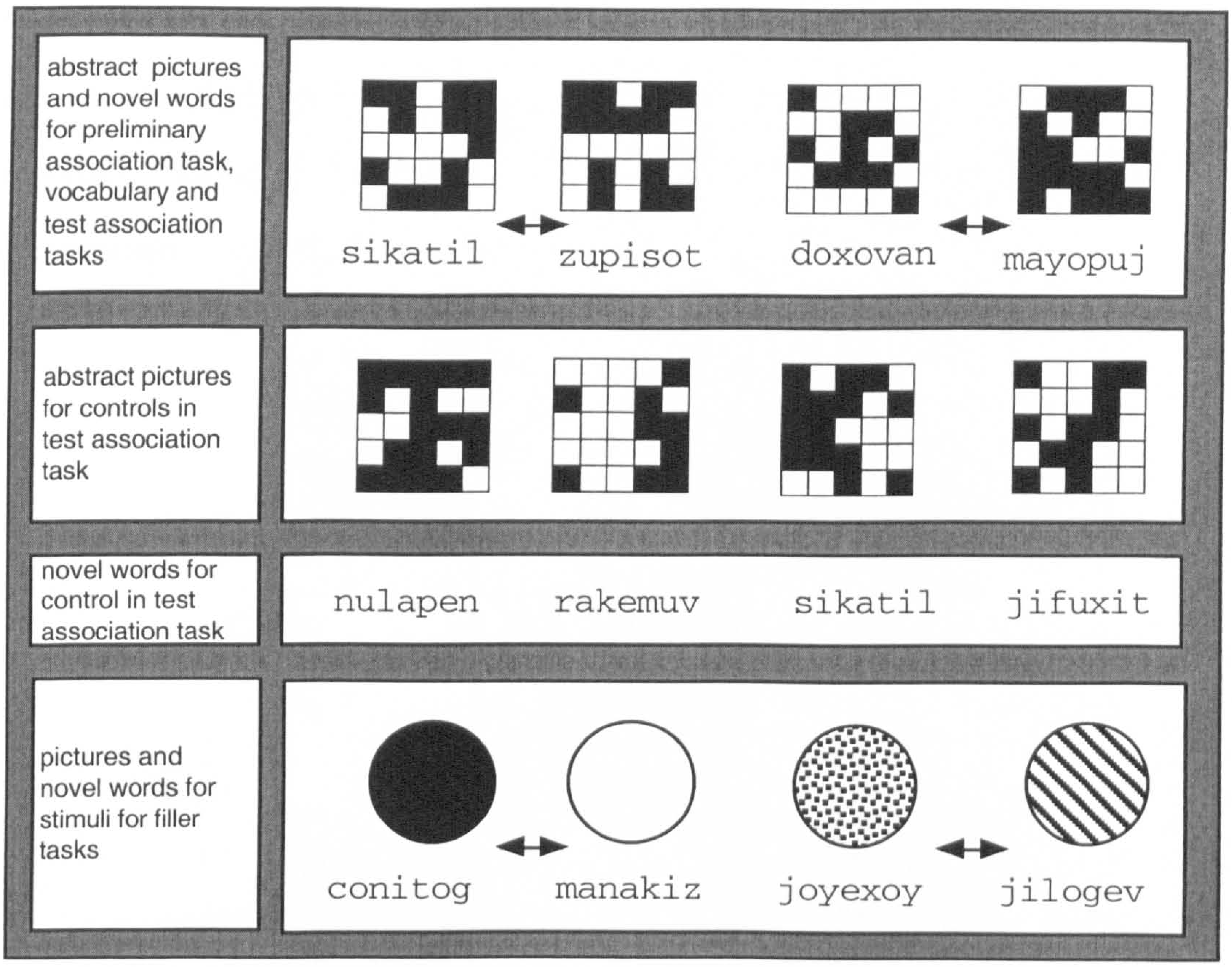


Figure 3.1: Experimental stimuli for paired association training tasks, association test tasks, vocabulary task, and filler tasks.

The stimuli are shown in Figure 3.1. The word stimuli were displayed in Courier, 18 point, and the picture stimuli were approximately 3 cm square. The abstract picture stimuli selected for the paired association training task were arranged in pairs. The two picture pairs were arbitrarily paired with the four novel words selected for the paired association training task. Novel word pairs were selected to correspond with their paired picture referents. The remaining picture and word stimuli for the experimental tasks were reserved to be controls in the final test task.

In each of the four tasks the stimulus array was the same (see Figure 3.2). Five squares were displayed on the screen. The target stimulus was always displayed in the central square and comparison stimuli in the outer squares.

Programs generated using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993) were used to display the stimuli for each task, and to record the participants' responses. The experiment was run on a Macintosh II fx, and displayed on a 15" Apple monitor. Timing relied on the Mac timer, accurate to 1/60 second.

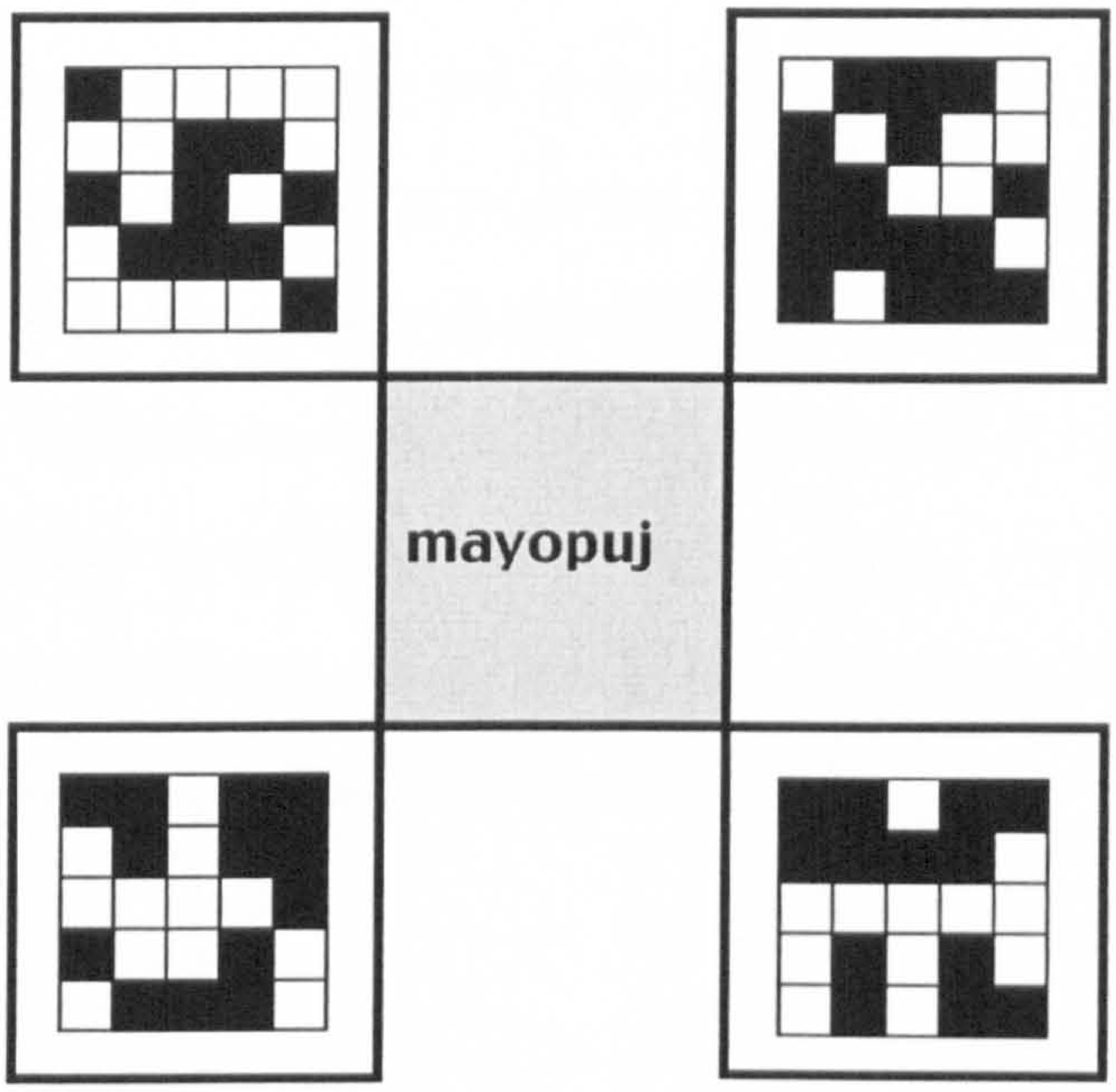


Figure 3.2: Stimulus array for the vocabulary training task.

Design

A mixed design with six independent conditions was employed. Each condition consisted of four tasks: three different paired association-training tasks, and an association test task. The sequence of the tasks was manipulated between the conditions. The sequence of tasks in each condition is illustrated in Table 3.1.

Conditions 1, 2, 3, and 4 were the experimental conditions; Conditions 5 and 6 were the control conditions. Conditions 1 and 2 were designed to detect whether novel associations formed in verbal memory produced corresponding associations between their picture referents (Condition 1), and whether picture associations produce corresponding verbal associations between their names (Condition 2). Conditions 3 and 4 were designed to examine the role of the picture-word name relation in mediating the transfer of information between the picture and the verbal symbolic systems. In Conditions 1 and 2, participants learned the name relation before studying either the picture association-training task or the word association-training task. In Conditions 3 and 4, participants learned the name relation after completing the paired association training task. A comparison of Conditions 1 and 2 with Conditions 3 and 4 should determine whether transfer of associative information is dependent on participants' subvocally naming the pictures (thereby creating a word association as they learn the picture associations, or activating a mental image of the referent pictures when the associated words are studied).

Table 3.1: Order of tasks for each condition

Condition	1st Task	2nd Task	3rd Task	4th Task
Condition 1	vocabulary (*picture-word association*)	picture paired association training	filler vocabulary (*irrelevant picture- word association*)	word association test (*word-word*)
Condition 2	vocabulary (*picture-word association*)	word paired association training	filler vocabulary (*irrelevant picture- word association*)	picture association test (*picture-picture*)
Condition 3	filler vocabulary (irrelevant picture-word association)	picture paired association training	vocabulary (*picture-word association*)	word association test (*word-word*)
Condition 4	filler vocabulary *(irrelevant picture-word association)*	word paired association training	vocabulary (*picture-word association*)	picture association test (*picture-picture*)
Condition 5 (control)	filler vocabulary (*irrelevant picture-word association*)	filler visual association *(irrelevant picture-picture association)*	vocabulary (*picture-word association*)	word association test (*word-word*)
Condition 6 (control)	filler vocabulary (*irrelevant picture-word association*)	filler verbal association *(irrelevant word-word association)*	vocabulary (*picture-word association*)	picture association test (*picture-picture*)

Note: that the stimulus pairings used in each condition are illustrated in Figures 3.3 - 3.8

Conditions 5 and 6 were control conditions, included to ensure that the pairings between the experimental stimuli were arbitrary and could not be attributed to similarities with previously associated words or items. The only relevant information that participants had acquired prior to the test task was the picture-word relation. The associations studied in the filler tasks were irrelevant to the test task. Filler tasks were used to control for practice effects. Participants in each condition had been asked to learn the same number of paired associations, and were equally familiar with the stimulus array and response keys before they commenced the final association test task. Participants were not told that the associations presented in the filler tasks were irrelevant to the test task.

The final test task for three of the conditions was the picture association test task; for the other three conditions the word association test task was used. In the final test tasks, participants were asked to select a comparison stimulus associated with the probe stimulus for both the experimental and the control stimulus sets. The dependent variables were the number of correct trials and the time taken to make the decision response.

Condition 1

Condition 1 started with the vocabulary task. Participants were presented with the names of the novel pictures before they were given the paired picture association-training task. The filler vocabulary-training task was presented after the picture association-training task, but before the word association test task. The sequence in which the stimuli were presented is illustrated in Figure 3.1. Condition 1 tested for a transfer of associative information from the picture processing system to the verbal system. Verbal associations might be established by participants' naming of the associated pictures during the paired association training task.

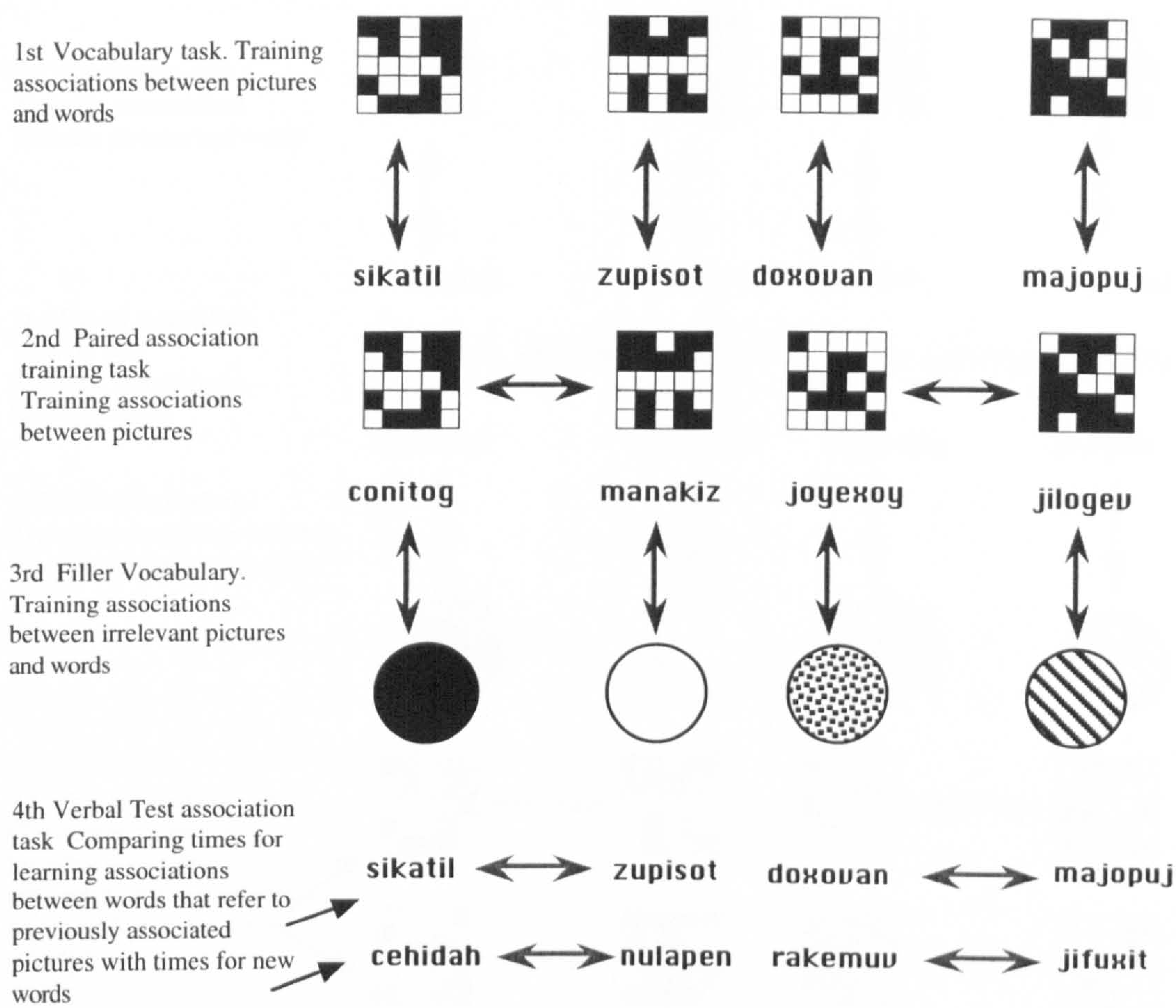


Figure 3.3: Order in which the tasks were presented to participants in Condition 1.

Condition 2

This condition tested for a spread of associative information from the verbal system to the visual system. The order in which information was presented to the participants in Condition 2 is illustrated in Figure 3.4. Participants were presented with the names of the pictures before they were given the word association-training task. This sequence of exposure allowed for corresponding picture representations to be activated during the word association-training task. Participants completed a filler vocabulary task before they were given the picture association test task.

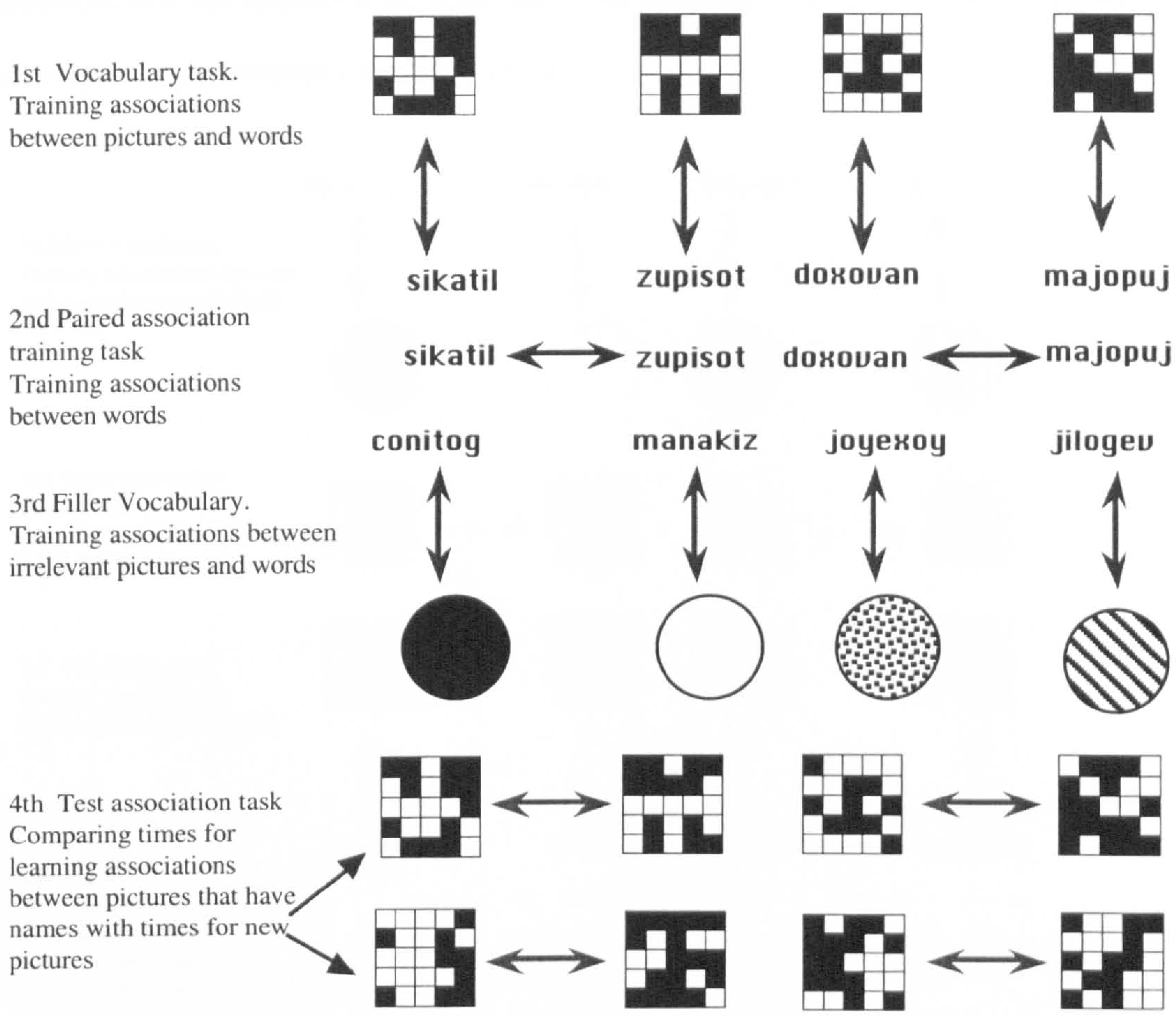


Figure: 3.4: Order of exposure to information in Condition 2

Condition 3

Condition 3 started with the filler vocabulary task during which participants studied irrelevant picture-word associations. In the third task, the vocabulary task, the names for the pictures were presented. The last task was the verbal association test task. The tasks presented in Condition 3 are illustrated in Figure 3.5. This condition was compared with Condition 1 to examine the effect of participants' using a name for the pictures before pictures were associated with each other; that is, to detect transfer of associative information from the perceptual to the verbal system. If associative information is stored as propositions within a common semantic store, it can be predicted that the sequence of exposure to information will not have an effect on participant's performance in the test task.

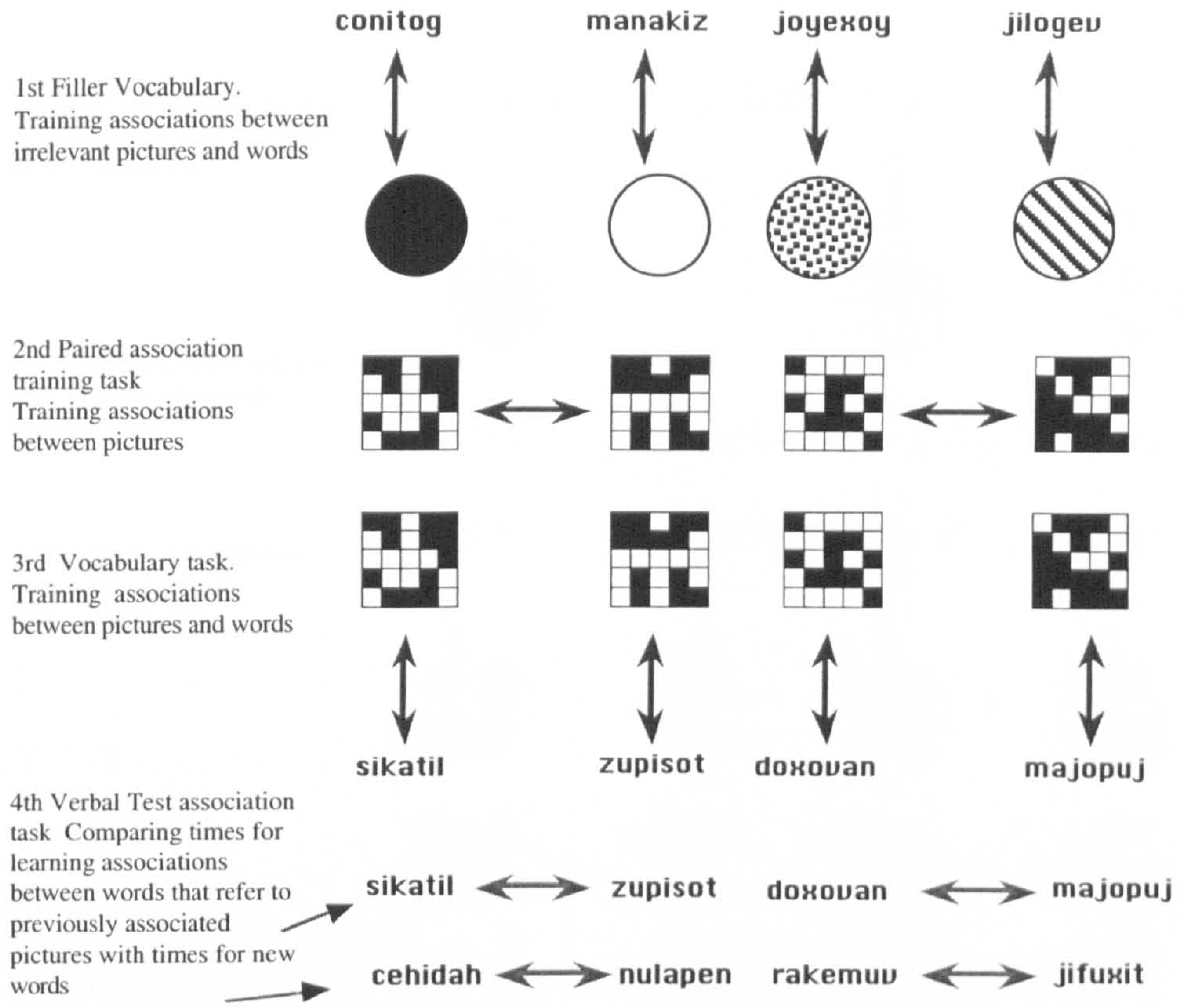


Figure 3.5: Sequence of tasks, and order of exposure to information in Condition 3.

Condition 4

Condition 4 mirrored Condition 3. The first task was the filler vocabulary task. The second task was the word association-training task. The novel words were associated before the picture-word name associations were trained during the vocabulary task. The final task was the picture association test task. A comparison of the results of Conditions 2 and 4 would show whether knowing the name (picture-word association) at the time of learning the word associations had an effect on the availability of the word associations to the picture processing system. The sequence of tasks is illustrated in Figure 3.6.

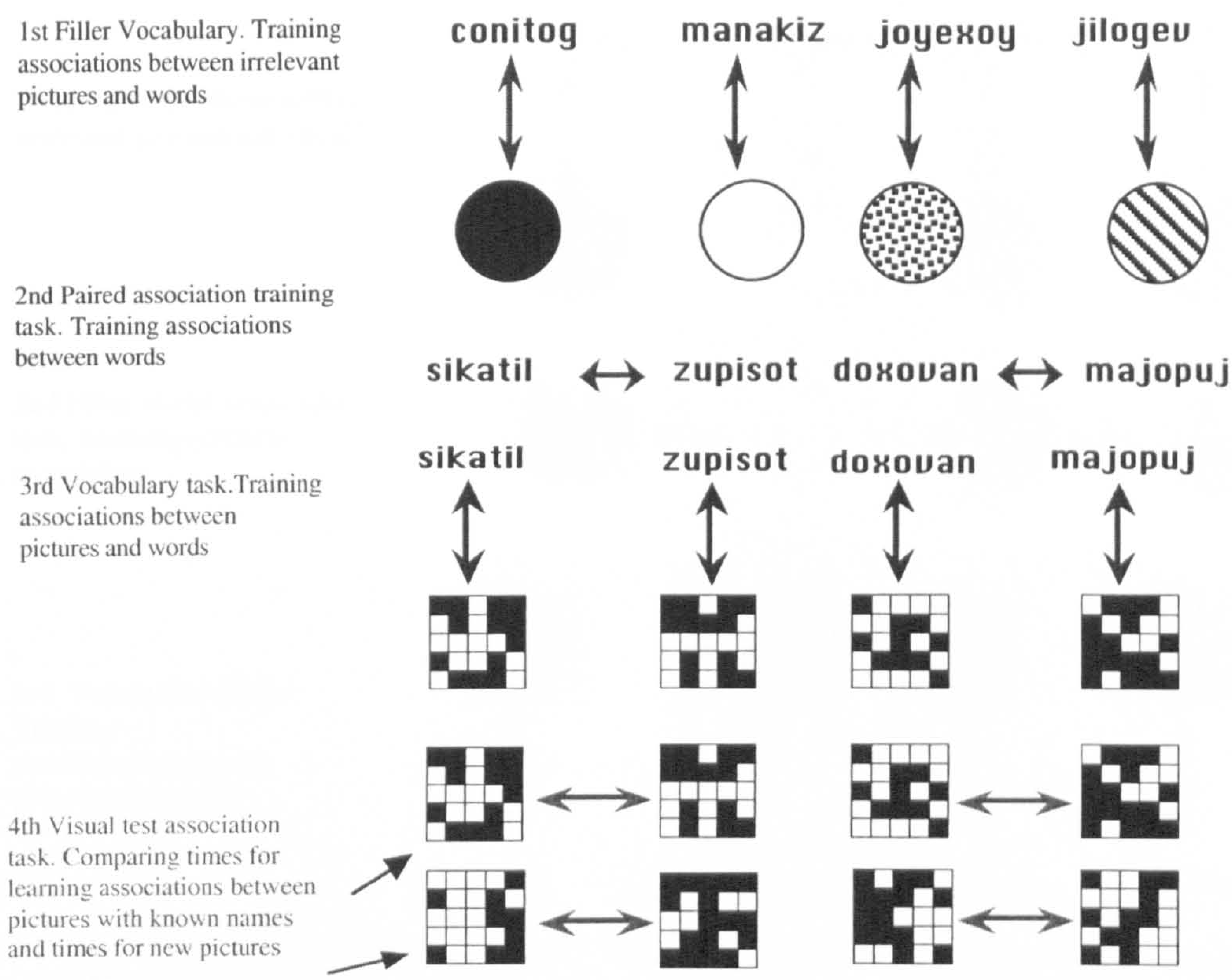


Figure 3.6: Sequence of tasks, and order of exposure to information in Condition 4.

Condition 5

This condition controlled for the effect of previous exposure to the stimuli, since the experimental stimuli had been encountered in the vocabulary task. Participants in this condition were given no exposure to relevant information about the paired relationships between these words prior to the test task. The filler vocabulary task was presented first, followed by the filler picture association task. Participants were then given the vocabulary-training task followed by the word association test task. This is illustrated in Figure 3.7.

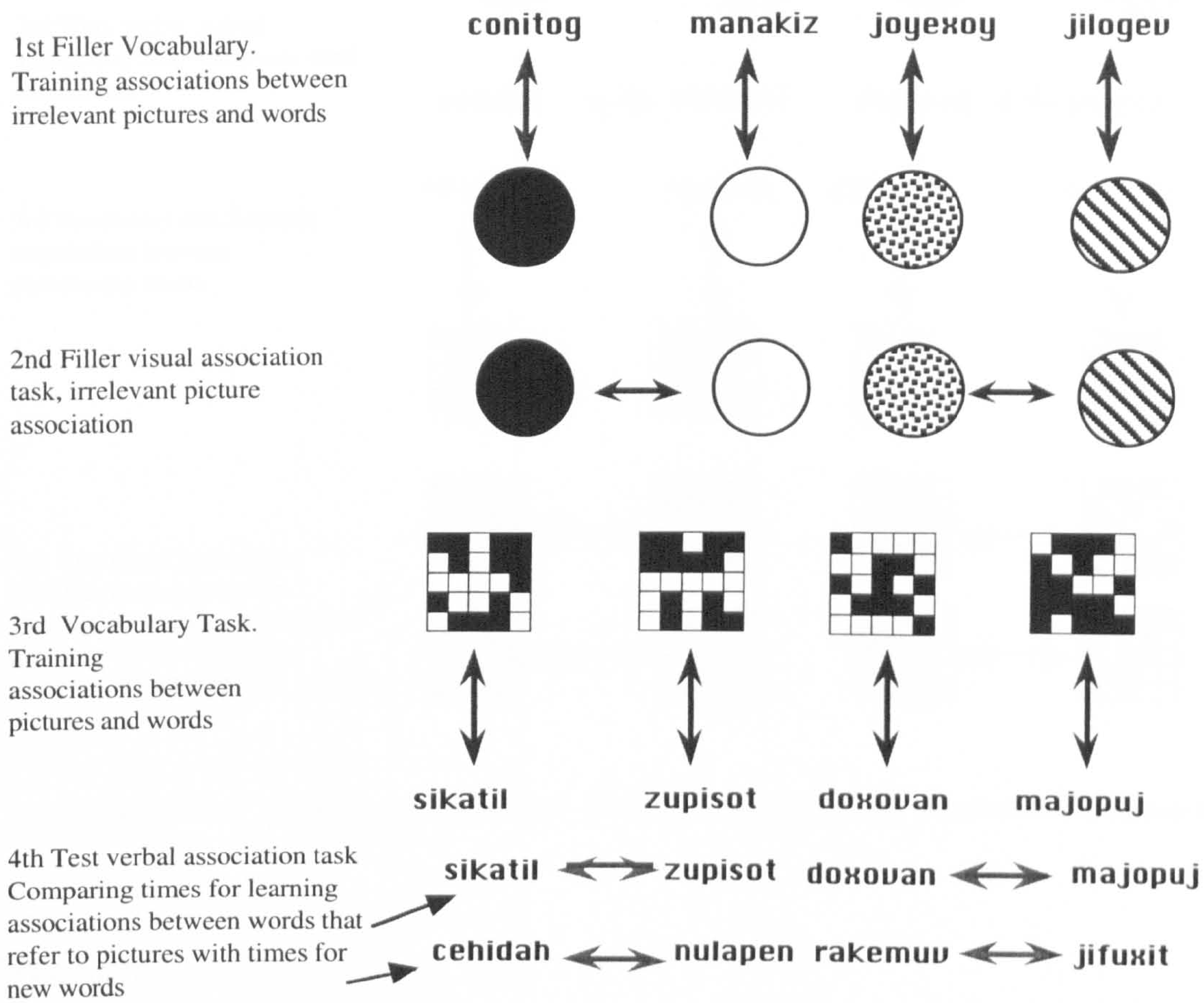


Figure 3.7: Sequence of tasks and order of exposure to information in Condition 5.

Condition 6

This was the visual equivalent of Condition 5. The effects of previous exposure to the picture stimuli were controlled for. The filler vocabulary task was presented first, followed by the filler word association task. Then the vocabulary training task was presented, followed by the picture association test task. This is illustrated in Figure 3.8.

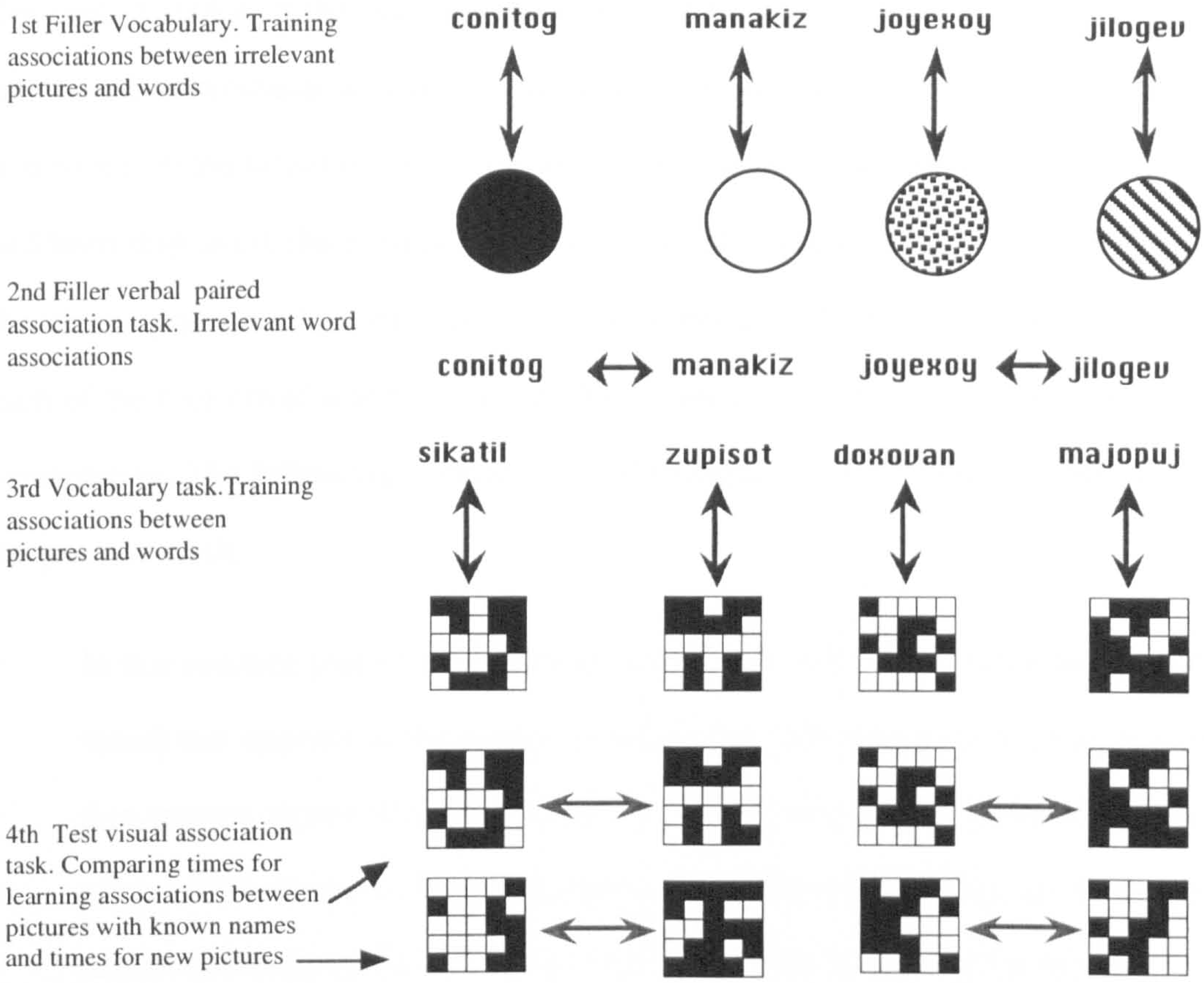


Figure 3.8: Sequence of tasks, and order of exposure to information in Condition 6

Procedure

Vocabulary task

The objective of this task was to teach the participants the names of the four experimental novel pictures, by training four bi-directional picture-word (and word-picture) associations. This task consisted of 16 practice trials and 32 training trials. During each trial, a sample picture or word stimulus was displayed in the central field of a stimulus array comprising four squares arranged around a central square (each approximately 5 x 5 cm). Four comparison stimuli were displayed in the outer squares. The stimulus array for one of the training trials is illustrated in Figure 3.2.

The task started with the practice trials. The practice trials were designed to familiarise participants with the response keys and stimuli. For these trials, the task was to match the target stimulus to itself. For example, if the probe stimulus *mayopuj* had been displayed, the correct response would be to press the key corresponding to the outer square in which *mayopuj* was also displayed. Each of the four pictures, and each of the four novel words, appeared four times as targets in a random order of presentation. The following instructions were displayed on the screen at the start of the practice trials:

> In this practice part of the experiment you have to quickly match the picture (or word) that appears in the middle of the screen with the same word or picture that appears as one of four options around it. There are two types of trial picture trials and word trials. On word trials a word will appear in the centre of the screen and four words will surround it. Your task is to press the key that corresponds to the square containing the word that matches the centre word. (The experimenter will now show you what keys to use.) If you press the wrong key you will hear a BEEP. If you haven't pressed a key inside two seconds, the correct choice will turn red and you should then press the appropriate corresponding key. Picture trials are just the same except you are matching pictures with themselves. Please use only one finger for your responses. If you have any questions, ask the experimenter now; otherwise press the "/" key to begin the practice trials.

The stimulus appeared in the central square and was highlighted with a pink background. Participants selected the comparison stimulus associated with the probe stimulus by pressing the number key at the corresponding corner of the square made up of the keys 1, 2, 4, and 5 on the number keypad. Each trial ended when one of these keys was pressed. The position of the correct response was varied randomly between the trials. Incorrect responses produced an "incorrect" beep sound. If no response had been made 2 seconds from the onset of the comparison stimulus array, the correct response was highlighted in pink and remained on the screen until a response was made. There was an interval of 2000ms between the trials.

Each trial commenced with a fixation mark appearing in the central square. After 200ms, this was then replaced by an array of five stimuli, one in each of the squares. The probe stimulus appeared in the central square and was highlighted with a pink background. Participants selected the comparison stimulus associated with the probe stimulus by pressing the number key at the corresponding corner of the square made up of the keys 1, 2, 4, and 5 on the number keypad. Each trial ended when one of these keys was pressed. The position of the correct response was varied randomly between the trials. Incorrect responses produced an "incorrect" beep sound. If no response had been made 2 seconds from the onset of the comparison stimulus array, the correct response was highlighted in pink and remained on the screen until a response was made. There was an interval of 2000ms between the trials.

The response latency, measured from the onset of the choice stimuli, was recorded. The response choice was also recorded. In addition to the instructions displayed on the screen, the experimenter verbally instructed the participants to use the feedback so that they could make their responses before the correct stimulus was highlighted. The experimenter also asked participants to use only one finger to respond, and to return their finger to the crack between the four keys after each response so that the distance to the response key was equidistant for each trial.

After the practice trials had been completed the following instructions were displayed:

> OK. Now you have learned to make the responses here is your main task. In this part of the experiment you have to learn the names for the shapes. There

are two types of trials: word trials, in which a word will appear in the centre of the screen and four pictures will surround it. Your task is to press the key corresponding to the location of the picture named by the target word. If you press the wrong key you will hear an "incorrect" beep sound. If you haven't pressed a key inside two seconds, the correct picture will turn red and you should then press the corresponding key. Use this feedback to learn the name-shape relations. Picture trials are just the same except that a picture appears in the middle and you have to press the key to select its corresponding word. Eventually you should get to the point where you are able to press the right key before the computer shows you the correct choice highlighted in red.

Try to respond as quickly as you can while maintaining accuracy. If you have any questions ask the experimenter now; otherwise press the "?" key to start the experimental trials.

There were 32 experimental trials, in which each of the four words had to be matched with its picture referent four times, and each picture was matched with its name four times.

Paired association training task

Depending on the experimental condition, participants either performed a novel word association task or a novel picture association task. The aim of the training task was to teach participants two pairs of associations, either two novel word pairs, or two novel picture pairs. The same verbal and picture stimuli were used in this task as in the vocabulary task.

Each task started with 16 practice trials. These were identical to those of the vocabulary task, except that only the picture trials were presented to the participants performing the picture association task, and only the word trials were presented to the participants performing the word association task. The picture association training task started with the following instructions displayed on the screen:

> In this part of the experiment your task is to match up a picture that appears in the middle of the screen with the same picture, from one of four options that appear around it. On each trial a picture will appear in the middle of the screen and four pictures will surround it. You should press the key that corresponds to the location of the matching picture. (The experimenter will now show you which keys to use.) If you press the wrong key you will hear a BEEP sound.
>
> If you haven't pressed a key inside two seconds the correct picture will turn red and you should then press the key corresponding to it. You should try to press the right key before the computer shows you the correct response by highlighting it in red.
>
> If you have any questions ask the experimenter now; otherwise press the "/" key to begin the practice trials.

As in the vocabulary training task, the experimenter instructed participants to use only one finger to make their responses, and to return their finger to the crack between the four response keys after each trial. After the practice trials, 32 training trials were presented, during which either picture-picture or word-word associations were studied. The training trials followed the same presentation procedure as the training trials in the vocabulary task, except that there were only two comparison stimuli in the outer squares of the stimulus array; the other two squares remained empty. The location of the comparison stimuli was randomly varied between trials. The training trials commenced with the following instructions displayed on the screen:

OK. Now you've learned how to make the responses, here's your main task. In this part of the session, you have to learn which pictures are paired together. On each trial, a picture will appear in the centre of the screen and two different pictures will surround it. Your task is to press the key corresponding to the location of the picture's paired associate. If you press the wrong key you will hear a BEEP. If you haven't made a response inside two seconds, the correct picture will be highlighted in red and you should press the corresponding key. Use this feedback to learn the picture-picture associations. Eventually you should get to the point where you are able to press the right key before the computer highlights the correct choice in red. Try to respond as quickly as you can while maintaining accuracy.

If you have any questions, ask the experimenter now. Otherwise press the "/" key to begin.

The response key selected and the location of the correct picture for each trial was recorded. The word association training task was procedurally identical, except that word stimuli were presented instead of picture stimuli.

Filler tasks

Filler tasks were employed for control purposes, to ensure that the participants were all equally familiar with the task prior to the test association task, and that the same number of intervening trials had elapsed before the test task to control for fatigue effects. The filler vocabulary task and the filler paired association training task were procedurally the same as the vocabulary training task and the paired association training task, except that different stimulus sets were used. Associations between filler picture stimuli were presented for the filler version of the preliminary picture association task, and associations between filler name stimuli were presented for the filler word association task.

Test association tasks

These tasks were always presented last. Depending on condition, either the picture association test or the word association test was used for the final test task. There were 32 practice trials, and 64 experimental trials. The presentation and procedure was the same as for the paired association training task. The associative pairs tested were of the opposite symbolic modality to the stimuli that had been studied in the paired associate training task. For instance, if picture associations had been studied in the training task, then word associations were tested in the test task. The stimulus pairs corresponded with the pairs presented in the training task. For example, if the pictures that were named *doxovan* and *mayopuj* were trained paired associates, then the words *doxovan* and *mayopuj* were presented in the test task. Two pairs of control stimuli were used. Control stimuli had not been exposed to the participants prior to the test task. Paired associations between the control stimuli were arbitrarily designated. The word association test task demanded that participants select the paired associate for each of the target words. The instructions shown at the start of the practice trials, and at the start of the experimental trials, were the same as for the paired association training task. Participants were reminded to use only one finger for selecting the response key, and to return their finger to the crack between the keys after each trial. Each word formed the target 8 times, making a total of 64 trials for this task: 32 experimental trials and 32 control trials. For each trial, the latency of the response from the onset of the comparison stimuli was recorded, as was the key selected and the position of the associated stimulus.

An explanation of the experimental aims was given to participants when they had completed all of the tasks. Participants' questions were answered and any comments were noted.

Results

The order of exposure to information about the relationships between the word and picture stimuli was manipulated between conditions. For each condition the data collected in the test task (word association test or picture association test) was the latency of the response (in ms) from the onset of the comparison stimuli. Mean response times to the experimental stimuli and the control stimuli were calculated. The number of correct responses was also calculated. The alpha level was set at 0.05 in all of the following analyses.

Analysis of the test association tasks

Analysis of the Stimuli

A preliminary analysis of the individual stimuli used in the final test tasks was carried out. A mixed ANOVA was performed on the response times for each stimulus. The stimuli within each stimulus set (experimental and control) were treated as repeated measures and stimulus type (picture or word) was treated as the between subjects factor. The means tables and ANOVA tables are presented in Appendices 3.1a,b. The responses to the word stimuli were significantly faster than to the picture stimuli ($F = 59.2$, $df = 1, 108$, $p < .0001$). The mean response times to the picture stimuli and word stimuli were 2320.6 ms ($SD = 661$) and 1700.5 ms ($SD = 492$), respectively. The ANOVA was repeated to analyse the picture stimuli and the word stimuli separately (Appendix 3.1.c and 3.1.d). There was no main effect of individual picture stimuli, nor was there an interaction between stimulus set (control or experimental) and stimulus. There was no main effect of individual word stimuli, nor of an interaction between individual word stimuli in each stimulus set. Because there was no difference between the individual stimuli, it was decided that the data should be collapsed. The mean response times for all the picture stimuli within each stimulus set, and the mean response time for all the word stimuli within each stimulus set was calculated and used as the dependent variable in the following analyses.

Analysis of mean response times for stimulus set (control vs. experimental) between conditions

A mixed ANOVA was carried out to examine the effect of condition (vocabulary training before or after paired association training) on the transfer of associative information across stimulus modalities. The between subject variable was condition, the within subject variable was stimulus set (control or experimental). The dependent variable was the mean response time for correct responses to the stimuli in each set. The means for each condition are given in Table 3.2.

There was a significant main effect of condition ($F = 16.4$, $df = 5, 104$, $p < .0001$), and a main effect of stimulus (experimental or control) set ($F = 5.3$, $df = 1, 104$, $p = .02$). Responses to the experimental stimuli were faster than to the control stimuli. There was no significant interaction between condition and stimulus set. The ANOVA table for this is given in Appendix 3.2.

Table 3.2: Mean reaction times in ms (+ SD) for correct responses to the control and experimental stimuli in the test association tasks for each condition

Condition	*n*	Control	Experimental
Condition 1 *Vocabulary training, Picture association training, Filler vocabulary, Word association test*	19	1843.6 (408)	1680.5 (382)
Condition 2 *Vocabulary training, Word association training, Filler vocabulary, Picture association test*	18	2253.0 (497.4)	2166.4 (398)
Condition 3 *Filler vocabulary, Picture association training, Vocabulary training, Word association test*	19	1642.1 (328.7)	1475.6* (276)
Condition 4 *Filler vocabulary, Word association training, Vocabulary training, Picture association test*	18	2504.8 (561)	2587.2 (750)
Condition 5 *Filler vocabulary, Filler picture association training, Vocabulary training, Word association test*	18	1950.3 (511.6)	1639.9* (553)
Condition 6 *Filler vocabulary, Filler word association, Vocabulary training, Picture association test*	18	2557.4 (743)	2588.9 (525)

Note: * significant difference between novel and experimental stimuli demonstrated by simple main effects

A series of planned means comparisons were carried out. A comparison was made of the stimulus types: conditions employing the word association task (Conditions 1, 3, and 5) compared with conditions employing the picture association task (Conditions 2, 4, and 6 combined). The overall mean response time to word stimuli (M = 1809.5; SD = 432.8) was faster than to picture stimuli (M = 2438 ms; SD = 612). This difference was significant ($F = 71.9$, $df = 1, 104$, $p < .0001$). The comparison of the interaction of stimulus type (picture or word) with stimulus set (experimental or control) was significant ($F = 6.3$, $df = 1, 104$, $p = .014$). This showed that the difference between the experimental and control conditions was greater for the word stimuli than for the picture stimuli. The means are given in Table 3.3.

Table 3.3: The mean RT in ms (+ SD) for correct responses for stimulus types (picture and word) in each stimulus set (experimental and control)

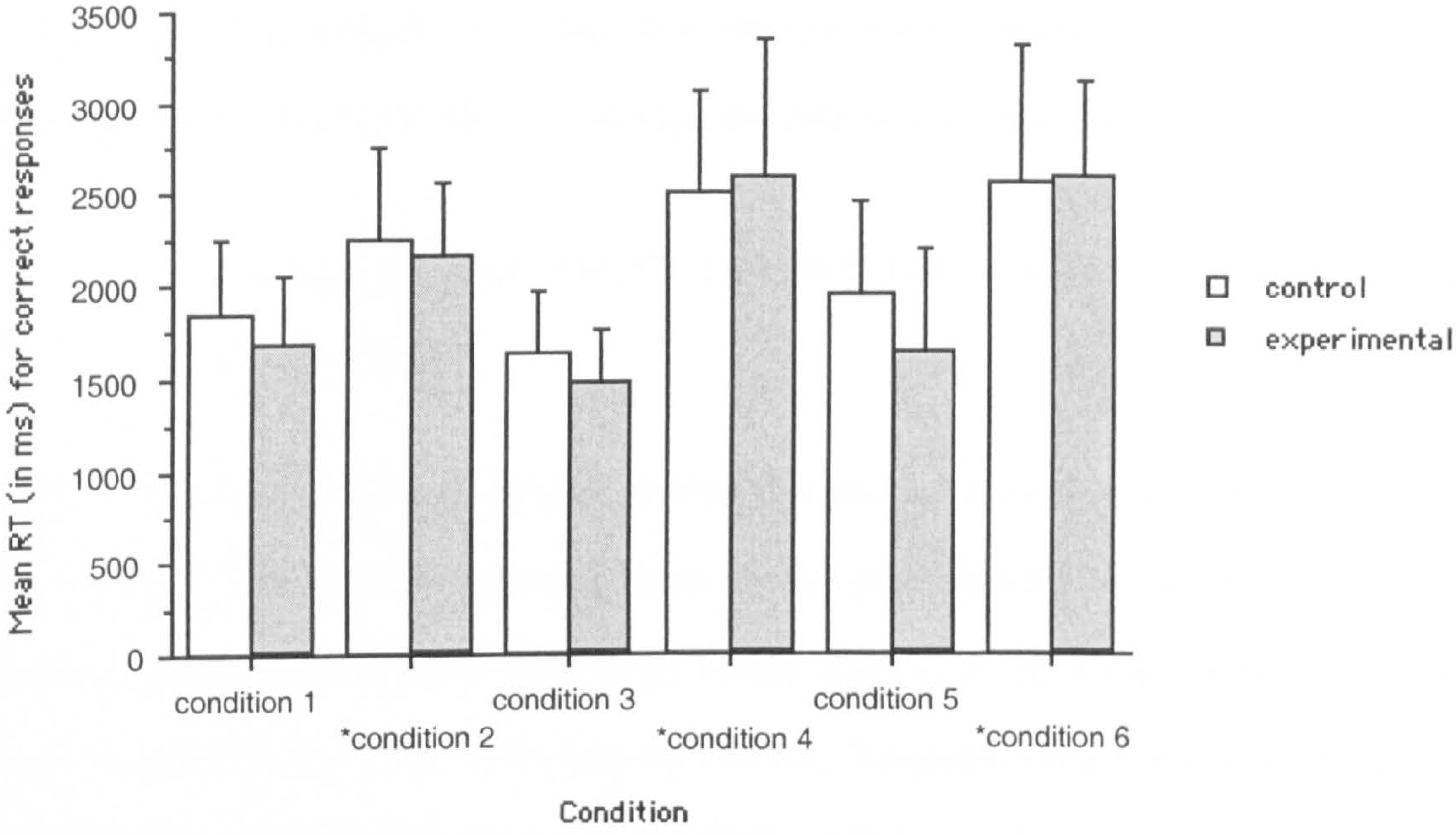
Stimulus type	n	Control	Experimental
Picture	54	2438.4 (613)	2447.5 (600)
Word	56	1809.5 (433)	1597.9 (419)

Simple main effect analyses were carried out on stimulus type (control vs. experimental stimuli) for each condition. (The ANOVA tables for these analyses are given in Appendices 3.2.b-g.) There was no significant difference between experimental and control stimuli in Condition 1, nor in Condition 2. There was a significant difference between the stimulus types in Condition 3 ($F = 6.3$, $df = 1, 18$, $p = .02$), but not in Condition 4. The difference between the control and experimental word stimuli for control Condition 5 was significant ($F = 20.7$, $df = 1, 17$, $p = .0003$), but there was no significant difference between the control and experimental picture stimuli in control Condition 6.

There was no significant difference in the overall response times to the word stimuli in the experimental Conditions (1 and 3) compared with control Condition 5, nor was there an interaction between stimulus type and experimental and control conditions. Planned means comparisons showed no significant difference or interaction between Conditions 1 and 5 between Conditions 3 and 5 or between Conditions 1 and 3. Planned mean comparisons showed no significant difference in response times to the word stimuli between Condition 1 versus control Condition 5, Condition 3 versus control Condition 5 nor between Conditions 1 and 3.

Planned means comparisons showed there was no significant difference in the overall response times to the picture stimuli in the experimental Conditions (2 and 4) compared with control Condition 6. Nor was there an interaction between stimulus set and experimental vs. controls. Planned means comparisons showed no significant difference or interaction between Conditions 2 and 4. There was a significant difference in overall response times to Conditions 2 and 6 ($F = 5.7$, $df = 1, 104$, $p = 0.2$) but the interaction between stimulus set and condition was not significant for this comparison. The overall difference in response times between Condition 2 and Condition 4 was significant ($F = 4.9$, df 1, 104, $p = .03$) but the interaction between stimulus set and condition was not significant.

The differences between the response times to each condition and the interaction between condition and stimulus set is illustrated in Figure 3.9.



Note * indicates the visual condition where picture associations were tested

Figure 3.9: Mean response time (+SE) for stimulus set (experimental or controlled) across conditions.

Analysis of the number of correct responses to each stimulus

The number of correct responses to each stimulus was analysed. A mixed ANOVA was performed; the two repeated measures were stimulus set (control or experimental) and individual stimulus and the independent measure was stimulus type (picture or word). The means table and the ANOVA table are presented in Appendix 3.3. There was no main effect of stimulus nor was there an interaction between stimulus set and stimuli. There was a main effect of stimulus set ($F = 5.3$, $df = 1, 108$, $p = .023$) with 83% of the total Reponses to the control stimuli correct and 86% of the total responses to the experimental stimuli correct. There was a main effect of stimulus type ($F = 16$, $df = 1, 108$, $p < .0001$). A greater proportion of correct responses was recorded for the word stimuli than for the picture stimuli (89% and 79% respectively), but there was no interaction between individual stimuli and stimulus type. Because there was no difference in the number of correct responses produced for individual stimuli for each stimulus type, it was decided to collapse the data across stimulus sets.

Analysis of the number of correct responses in each condition (excluding scores > 2000 ms

The two test tasks (picture association test task and word association test task) were procedurally similar to the training tasks. It was predicted that a transfer of associations across stimulus modalities would result in more correct responses to the experimental stimuli than to the control stimuli. Responses were only counted as correct if the appropriate comparison stimulus had been selected before it had been highlighted by the computer (2000 ms after the onset of the comparison stimuli). The dependent variable for this analysis was the mean number of correct responses < 2000 ms for the control and the experimental stimuli. The means for each condition are shown in Table 3.5. The maximum mean score was 8, because each stimulus was presented 8 times.

A mixed ANOVA was performed, the repeated measure was stimulus set (control or experimental) and the between subjects factor was condition. There was a main effect of stimulus set ($F = 11.64$, $df = 1, 103$, $p = .0009$) and a main effect of condition ($F = 11.4$, $df = 5, 103$, $p < .0001$). The interaction between stimulus set and condition was also significant ($F = 2.43$, $df = 5, 103$, $p = .04$). The ANOVA tables for these analyses are presented in Appendix 3.4.

Simple main effects showed that there was no significant difference between the number of correct responses <2000 ms for the control and experimental stimuli in Conditions 1, 2, 3, 4, and 6. There was a significant difference in control Condition 5 ($F = 18.96$, $df = 1,17$, $p = .0004$). A greater number of correct responses were made for the experimental stimuli than the control stimuli.

Table 3.5: The mean number of correct responses < 2000ms (+ SD) for control and experimental stimuli in each condition

Condition	n	Control	Experimental
Condition 1 *Vocabulary training, picture association training, filler vocabulary, word association test*	19	4.91 (1.97)	5.76 (1.67)
Condition 2 *Vocabulary training, word association training, filler vocabulary, picture association test*	18	3.54 (1.93)	4.08 (1.87)
Condition 3 *Filler vocabulary, picture association training, vocabulary training, word association test*	19	5.44 (1.72)	6.06 (1.87)
Condition 4 *Filler vocabulary, Word association training Vocabulary training, Picture association test*	18	3 .00 (1.68)	2.88 (1.94)
Condition 5 *Filler vocabulary, filler picture association training, vocabulary training, word association test*	18	4.51 (2.07)	6.24 (1.98)
Condition 6 *Filler vocabulary, filler word association training, vocabulary training, picture association test*	18	3.04 (1.69)	3.01 (1.6)

A series of planned means comparisons was carried out. A comparison was made of the total number of correct responses in conditions in which the word association test task was presented (Conditions 1, 3, and 5) and conditions in which the picture association task was presented (Conditions 2, 4, and 6). There was a significant difference ($F = 53$, $df = 1, 103$, $p < .0001$). A greater number of correct responses were made for the word stimuli than for the picture stimuli ($M = 5.48$, $SD = 1.94$ and $M = 3.26$, $SD = 1.8$ respectively). The interaction between stimulus type and stimulus set was significant ($F = 7.13$, $df = 1, 103$, $p = .0088$). The means for experimental and control stimuli for each stimulus type are shown in Table 3.6.

The experimental conditions employing word stimuli (Conditions 1 and 3) were compared with the word control Condition 5; there was no significant difference, nor was there a significant interaction between condition and stimulus set. There was no significant difference or interaction between Condition 1 and control Condition 5, nor between Condition 3 and control Condition 5, nor between Conditions 1 and 3.

The experimental conditions presenting picture stimuli (Conditions 2 and 4) were compared with the picture control Condition 6. There was no significant difference, nor was there a significant interaction between experimental and control stimuli and stimulus set. There was no significant difference or interaction between experimental Condition 2 and control Condition 6, nor between experimental Condition 4 and control Condition 6, nor between experimental Conditions 2 and 4. The *SS* and *MS* terms for these comparisons are given in Appendix 3.4.

The main effect of condition can be attributed to stimulus type rather than to the manipulation of the sequence of tasks between the conditions. There were significantly more correct responses made for the experimental word stimulus set than for the control word stimulus set for word stimuli, but the difference was not significant for the picture stimuli.

Table 3.6: The mean number of correct Reponses < 2000 ms for each stimulus type and each stimulus set (with SD in parenthesis). The maximum number was 8.

Stimulus type	n	Control	Experimental
Picture	54	3.19 (1.75)	3.32 (1.86)
Word	56	4.95 (1.93)	6.01 (1.82)

Analysis of the order of the first correct response < 2000 ms

A comparison of the number of trials required before the first correct responses without feedback was performed. The trials within each condition were sorted by stimulus and the rank order of the first correct response made in less than 2000 ms was calculated. For example if the first correct response was made in less than 2000 ms from the onset of the second presentation of a given stimulus, then this would be scored as 2. Each stimulus appeared 8 times. If no correct responses were obtained, a score of 9 was given. The means for the control and experimental stimuli are presented in Table 3.7. The stimuli were analysed according to type (picture or word)

The scores for Conditions 1, 3, and 5 were entered into a mixed ANOVA. The repeated measures were stimulus and stimulus set (control vs. experimental) and the independent measure was rank order score . There was no main effect of condition, or of stimulus set. There was no interaction between condition and stimulus set.

The analysis was repeated using the scores for picture association test task from Conditions 2, 4, and 6. There was no main effect of stimulus set, nor of condition. The ANOVA tables are shown in Appendix 3.5.

The pattern of results for the experimental tasks showed an effect of stimulus type (picture vs. word). The time taken to select an associate for the word stimuli was faster than to the picture stimuli. A greater number of correct responses were made for word stimuli than for picture stimuli. The first correct response without feedback was made after fewer test trials for the word stimuli than for the picture stimuli.

There was an effect of stimulus set (experimental vs. control) for the word stimuli but not for the picture stimuli. Responses to the experimental word stimuli were faster than to the control word stimuli. This effect was only observed in Condition 3. The difference in the number of correct responses to the experimental and control stimuli was not significant, nor was there a difference in the rank order of the first correct responses without feedback.

Table 3.7: The mean numerical order(+ SD) of the first correct response for experimental and control stimuli in each condition.

Condition	n	Control	Experimental
Verbal			
Condition 1 *Vocabulary training, picture association training, filler vocabulary, word association test*	19	2.7 (2)	2.2 (1.7)
Condition 3 *Filler vocabulary, Picture association training, vocabulary training, word association test*	18	2 (1.5)	1.8 (1)
Condition 5 *Filler vocabulary, filler picture association, vocabulary training, word association test*	18	2.6 (2.1)	2.2 (2)
Visual			
Condition 2 *Vocabulary training, word association training, filler vocabulary, picture association test*	18	4 (2.7)	3.4 (2.3)
Condition 4 *Filler vocabulary, word association training, vocabulary training, picture association test*	18	4.3 (2.7)	4.5 (2.8)
Condition 6 *Filler vocabulary, filler word association, vocabulary training, picture association test*	18	4 (2.9)	3.8 (2.7)

Exploratory analyses

Because the experimental treatments had not produced any differences between the conditions, exploratory analyses were carried out to determine whether there was any relationship between performance on the training tasks and the test task within each condition. The number of correct responses produced under 2000 ms (i.e. before the correct response was highlighted) was taken as a measure of learning, and this score was calculated for the vocabulary learning task, the preliminary paired association task, and the test association task. An additional variable was calculated to represent the interaction effect of vocabulary training score x preliminary association training score. The product of these two scores was entered into the model. The mean responses for the scores obtained for each task in each condition is presented in Table 3.8.

Table 3.8: The mean number (+ SD) of correct responses for each task

Condition	Vocab task	Paired assoc. task	Inter-action product	Test assoc. task
Verbal				
Condition 1 *Vocabulary training, picture association training, filler vocabulary, word association test*	5 (4.7)	15.6 (9.17)	97.3 (126.3)	23.3 (6.8)
Condition 3 *Filler vocabulary, picture association training, vocabulary training, word association test*	9.5 (5.6)	10.5 (7)	123.5 (141.3)	25.4 (5.3)
Condition 5 *Filler vocabulary, filler picture association vocabulary training, word association test*	7.2 (4.5)			25 (8.2)
Visual				
Condition 2 *Vocabulary training, word association training, filler vocabulary, picture association test*	4.6 (2.6)	25.6 (6.4)	129.6 (83.2)	16.3 (7.5)
Condition 4 *Filler vocabulary, word association training, vocabulary training, picture association test*	7.7 (4.4)	25.4 (4.9)	203.9 (138.2)	11.6 (7.6)
Condition 6 *Filler vocabulary, filler word association, vocabulary training, picture association test*	7.7 (5.5)			11.9 (6.4)

Note: the paired association training task and the paired association test tasks had 32 response trials and the vocabulary task had 64 response trials.

Table 3.9: Intercorrelations between the number of correct responses made during the training and the test tasks for Conditions 1, 2, 3, and 4 (n =72)

Variables	1	2	3	4
1: Test association score	--	.009	-.34	.27
2: Interaction between training tasks	--	--	.61	.82
3: Paired association training task	--	--	--	.22
4: Vocabulary training task	--	--	--	--

The relationship between the training and test tasks in Condition 1

A stepwise multiple regression was carried out to investigate the relationship between the number of correct responses made in the vocabulary training and the picture paired associate training tasks, and the verbal association test task. The relationship between the interaction product of the training tasks and the test task was similarly investigated. The number of correct responses in the training tasks and the interaction product of these tasks were the predictor variables and the number of correct responses in the test association task was the outcome variable.

The variable entered in step one see (Table 3.10) was vocabulary (R = .66, R^2 = .44, p = .002) which appears to account for 44% of the variance in the number of correct responses. The other two variables had no significant effect.

Table 3.10: Summary of stepwise multiple regression for variables predicting performance on the verbal association test task in Condition 1

Variable	B	*SE* B	β
step 1			
Vocabulary	.97	.27	.66

The relationship between the training and test tasks in Condition 2

A stepwise multiple regression was carried out to investigate the relationship performance in the vocabulary task, the word paired associate training tasks, the interaction product for these two tasks, and performance in the picture association test task in Condition 2. The dependent variable was the number of correct responses in each task made < 2000 ms from the onset of the comparison stimuli. The summary table is shown in Table 3.11.

Table 3.11: Summary of stepwise multiple regression for variables predicting performance on the visual association test task in Condition 2

Variable	B	*SE* B	β
step 1			
Word paired association training	.73	.23	.62

The variable entered in step one was word paired association training ($R = .62$, $R^2 = .38$, $p = .006$); this accounted for 38% of the variance in the picture association test task. The other two variables had no significant effect.

The relationship between the training and test tasks in Condition 3

A stepwise multiple regression between the number of correct responses in the picture association training and the vocabulary training tasks and performance on the verbal association task showed no significant relationships.

The relationship between the training and test tasks in Condition 4

A stepwise multiple regression was carried out between the number of correct responses in the word paired association training and vocabulary training tasks on the scores obtained in the visual association task.

The variable entered in step one was word paired association training. The results showed a negative relationship between performance on the word association training task and the picture association test task ($R = .51$, $R^2 = .27$, $p = .027$). The other variables did not reach significance. The summary table is shown in Table 3.12.

Table 3.12: Summary of stepwise multiple regression for variables predicting performance on the visual association test task in Condition 4

Variable	B	SE B	β
step 1			
Word association training	-.81	.33	-.51

The relationship between the vocabulary training and association test tasks in Control Conditions 5 and 6

In these conditions the only relevant training task was the vocabulary training task. There was a significant correlation between the vocabulary training score and the word association test score in Condition 5 ($R = .49$; $R^2 = .25$, $p = .037$). There was no significant correlation between performance on the vocabulary training and the picture association test task in Condition 6.

The relationships between the training tasks and the test tasks did not form a coherent pattern across conditions. Therefore, an analysis of performance on the preliminary tasks was performed to examine what participants had learned from each of the tasks within the experiment.

Analysis of the training tasks

Analysis of the vocabulary task

The independent variable was the order in which the tasks were presented to each condition. The dependent variable was the number of correct responses made before feedback was presented. Any difference in the performance on the vocabulary task between conditions must be due to either a practice effect for the task, or result from familiarity with the stimuli. A one factor ANOVA for independent measures was carried out on the number of correct responses obtained in each condition. There was a significant effect of condition ($F = 2.75$, $df = 5, 102$, $p = .02$). (The ANOVA table is shown in Appendix 3.6a).

A series of planned means comparisons were carried out to investigate the following four predictions:

1. No difference between Conditions 1 and 2 was predicted, because the vocabulary task is the first phase for both conditions. This was supported by the data: There was no significance between the means ($M = 5$; $SD = 4.6$) and ($M = 4.6$; $SD = 2.6$) for Conditions 1 and 2 respectively.

2. A similar performance for Conditions 5 and 6 was predicted because the vocabulary task is the third task for each condition and the preceding tasks contain no relevant information. This was supported by the data: there was no significant difference in the number of correct responses between Conditions 5 and 6.

3. If there was a practice effect, then a difference would be predicted between those conditions where the vocabulary task was presented first (Conditions 1 and 2) and those conditions where the filler tasks (using the same procedure, but containing no relevant information) preceded the vocabulary task (control Conditions 5 and 6). This was found to be the case; a planned means comparison showed a significant difference between Conditions 1 and 2 combined and Conditions 5 and 6 combined ($F = 5.9$; $df = 1, 102$, $p = .017$).

4. If there was an effect of stimulus familiarity then a difference between conditions where the vocabulary task is presented first (Conditions 1and 2) and those conditions

where the word or picture stimuli have been previously presented during the paired association training task (Conditions 3 and 4) would be predicted. A significant difference was found ($F = 11.66$, $df = 1, 102$, $p = .0009$). However, this familiarity effect appears to be confined to previous exposure to the picture stimuli: the difference between Conditions 1 and 3 was significant ($F = 8.13$, $df = 1, 102$, $p = .005$), whereas there was no significant difference between Conditions 2 and 4. This suggests that previous experience of the picture stimuli facilitates learning in the vocabulary task. (Appendix 3.6b)

Analysis of the paired association training task

The independent variable for this analysis was condition. The paired association training task was not included in control Conditions 5 and 6. The dependent variable was the number of correct responses made before feedback was presented. An independent one way ANOVA was carried out on the number of correct responses recorded in the paired association task for condition (see Appendix 3.7). There was a significant effect of condition ($F = 19.53$, $df = 3,68$, $p < .0001$).

However, this effect is largely due to the difference between the verbal and the visual task. Planned means comparisons showed there was a significant difference between the word paired association task (Conditions 1 and 3) and the picture paired association task (Conditions 2 and 4) ($F = 55.1$, $df = 1, 102$, $p < .0001$). There was a significant difference between Condition 1 and Condition 3 ($F = 4.7$, $df = 1, 102$, $p = .03$). (The ANOVA and means comparison tables are shown in Appendix 3.7) This suggests that the exposure to the picture stimuli that occurred during the vocabulary task in Condition 1 enhanced performance on the following paired association training task. In Condition 3 the picture paired association training was the first task. There was no difference between the mean scores of Conditions 2 and 4 (25.6 and 25.4

respectively). Again, it appears that learning the picture stimuli takes more exposure than the word stimuli.

Analysis of the association test task

In this analysis, the independent variable was condition and the dependent variable was the number of correct responses made before feedback was presented (the means are shown in Table 3.8). A one way ANOVA was performed. There was a significant difference ($F = 14.8$, $df = 5, 102$, $p < .0001$). To identify where the differences between the conditions lay, a series of planned means comparisons were undertaken. Significantly more correct responses were made during the word association test task (Conditions, 1,3, and 5) than during the picture association test task (Conditions 2,4, and 6), ($F = 68.3$, $df = 1$, $p < .0001$). Neither Condition 1 nor Condition 3 was significantly different from control Condition 5, and there was no significant difference between Conditions 1 and 3. Neither Condition 2 nor Condition 4 was significantly different from control Condition 6, nor was there a significant difference between Conditions 2 and 4. (See Appendix 3.8).

Discussion

From a first inspection of these results, it might be concluded that there was no transfer of associative information between picture and word modalities. However, analyses of the training tasks within each condition lead us to conclude that there was insufficient evidence that the participants had learned the paired associations presented in the training tasks.

When designing the experiment, it had been assumed that 32 trials would be sufficient for paired associations to be established, but the results show that participants produced very few correct trials, particularly on the tasks involving picture stimuli. It was decided that the paired associations should be trained to a pre-determined criterion of correctness. Training to a criterion of correctness would ensure learning without introducing excessive effects of task familiarity.

It can be seen from the results that responses were slower, and more incorrect responses were made, in the tasks that used the picture stimuli compared with the word stimuli. During debriefing, many of the participants reported having studied one edge of the picture matrix and memorised a verbal string of "black, two whites, black, then white goes with two blacks three whites". Of those that tried to see a pattern or a familiar object in the matrix, several went on to give the pattern a name, and to elaborate on the names to create associations -- for example, "donkey" paired with "manger" and "upside-down J " paired with "T" short for "John Thomas". Given that the performance on the picture stimuli was much worse than for the verbal stimuli, it was decided that less artificial picture stimuli should be used in future experiments.

It was concluded that this experiment had failed to provide answers to the research question due to problems with the design and procedure identified here.

Experiment 3

Introduction

Experiments 1 and 2 required that participants learn a chain of associations. The behaviourist school of psychology has a wide literature on language and language acquisition based on establishing associations between novel items. The "matching to sample" technique is one methodology employed by behaviourists which has proved very successful for training novel associations. Matching to sample is similar to the training tasks in Experiment 2. It was decided to employ a matching to sample technique for training the associations between the novel pictures and words, and for testing the participants in Experiment 3.

There are parallels between the empirical questions addressed in this thesis and those of the behaviourists who have been engaged in investigating the phenomenon of stimulus equivalence. A brief review of this literature will be given to clarify the differences between that research tradition's goals and the experimental question addressed in this experiment.

Is language more than chained associations?

There is mounting evidence in the literature - including the behaviourist literature - that language is more than a chained association between an object in the world and a sound pattern or visual pattern of letters. In the behaviourist literature it is widely recognised that verbal behaviour is distinct from both stimulus-response behaviour and operant behaviour.

Skinner (1957) described the development of word-to-object relations in terms of *tacts* and *mands*, two types of unidirectional relationship. A *tact* is a word elicited by the presence of a discriminative stimulus, for example, saying "apple" in the presence of an apple. A *tact* is not the same as a name in that it does not *refer to* the apple; it is simply a behaviour that has been conditionally reinforced. A *mand* is a verbal request that specifies an outcome. It is an example of an operant behaviour, with an antecedent, a behaviour and a consequence. A child might say "apple" because saying "apple" has often been followed by the presence of an apple; this does not imply any symbolic relation.

Hayes and Hayes (1992) analysed the inadequacies of Skinner's account of verbal or rule-governed behaviours. They claimed that Skinner focused entirely on "speaker" behaviour, and that his theories lacked any account of how a word meaning common to speaker and listener comes about. Skinner categorised stimuli according to their functional relations with given behaviours, for example discriminative stimuli or eliciting stimuli. Skinner did not see verbal stimuli as anything other than the product of verbal behaviour. He explained the effect of a verbal stimulus on a listener's behaviour as operant behaviour under the discriminative control of speech. Hayes and Hayes (1992) observed that, given this analysis of verbal stimuli, it makes about as much sense to view control by verbal rules as a distinguishable category of stimulus control as it would to claim that a pigeon pecking an electric light was engaging in "Edison governed behaviour" (p.1384). They went on to give an account of evidence that verbal behaviour cannot be accounted for within the framework established in the animal learning literature. Much of their argument is based on the difficulty of providing a behavioural account of derived stimulus functions demonstrated by the phenomena of stimulus equivalence. This phenomenon has recently been the subject of much study within the behaviourist approach to psychology (as evinced by the commentaries provoked by Horne and Lowe, 1996).

Stimulus equivalence: A measure of symbolic relations?

Stimulus equivalence is defined as the ability to form arbitrary classes of stimuli (equivalence classes), within which the stimuli have a special relationship whereby one stimulus can be substituted for another. It appears to tap fundamental symbolic abilities; Bentall and Dickens (1994), and Sidman (1992) give a definition that requires equivalence relations to possess the properties of reflexivity, symmetry, and transitivity, analogous to the mathematical definition of algebraic equivalence classes.

There are telling formal similarities between linguistic and other kinds of symbolic activity.

Stimulus equivalence has usually been studied by means of matching-to-sample (MTS) training of arbitrary pairings. The participant is presented on each trial with a single sample stimulus, and is then required to select the appropriate comparison stimulus from an array of at least two comparison stimuli. For example, the participant learns that stimulus A1 is a match for stimulus B1 but not for stimulus B2. The relationship between the stimuli is arbitrary; there is no pre-experimental reason why particular stimuli should be paired (Bentall & Dickens, 1994). The participant learns to select the stimulus pairs by being selectively reinforced for correct choices, establishing a conditional discrimination relation between the sample stimulus and the comparison stimulus (Sidman, 1992).

The stimulus equivalence phenomenon is as follows. If language-competent humans are trained with unidirectional relationships between stimuli A1-B1 and A2-B2, and are then trained with a unidirectional relationship between stimuli B1-C1 and B2-C2, the following untrained relationships will arise: (a) *Symmetry*: a bidirectional relationship emerging from the unidirectional training such that a participant will match B1 to A1, C1 to B1, B2 to A2 or C2 to B2. (b) *Reflexivity*: a stimulus will be matched to itself, such that A1 would be matched to A1, and so on. (c) *Transitivity*: A1 is paired with C1 (via the A1-B1 and B1-C1 pairings). An equivalence relation is one that combines both transitivity and symmetry, so C1 is paired with A1. These relations are illustrated in Figure 3.10.

Hayes and Hayes (1992) suggested that the phenomenon of stimulus equivalence is central to contemporary cognitive interests, since it reflects both on stimulus class formation and semantic meaning. Sidman (1990) used equivalence relations to define word meaning. For example, people can define a word in terms of a synonym, in terms of its referent, or in terms of a symbol and substance (number and quality). Sidman proposes that all these definitive relations (word and synonym, word and referent, word and symbol) can be tested using equivalence tests.

Consider the example of a child learning to match a word to a picture; this could be interpreted as implying that the child is reading that word. But a pigeon can be trained to perform the same matching task, and it seems improbable that the pigeon is reading or has comprehension though behaviourally their performances are the same. By testing for equivalence relations we can tap abilities which seem to be central to "true" comprehension. Sidman (1990) trained a group of children who had not yet learned to read to select a picture of a car when he said "car". He then trained them to select the word "car" when he said "car". The children were able to match the word "car" with the picture of the car without any further training; the written word and the spoken word had become symbolically equivalent.

Equivalence relations appear to be restricted to language-competent human beings. Animals, pre-verbal children and language disabled children show no equivalence relations after having been trained on the initial relations (Devany, Hayes, & Nelson, 1986; Lipkens, Kop, & Matthijs, 1988; Lowe & Beasty, 1987). Dugdale and Lowe (1990) have argued that naming is a prerequisite for forming stimulus equivalence classes.

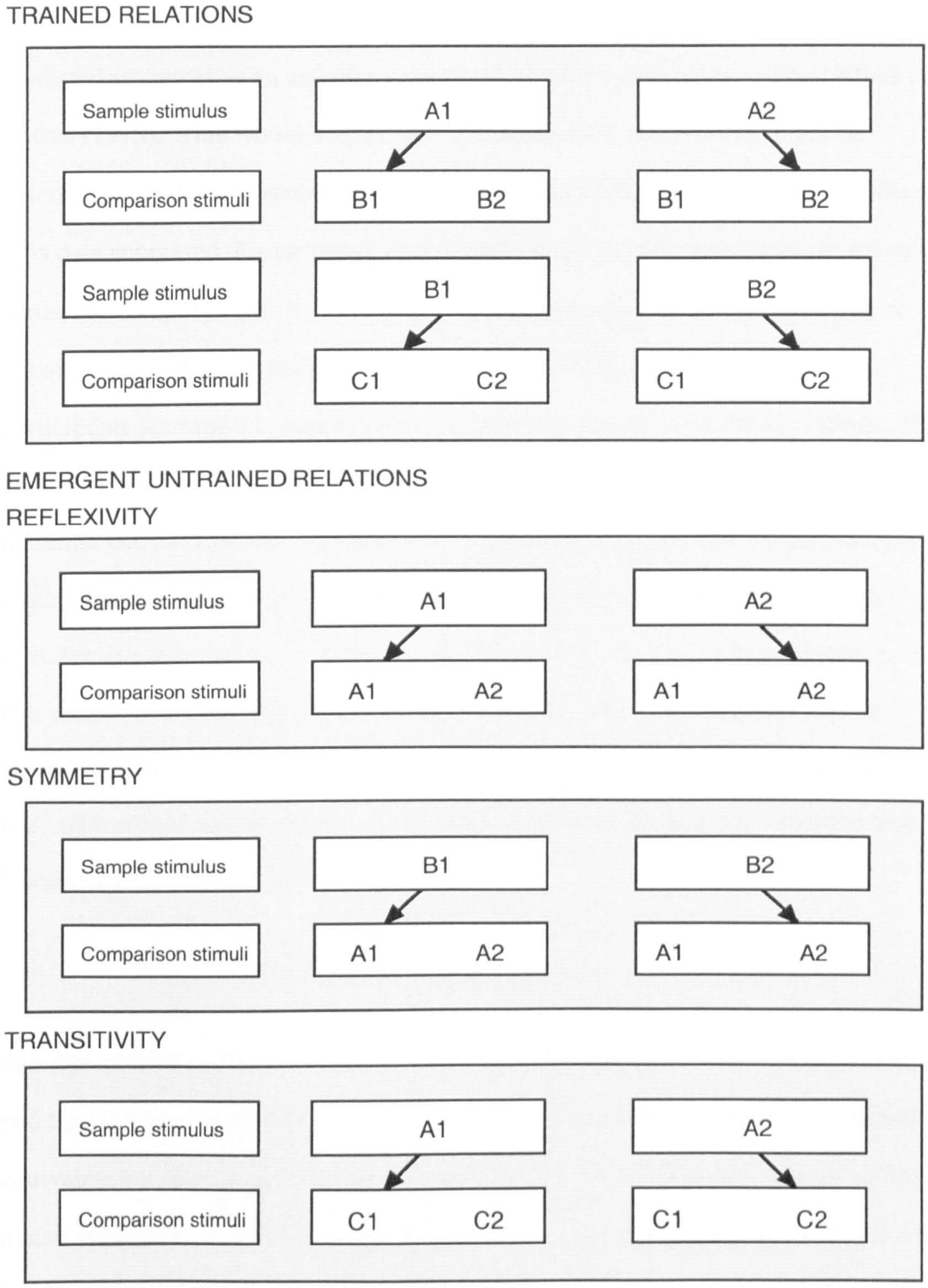


Figure 3.10: Unidirectional relations trained using a matching-to-sample procedure, followed by the three tests for the emergent relations that are found in an equivalence class.

Fields, Adams, Verhave, and Newman (1990) proposed that stimulus equivalence is mediated via nodes in an associative network similar to that proposed by Collins and Loftus (1975). This would suggest that the structure of the network might be determined by the sequence in which the associative links are established. Fields et al.'s data supported this proposal: they found a reduced accuracy in tests of transitivity across the relations A-B, B-C, and C-D. They accounted for this as a function of nodal distance. The behaviourist experiments described above relied on the participants learning a common name for each stimulus class (as in the Sidman, 1990, example). Bentall, Dickens, and Fox (1993) have successfully produced equivalence relations that have not been mediated by a common name. In their experiment, they established classes of three abstract items, where each item was designed to be difficult to name. In one condition, the three abstract items were individually named, in a second condition the stimuli were given a class name. Participants in both conditions demonstrated stimulus equivalence by successfully passing the transitivity test, although the response times were slower for participants in the condition that learned names for each item.

Transfer of associations across modalities

The difference between the relations investigated by the use of stimulus equivalence and the relations investigated in Experiment 3 is illustrated in Figure 3.11. Stimulus equivalence reveals emergent transitive relations by testing for participants' ability to match stimulus C with stimulus A after the unidirectional relations A->B and B->C had been trained. The experimental questions in Experiment 3 focus on the emergent associative relationship F<-> G, after the relationships D <-> E, D <->F, and E <->G have been trained.

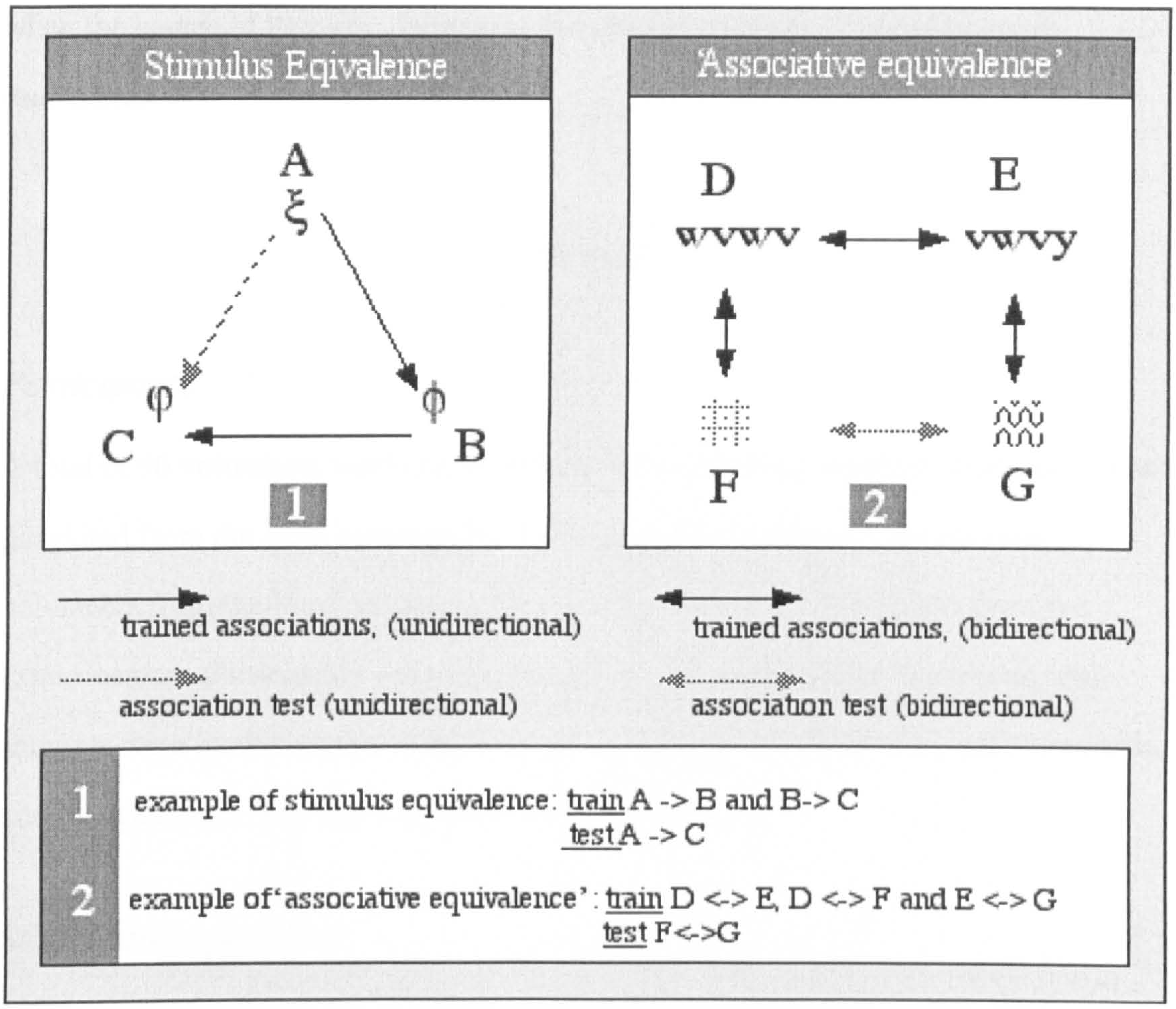


Figure 3.11: The different sequence of training and tests for stimulus equivalence and "associative equivalence", that is, the transfer of associative information between stimulus modalities.

Experimental Aims

Experiment 3 aimed to determine whether patterns of association established between two words can produce a corresponding association between pictures. It also aimed to replicate the evidence produced in Experiment 1 (Chapter 2) for the transfer of paired association information from the picture modality to a verbal modality. The sequence of exposure to information was manipulated as in Experiment 2 (this chapter) so that it could be determined whether patterns of association are transferred more readily when the names of items are learned before the associations between items are established.

Method

Participants

A total of 90 volunteers were recruited from the psychology undergraduate participant panel and from the local community. Undergraduates received a course credit; volunteers from the local community received refreshments and thanks from the experimenter. Participants were randomly allocated to one of six conditions. No attempts were made to balance the number of males or females within each condition, nor the age range. The age range was 16 - 45 (approx.).

Stimuli and apparatus

Twelve pictures of non-objects were taken from Kroll and Potter (1984). These were line drawings of structurally possible, but non-existent, objects. All of Kroll and Potter's drawings had been rated by a group of participants (n = 100) for similarity with real objects on a scale of 1-7, where 7 = "nothing like a real object". The twelve drawings selected for this experiment had a mean non-object rating > 5.5.

A corpus of 7-letter novel words, each of a 3 syllable, consonant vowel consonant pattern (e.g., *milabon)* were generated using the computer program "Nonwords to Go" (Graham, 1996). The novel words were independently rated by postgraduate researchers (n = 8) for ease of pronunciation on a scale where 1 = totally unpronounceable, and 7 = transparent pronunciation. The twelve novel words that had been judged as the most easily pronounceable were selected. There was a mean ease of pronunciation rating of 6.88.

Picture stimuli and word stimuli were then arbitrarily allocated to each of the tasks. Four of the stimuli of each type (picture and word) were allotted to the training trials and four to the filler training trials; the remaining four served as control stimuli for the test task. The stimuli selected for the training trials were arbitrarily paired to form four picture-word pairs. These picture-word pairs were then arbitrarily paired with each other to form two associations. The stimulus pairs for the training tasks are illustrated in Figure 3.12. Picture-word pairs were arbitrarily selected for the filler vocabulary task, and word-word pairs and picture-picture pairs for the filler trained association tasks. The word stimuli were shown in Courier 18 point; the picture stimuli were approximately 3cm square.

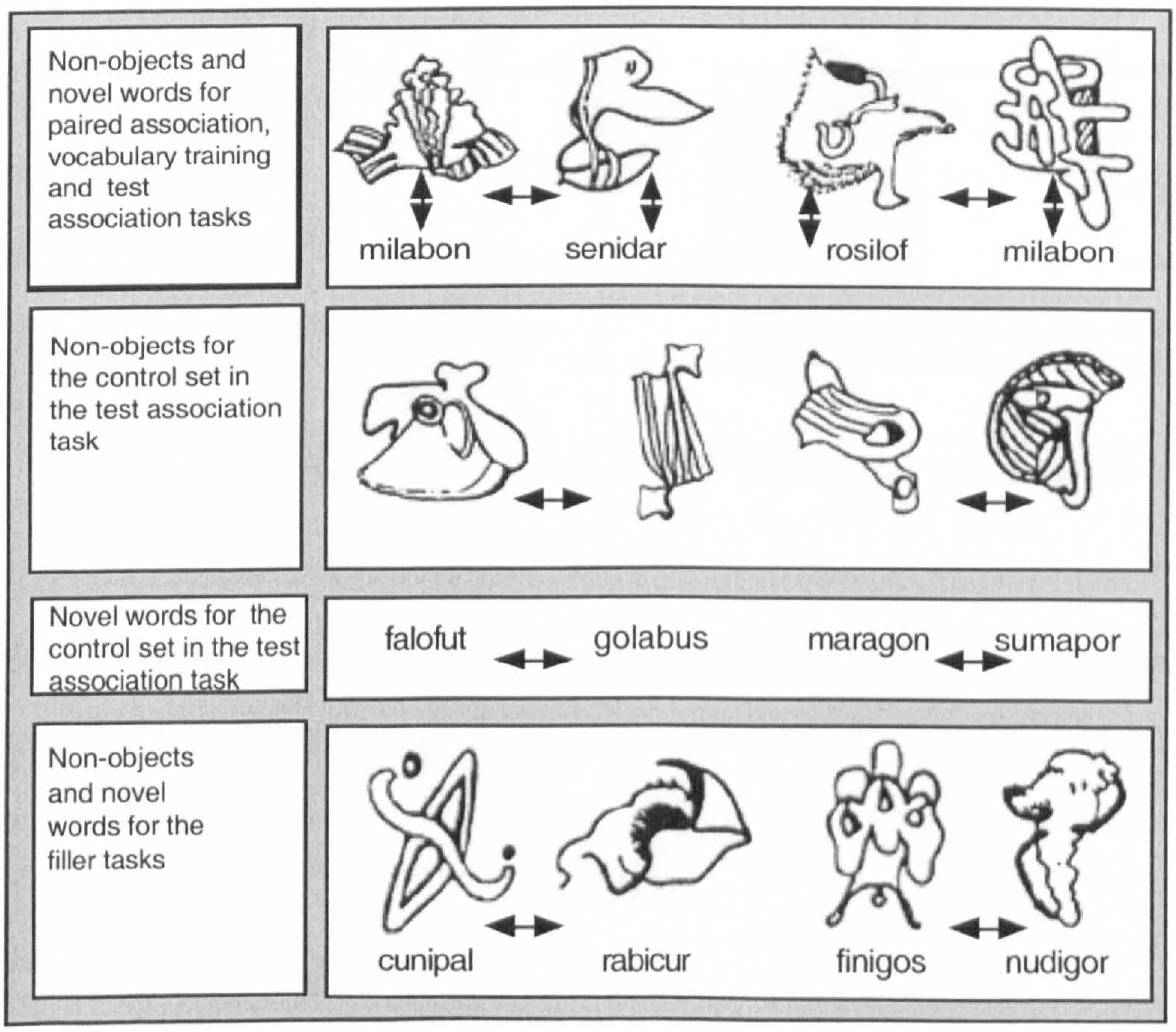
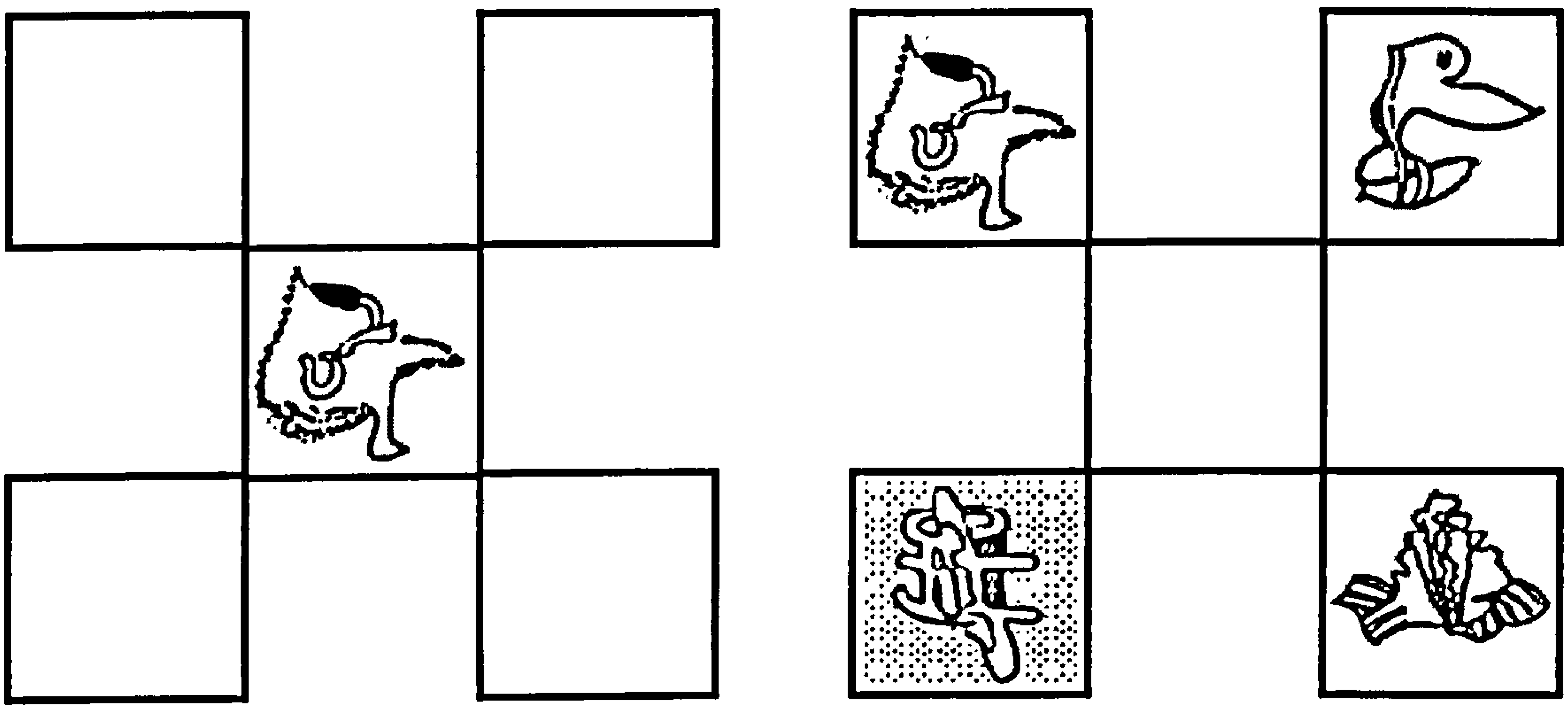


Figure 3.12: Experimental stimuli for test association tasks, vocabulary training, preliminary association training and filler tasks.

The same stimulus array was used for each of the four tasks; it comprised five squares in which the probe and comparison stimuli were displayed. The response keys 4, 5, 1, and 2 on the number pad were designated to correspond with the four outer squares of the stimulus array. The probe stimulus was always displayed in the central square of the array. The four comparison stimuli appeared in the outer squares. The stimulus array is depicted in Figure 3. 13.



The target stimulus was displayed untill the spacebar was pressed

Two seconds after the onset of the comparison array, the correct choice was hi-lighted

Figure 3.13: The stimulus array showing the stimuli for picture association training task.

The stimuli were displayed and their responses recorded using a program generated using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993). The experiment was run on a Power Macintosh 4400/160, and displayed on a 15" Apple colour monitor.

Design

The mixed design employed in Experiment 2 was used in this experiment. There were six between subject conditions; the order of the training tasks was manipulated between them. The vocabulary training was presented either before or after the paired association training tasks (during which novel picture pairs or novel word pairs were trained). The sequence of tasks presented in each condition is presented in Table 3.13 The association test task was the last task in all conditions. In the final test task, the repeated measures were number of correct pairs selected from the experimental stimuli, and number of correct control stimulus pairs.

All participants completed three training tasks and one test task. The sequence of training tasks differed between conditions. In Conditions 1 and 2, the first task was a vocabulary task (picture-word and word-picture associations). After they had learned the names of the pictures, participants in Condition 1 were presented with the picture association training task; those in Condition 2 were presented with the word association training task. The filler vocabulary task (in which irrelevant picture-word associations were presented) was then given. The final task was the word association test task for participants in Condition 1, and the picture association test task for those in Condition 2.

Conditions 1 and 2 were designed to detect whether novel associations formed in verbal memory produced corresponding associations between their picture referents (Condition 1), and whether picture associations produced corresponding verbal associations between their names.

In Conditions 3 and 4, participants started with the filler vocabulary task, then performed the paired association training tasks before they learned the names for the pictures (or the referent pictures for the words). Participants in Condition 3 completed the picture association training task; those in Condition 4 completed the word association training task. The paired association training task was followed by the vocabulary training task. The last task was the association test task (word association test in Condition 3, picture association test in Condition 4).

Table 3.13: The Order of Tasks Within Each Condition in Experiment 3

Condition	1st Task	2nd Task	3rd Task	4th Task
Condition 1	vocabulary (*picture-word association*)	picture association training (*picture-picture*)	filler vocabulary (*irrelevant picture-word association*)	word association test (*word-word*)
Condition 2	vocabulary (*picture-word association*)	word association training (*word-word*)	filler vocabulary (*irrelevant picture-word association*)	picture association test (*picture-picture*)
Condition 3	filler vocabulary (*irrelevant picture-word association*)	picture association training (*picture-picture*)	vocabulary (*picture-word association*)	Word association test (*word-word*)
Condition 4	filler vocabulary (*irrelevant picture-word association*)	word association training (*word-word*)	vocabulary (*picture-word association*)	picture association test (*picture-picture*)
Condition 5 (control)	filler vocabulary (*irrelevant picture-word association*)	filler picture association (*irrelevant picture-picture association*)	vocabulary (*picture-word association*)	word association test (*word-word*)
Condition 6 (control)	filler vocabulary (*irrelevant picture-word association*)	filler word association (*irrelevant word-word association*)	vocabulary (*picture-word association*)	picture association test (*picture-picture*)

Conditions 3 and 4 were designed to examine the role of the name relation in mediating the transfer of information between the picture and verbal systems. A comparison of Conditions 1 and 2 with Condition 3 and 4 was planned, so that it could be determined whether information is transferred more readily across stimulus modalities (picture to word or vice versa) when the picture-word relation is established prior to the paired associations being learned. The vocabulary filler task was included to control for fatigue effects. It ensured that participants had learned an equal number of associations between the paired association training task and the association test task.

Conditions 5 and 6 served as control conditions to determine whether there was any bias in the selected stimulus pairs -- for example, a resemblance to real world objects or words that had pre-existing associations. In these conditions, filler tasks were presented: participants learned irrelevant paired associations and picture-word associations before they performed the vocabulary task and the test association task. Thus, all participants had been trained with the same number of paired associations prior to commencing the test association task. In control Condition 6, the word association filler task was used in place of the word association training. The picture association filler task replaced the picture association training task in control Condition 5. The only relevant information that participants had been given prior to the test association task was the picture-word relationship.

In all training tasks, participants were trained to a criterion of 16 consecutive correct trials. Responses made after feedback had been given were not counted as correct.

Procedure

Vocabulary training

The objective of this task was to teach participants the names of four pictures (a bi-directional association between four novel picture-word pairs). Each trial commenced with an array of five boxes (each approximately 5 x 5 cm) appearing on the screen (see Figure 3.13). Either a novel picture or a novel word was displayed in the central square. For example, if a novel word stimulus appeared as the probe stimulus, four picture stimuli would be presented as the comparison stimuli. The probe stimulus displayed in the central square remained on the screen until the participant pressed the space bar, at which point the probe stimulus disappeared and four comparison stimuli, one in each of the outer squares, were displayed. The participant's task was to select the paired associate for the probe stimulus from the comparison array by pressing the number key at the corresponding corner of the square made up of the keys 1, 2, 4, and 5 on the number keypad. Two seconds after the onset of the comparison stimuli, the correct choice was highlighted in pink. The trial ended when one of the response keys was pressed. The position of the comparison stimuli was varied randomly between trials. At the start of this task, the following instructions were displayed on the screen:

> In this part of the experiment you have to learn the names for some pictures of novel objects. There are two types of trials, picture trials and word trials. On word trials, a word will appear in the centre of the screen. It is the name of one of four pictures. The word will remain on the screen until you press the space bar, then it will disappear and be replaced by four pictures in the surrounding squares. Your task is to press the key which corresponds with the square containing the picture that the word named. (The experimenter will now show you which keys to use.)
>
> If you press the correct key you will hear a BEEP, otherwise there will be a BURP sound and an error message will appear when the correct alternative is highlighted. If you haven't done it in two seconds, the correct alternative will turn red and you should then press the appropriate key. Please press only ONE key for each trial. Eventually you should get to the point where you are able to press the right key before the computer shows you the correct choice in red. Picture trials are just the same except a picture appears in the centre of the

screen and is replaced by four words. There are no practice trials, but don't let this worry you as the program keeps running until you have made 16 consecutive correct responses.

If you have any questions, ask the experimenter now. Otherwise press the SPACE BAR to begin.

In addition to the instructions displayed on the screen, participants were asked to use only one finger to respond and to return their finger to the intersection between the four keys after each response. This ensured that the distance to the response key was the same for each trial; it also made it easier for responses to be made without having to look at the keyboard. To help participants learn the paired associations, the following feedback was given:

If participants responded correctly in less than two seconds, a beep sound was played and the message "Correct" was displayed. If participants responded incorrectly, an unpleasant "burp" sound was played, the message "Wrong" was displayed, and the correct choice was then highlighted. If no response had been made within 2 seconds of the appearance of the comparison stimuli, the correct response was highlighted in pink and remained on the screen until a response was made. A correct response produced at this point caused the message "Correct but too slow" to appear, and was not counted as correct. The training program kept running until 16 consecutive correct trials had been recorded. Trials were only classified as correct if the appropriate response had been made before the correct choice was highlighted. There were no practice trials. The trials were presented in random order, with either the word or the picture from the four picture-word pairs appearing as the probe stimulus. The inter-trial interval was 2000 ms. The response key selected was recorded.

Paired association training task

This was either a novel word association task or a novel picture association task. The same word and picture stimuli were used in these tasks as in the vocabulary training task. Participants were asked to learn either two pairs of word associations or two pairs of picture associations. The stimulus array and the feedback were the same as for the vocabulary training task. The following instructions were displayed on the screen at the start of the visual association task:

> In this part of the experiment you will be learning paired associations between pictures of novel objects. In each trial a picture will appear in the centre of the screen, study it for as long as you like. When you are ready to select this picture's associate press the space bar. After pressing the space bar the picture in the centre will be replaced by four pictures in the surrounding squares, one of which is the paired associate of the picture you have just been looking at. Your task is to press the key that corresponds to the square containing the picture associate. (The experimenter will show you now which keys to use.) If you press the correct key you will hear a BEEP, otherwise there will be a BURP sound and an error message will appear when the correct alternative is highlighted. Please press only ONE key for each trial. If you haven't done it in two seconds, the correct alternative will turn red and you should then press the corresponding key. Eventually you should get to the point where you are able to press the right key before the computer shows you the correct choice in red.
>
> There are no practice trials but don't worry if you make some mistakes to start with because the program will keep running until you have made 16 correct responses, before the computer has high-lighted the correct option.

> If you have any questions, ask the experimenter now, otherwise press the space bar to begin.

Each trial commenced with a probe stimulus that appeared and remained on the screen until the participants pressed the space bar, at which point the four comparison stimuli appeared in the outer boxes. Participants received the same feedback messages as shown in the vocabulary training task. During the paired associate training trials it was possible for participants to match the target stimulus to itself; if they did so, the error message "wrong" appeared, and the correct paired associate was highlighted. The trials were presented in random order, and the program kept running until 16 consecutive correct trials had been recorded. As in the vocabulary training task, trials were only counted as correct if the correct response was made in less than 2 seconds (i.e., before the correct stimulus was highlighted). The word association task was identical, but with word stimuli displayed instead of picture stimuli. The participants' responses were recorded for each trial.

Filler tasks

A vocabulary filler task, and paired association filler tasks were employed for control purposes. They ensured that participants in all conditions had taken part in the same number of learning tasks and were equally familiar with the response procedure prior to the test association task. The filler tasks used the same procedure as the vocabulary training and preliminary association training tasks, but presented different stimulus sets; the trained paired associations were not relevant to the final test task. Participants were not aware that these tasks were irrelevant.

Association test task

This was the last task presented in each condition; depending on the condition, it was either a picture association test or a word association test. Participants who had learned picture associations were given the word association test task; participants who had learned word associations were given the picture association test task. The stimulus pairs corresponded with the associations learned during the paired association training. For example, those participants who had learned picture associations during the training task were presented with the names for these pictures during the test task. These stimulus pairs appeared in half of the test trials. In the other half of the test trials, control stimuli were presented; participants had not seen these stimuli prior to commencing this test task. The stimulus array and the means of response were the same as the paired association training task, but on the test tasks no feedback was given. At the start of the picture association task the following instructions were displayed:

> In this part of the experiment you will be asked to look at a picture and then to select its associate from an array in much the same way as you have done in the previous trials; however, in this test you will receive NO FEEDBACK. Please use any information that you have learned in the course of this experiment to help you make your choices. There are no practice trials.
>
> On each trial, a picture will appear in the centre of the screen. It will remain on the screen until you press the space bar. It will then be replaced by four different pictures. Your task is to press the key that corresponds to the location of the first picture's pair-mate. These are the same keys as in the previous phases of the experiment.

Please make your responses as accurate as you can. If you have any questions please ask the experimenter now. Press the space bar when you are ready to begin.

Before participants started the test task the experimenter informed them that, on completing the test, they would be asked to explain their rationale for the stimulus pairings they had chosen. There were 32 test trials: 16 control trials and 16 experimental trials -- 4 trials for each probe stimulus. Trials were scored as correct if participants had selected the paired associate that corresponded with the paired associations established in the association training task. Because no feedback was given, there was no time limit for responding. The correct associates for the control stimuli had been arbitrarily selected before the experiment was run (see Figure 3.12 for an illustration of the paired associates). The order of experimental and control trials was randomised. There were no practice trials. The key selected for each trial was recorded.

Post experimental interview

After participants had completed the association test task, and before they were debriefed, the experimenter asked each participant to explain what rationale they had employed for selecting the word pairs or picture pairs in the final test task. This was an informal interview. The interview was included as an attempt to gain some insight into the way that the participants had approached the experimental tasks. Their responses were noted.

Results

In each of the tests the response key selected for each trial was recorded so that the number of correct responses could be calculated. The dependent variable for the test association tasks was the number of correct pairs selected. Each stimulus appeared 4 times so the maximum score for experimental stimulus pairs was 16. The alpha level was set at 0.05 in all of the following analyses.

Analysis of the Association Tests

Preliminary analysis of the stimuli

To ensure that the stimulus pairs within each stimulus set were functionally equivalent a 3 way mixed ANOVA was carried out on the number of correct responses to individual stimuli. The between subjects variable was stimulus type (picture or words) and the within subjects variables were stimulus set (control or experimental) and each of the four stimuli within each stimulus set. A table giving the means and standard deviations for each stimulus by condition and the ANOVA table are shown in Appendix 3.9.

There was no main effect of stimulus type (picture or word), nor a main effect of stimuli. There was no interaction between stimulus type and stimulus set. There was a main effect of stimulus set ($F = 24.14$, df 1, 88, $p < .0001$), with a greater number of correct responses recorded for the experimental stimuli than for the control stimuli ($M = 1.56$; $SD = 1.56$; and $M = .72$; $SD = 1.12$ respectively). There was no interaction between stimuli and stimulus set, nor between stimuli and stimulus type.

These results are illustrated in a bar chart given in Figure 3.14. It was decided that the data for the four experimental stimuli and the four control stimuli should be collapsed to form just two scores for each participant thus reducing the degrees of freedom in further Analysis of Test Association Task: stimulus set (experimental or control) by condition.

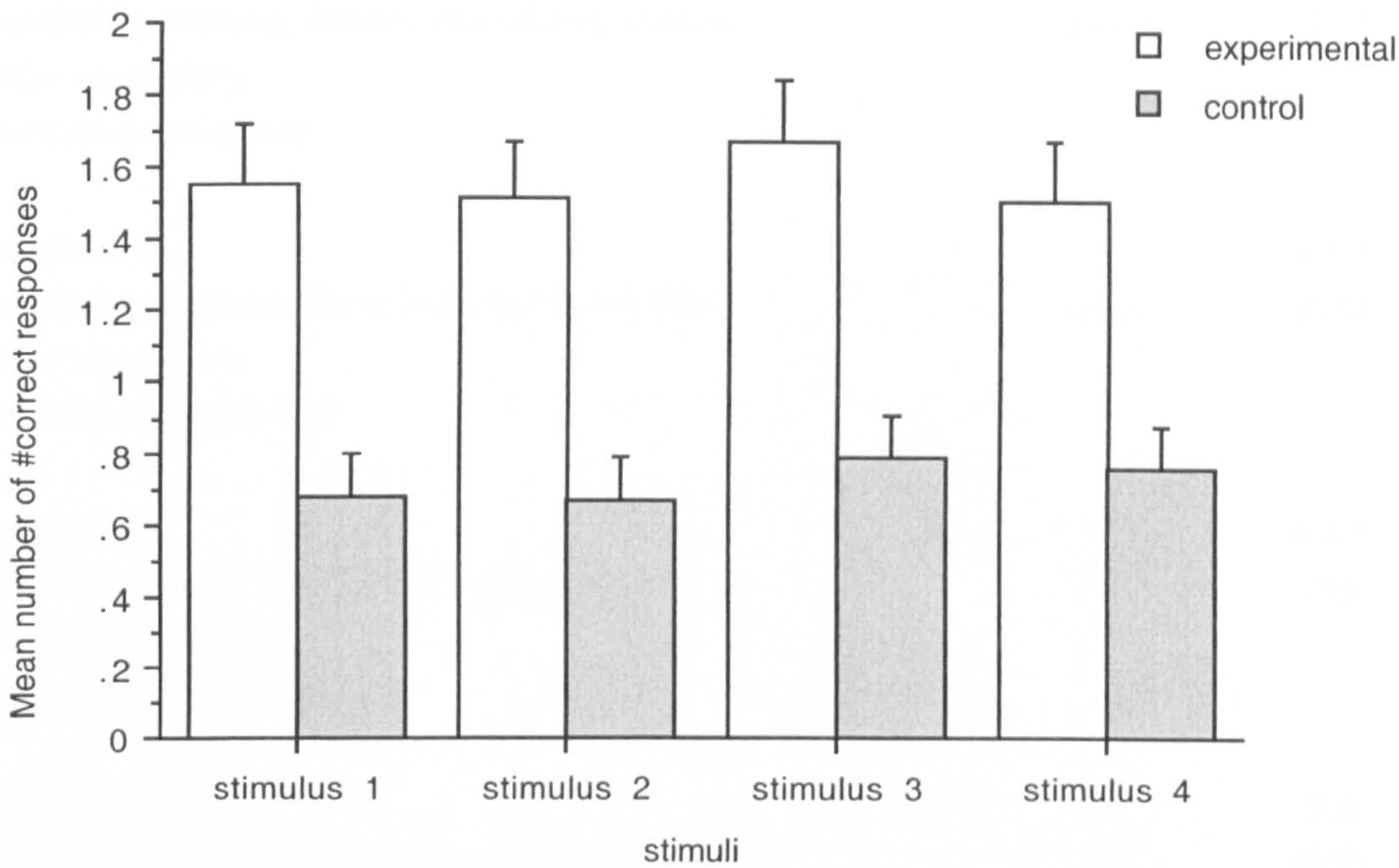


Figure 3.14: Mean number (+ SE) of correct pairs selected for each probe stimulus in the trained and the novel stimulus sets.analyses.

The mean number of correct responses and standard deviations for each stimulus set (experimental and control) in each condition are shown in Table 3.14. A mixed ANOVA was carried out on these data.

The within subjects factor was stimulus set (experimental or control), the between subjects variable was condition (the sequence of the training tasks). There was a main effect of stimulus set ($F = 26$, $df = 1, 84$, $p < .0001$); significantly more correct responses were recorded for the experimental stimuli than for the control stimuli. There was no main effect of condition. There was a significant interaction between stimulus set and condition ($F = 2.46$, $df = 5,84$, $p = .04$) (See Appendix 3.10.a).

Table 3.14: The mean number of correct pairs selected for the trained and the novel stimuli sets for the final association test task (with SD in parentheses)

Condition	*n*	Control	Experimental
Condition 1 *Vocabulary training, Picture association training,* *Filler vocabulary,* *Word association test*	15	3.2 (4.6)	8.3 * (7.3)
Condition 2 *Vocabulary training, Word association training,* *Filler vocabulary,* *Picture association test*	15	2.7 (4.1)	8.1 * (6.6)
Condition 3 *Filler vocabulary, Picture association training,* *Vocabulary training,* *Word association test*	15	2.7 (3.1)	8.6 * (6)
Condition 4 *Filler vocabulary, Word association training,* *Vocabulary training,* *Picture association test*	15	2.9 (3.5)	5.4 (5.7)
Condition 5 *Filler vocabulary, Filler picture association,* *Vocabulary training,* *Word association test*	16	3.3 (4.2)	4.7 (3.6
Condition 6 *Filler vocabulary, Filler word association,* *Vocabulary training,* *Picture association test*	14	2.6 (4.2)	2.3 (3.9)

Note * denotes a significant difference between the novel and the trained condition demonstrated by simple main effects. The maximum possible score for each stimulus set was 16.

Simple main effects showed a significant difference between the novel and the control stimuli in Condition 1 ($F = 6.8$, $df = 1, 14$, $p = .02$), Condition 2 ($F = 11$, $df = 1, 14$, $p = .005$), and Condition 3 ($F = 11.28$, $df = 1, 14$, $p = .004$). The difference between the novel and the trained stimulus pairs for Condition 4 was of borderline significance ($F = 4.6$, $df = 1, 14$, $p = .05$), control Condition 5 ($F = .94$, $df = 1, 15$, $p =. 35$), nor for control Condition 6 ($F = .03$, $df = 1, 13$, $p = .87$). The ANOVA tables are shown in Appendices 3.10.b-g.

A series of planned means comparisons were made to determine whether manipulating the sequence of training trials between conditions made a significant difference to the effect of stimulus set (experimental vs. control). The tables for these comparisons are given in Appendix 3.10h.

There was no significant difference in the total number of correct word associates between Condition 1 and control Condition 5, nor was there a significant interaction, that is, the effect of stimulus set was not different when Condition 1 was compared with Condition 5. There was no significant difference associates between Condition 3 and control Condition 5 in the total numbers of correct associates, but there was a significant interaction with stimulus set ($F = 3.98$, $df = 1, 84$, $p = .049$). The difference between the number of responses to the experimental and control stimuli was significantly greater in Condition 3 than Condition 5. There was no significant difference or stimulus set interaction between experimental Conditions 1 and 3.

Planned means comparisons between the number of correct picture associates between Condition 2 and control Condition 6 showed a significant difference ($F = 4.41$, $df = 1, 84$, $p = .039$). The interaction of stimulus set (control and experimental) between Conditions 2 and 6 was significant ($F = 6.22$, $df = 1, 84$, $p = .015$). The difference between experimental and control stimuli was significantly greater in Condition 2 than

Condition 6. The difference between Condition 4 and control Condition 6 was not significant, nor was there an interaction between stimulus set and these conditions. There was no significant difference between experimental Conditions 2 and 4, nor was there an interaction with stimulus set.

There was no significant difference between Conditions 1 and 2 (in which the first task was the vocabulary training), and there was no interaction with stimulus set. The difference between Conditions 3 and 4 was not significant; neither was there an interaction.

There was no significant difference between the conditions in which the picture association test was used (Conditions 2, 4, and 6) and the conditions in which the word association task was used (Conditions 1, 3, and 5).

A mixed ANOVA was to analyse the difference between the total number of trials and the number of correct trials for picture-word versus word-picture trials obtained in each condition. Condition was treated as the between subjects variable and the total number of scores and the number of correct scores were the repeated measures. There was a significant difference between the correct and total number of trials ($F = 4.53$, $df = 1, 84$, $p = .036$), but there was no interaction with the number of correct responses produced for the picture-word trials compared with the word-picture trials.

Analysis of the Vocabulary Task

Analysis of the number of responses in the vocabulary training task

The vocabulary training task was carried out to a criterion of 16 consecutive correct trials. The number of trials for each participant was counted for the picture-word trials (where the picture was the probe stimulus) and word-picture trials (where the probe stimulus was a word). The total number of correct trials for each participant was also calculated. The mean scores for each condition are shown in Table 3.15

There was a significant effect of condition ($F = 2.35$, $df = 5, 84$, $p = .048$), but no interaction between condition and the number of correct responses compared with the total number of responses. Nor was there any interaction between condition and trial type. The ANOVA table is given in Appendix 3.11. The comparisons are shown in Figure 3.15.

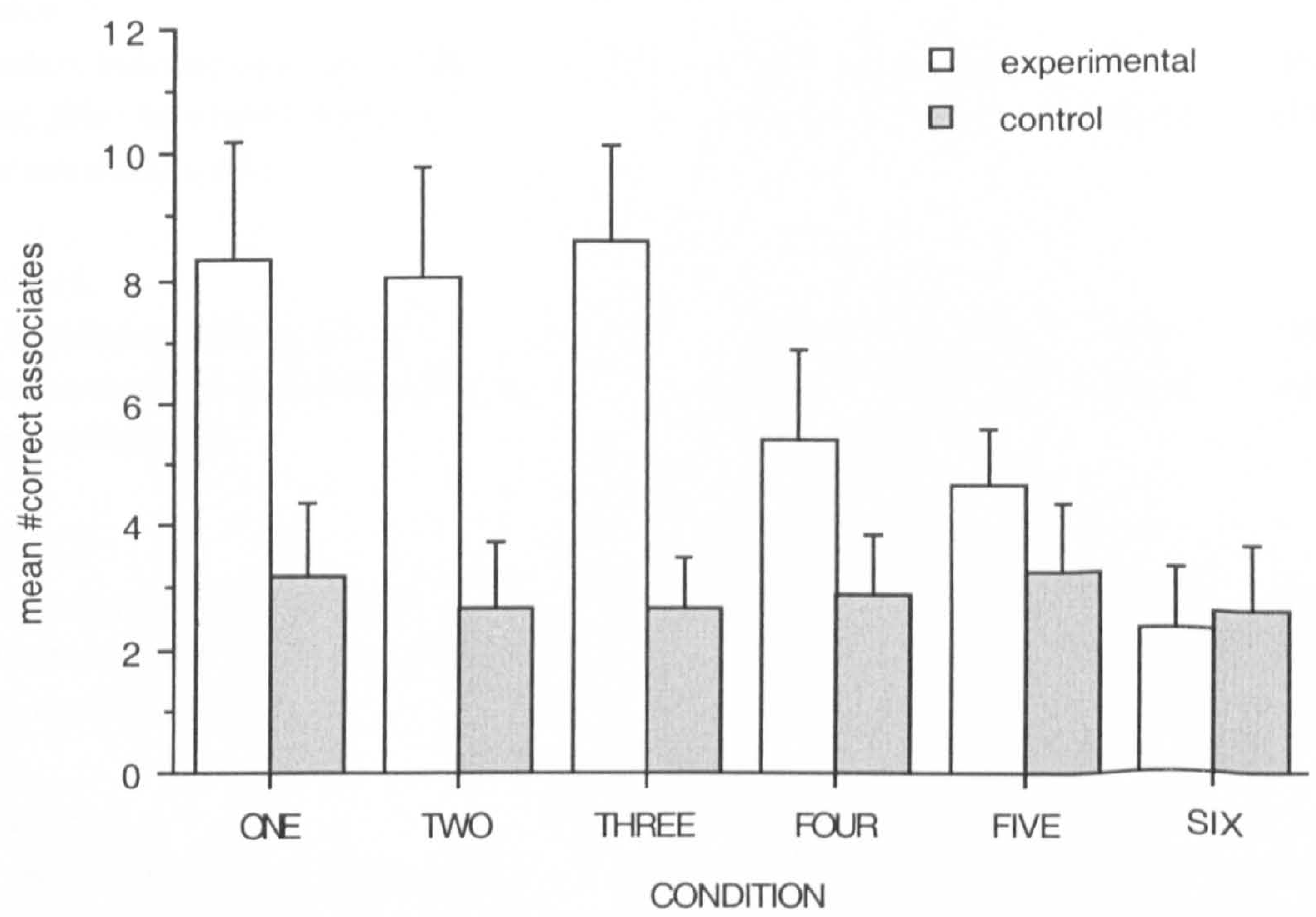


Figure 3.15: Mean number of correct associates (+ SE) in each stimulus set (experimental and control) selected for the vocabulary task each condition.

Table 3.15: The mean total of picture -word trials and word-picture trials and the mean number of correct trials for each condition (standard deviations are given in parentheses)

		Word-Picture		Picture-Word	
Condition	*n*	correct	total	correct	total
Condition 1 *Vocabulary training, picture association training, filler vocabulary training, word association test*	15	31.1 (12.1)	39.5 (16)	30.6 (10.7)	39.5 (15.8)
Condition 2 *Vocabulary training, word association training, filler vocabulary training, picture association test*	15	29.6 (12.41)	38.6 (15.9)	29.4.. (11.5)	38.6. (15.8)
Condition 3. *Filler vocabulary training, picture association training, vocabulary training, word association test*	15	13.1. (3)	15.9 (4.1)	13.8 (3.63)	15.9 (3.9)
Condition 4 *Filler vocabulary training, word association training, vocabulary training, picture association test*	15	23.1.. (14.2)	27.1 (23.6)	21.7 (15.4)	27.1. (23.7)
Condition 5 *Filler vocabulary training, filler picture association training vocabulary training, word association test*	15	27.2 (20.7)	34.5 (30)	29. (21.5)	34.5. (28.9)
Condition 6 *Filler vocabulary training, filler word association training, vocabulary training, picture association test*	15	29.4 (29.64)	37.2 (37.3)	31.47 (29.6)	37.7 (37.17)
Total	90	26. (18.1)	32.2 (24.3)	25.3 (18.07)	32.13.. (24.31)

Analysis of response times in the vocabulary training task

Since participants had been encouraged to study the stimuli before making their responses, an analysis was made of the response times to the picture-word trials compared with word-picture trials. To obtain homogeneity of variance the responses from the first two trials and outliers in excess of 4,000 ms were excluded from the data. Responses to the picture ->word trials were faster than to the word-> picture-trials (M =1140 ms; SD = 188 and M =1318ms; SD = 209.7 respectively).

A mixed ANOVA was carried out to determine whether the sequence of the task had any effect on the response times. The experimental condition was the between subjects measure and trial type (picture -> word vs. word -> picture) was treated as the repeated measure. The mean response time for each trail type is given in Table 3.16.

There was a significant effect of trial type ($F = 99.26$, $df = 1, 84$, $p < .0001$) and a significant effect of condition ($F = 4.92$, $df = 5, 84$, $p = .0005$). The interaction between condition and the response times to trial type was significant ($F = 2.88$, $df = 5, 84$, $p = .019$). The ANOVA table for this analysis is given in Appendix 3.12.

Planned means comparisons showed that the experimental conditions in which the vocabulary training task was carried out first (Conditions 1 and 2) were significantly slower than the experimental conditions in which the vocabulary task was carried out as the third task (Conditions 3 and 4) ($F = 21.7$, $df = 1, 84$, $p < .0001$). The interaction between condition (sequence of tasks) and trial type (picture-word vs. word-picture) was significant for this comparison ($F = 5.7$, $df = 1, 84$, $p = .02$).

Table 3.16: Response times to the different trial types (picture -> word and word -> picture) for the vocabulary task in each condition

Condition	*n*	Picture -> Word	Word -> Picture
Condition 1 *Vocabulary training, picture association training, filler vocabulary training, word association test*	15	11701 (176.4)	1383.9 (208)
Condition 2 *Vocabulary training, word association training, filler vocabulary training, picture association test*	15	1210.1 (160.3)	1501.1 (169)
Condition 3 *Filler vocabulary training, picture association training, vocabulary training, word association test*	15	1058.9 (160.3)	1148.5 (148.4)
Condition 4 *Filler vocabulary training, word association training, vocabulary training, picture association test*	15	1037.7 (167.2)	1244 (139.9)
Condition 5 *Filler vocabulary training, filler picture association training, vocabulary training, word association test*	15	1191.8 (221.4)	1306.4 (210.3)
Condition 6 *Filler vocabulary training, filler word association training, vocabulary training, picture association test*	15	1175.4 (196.2)	1325.6 (211.1)

Planned means comparisons showed there was no significant difference in the response times to Conditions 1 and 2 (vocabulary was the first task), compared with control Conditions 5 and 6 (vocabulary task third). There was an interaction between condition (task sequence) and the response times to the different trial types ($F = 8.5$, $df = 1, 84$, $p = .008$).

Planned means comparisons showed responses to experimental Conditions 3 and 4 were significantly faster than responses to control Conditions 5 and 6 ($F = 9.4$, $df = 1, 84$, $p = .003$). In experimental Conditions 3 and 4 the stimuli had been seen before and this was the third task performed, in the control conditions the vocabulary training task was the third task but the stimuli had not been seen in previous tasks. The interaction between this comparison and trial types was not significant.

The tables for these comparisons are given in Appendix 3.12b, and the interaction between condition and response times for each trial type is illustrated in Figure 3.16.

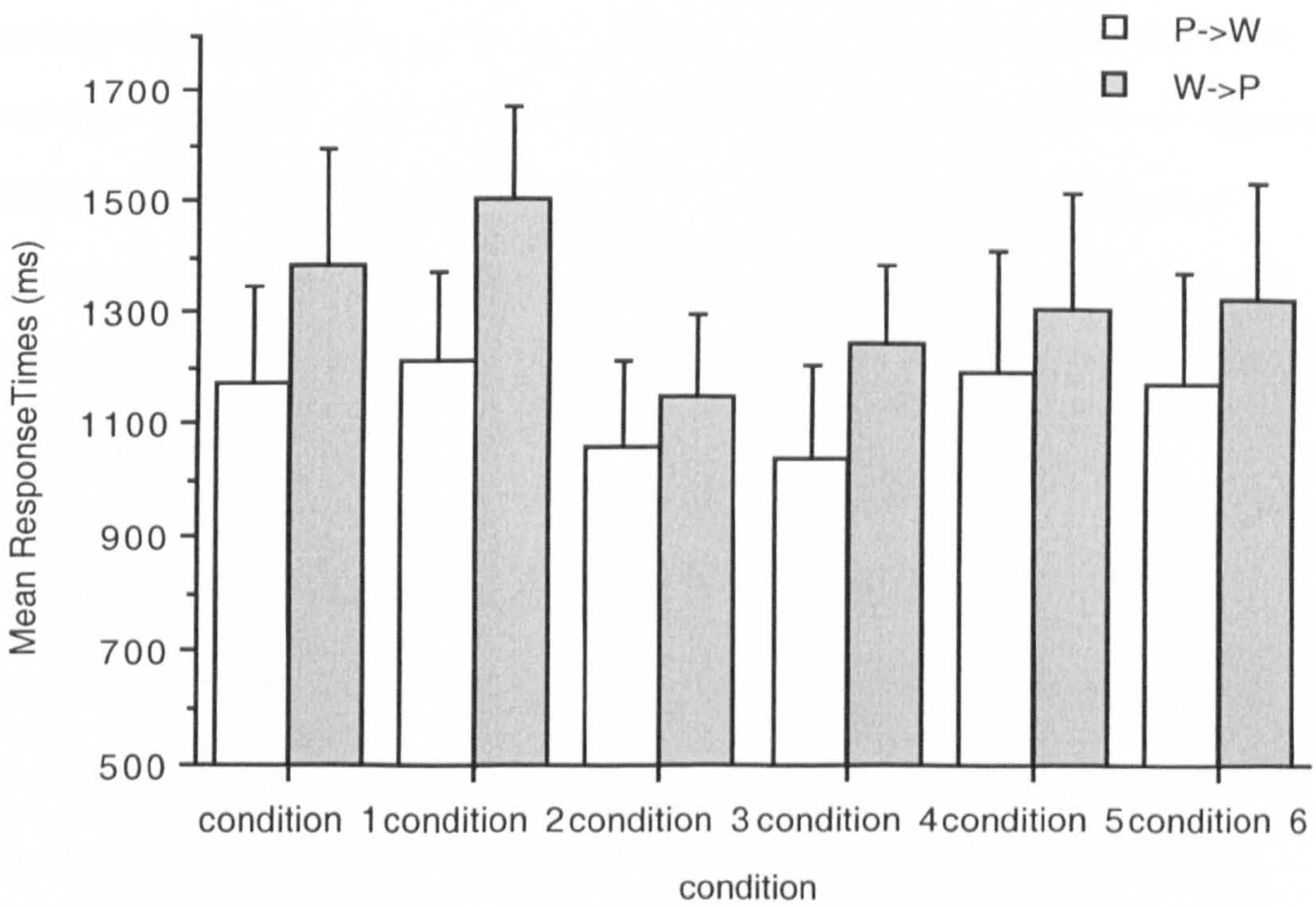


Figure 3.16: The interaction between response times with standard deviation bars to the different trial types (picture-word or word picture) for each condition of Experiment 3

Analysis of the Paired Association Training

The mean response times to the stimuli in the novel picture association task and the novel word association task were compared using an independent t test. There was no significant difference. The mean response times for participants in each condition were compared using a one way ANOVA. There was no effect of condition. The ANOVA table and means are shown in Appendix 3.12 a.

The total number of training trials required by participants in the novel picture association training task (39.75; $SD = 23.2$) was compared with the total number of training trials required by participants performing the novel word association training task (32.48; $SD = 18.9$). A t test showed that the difference was not significant ($t = 1.299$, $df = 53$, $p > .05$). A comparison of the number of responses made in each condition was made using a one way ANOVA. There was no significant effect of condition. The ANOVA table and means for this comparison are shown in Appendix 3.12.b. Post hoc analysis using Fisher's *PLSD* showed that significantly more presentations of the word pairs were required in Condition 2 than presentations of picture pairs in Condition 1 (Crit. Diff = 15.03, $p = .009$) or in Condition 3 (Crit. Diff = 14.77, $p = .045$).

Analysis of Participants' Rationale for the Pairs Selected.

After completing the test association task participants were asked to explain their rationale for the pairs they had associated, and their responses were noted. A table showing the responses recorded is given in Appendix 3.14. Twenty eight of the participants in the experimental Conditions (1, 2, 3, and 4) reported using the associations they had learned in the paired association task, mediated by the names they had learned in the vocabulary task, to form corresponding paired associations in the test task. The responses of the other 32 participants in the experimental conditions were similar to those given by participants in the control conditions who had not been given any relevant information about the stimulus pairings prior to the test task.

The responses were categorised as "aware of the transitive relations between the trained associations and the test associations", or as "unaware of the transitive relations between the trained associations and the test associations". Two independent raters who had no information about each participant's performance categorised the responses. There were two discrepancies in the categorisations, but these were resolved by discussion with the experimenter and 100% concordance was reached. The mean numbers of participants who were categorised as "aware" in each condition is shown in Table 3.17.

A t test was performed on the number of correct associates selected in the test tasks ($n = 13.4$, $SD = 2.8$) by those categorised as "aware of the transitive associations" compared with those who were "unaware of the transitive associations" ($n = 3$, $SD = 3.7$). The difference was significant ($t = 13.256$, $df = 88$, $p < .0001$).

Awareness of the transitive associations was entered as the between subjects variable in a mixed ANOVA in which stimulus set (experimental or control) was the repeated measure. The number of correct responses was the dependent variable. There was a significant main effect of awareness ($F = 82.8$, $df = 1{,}88$, $p < .0001$) and a significant main effect of stimulus set ($F = 86.9$, $df = 1{,}88$, $p < .0001$). The interaction between stimulus set and awareness was highly significant ($F = 72.7$, $df = 1{,}88$, $p < .0001$). The mean number of correct responses for the experimental stimuli was significantly greater than for the control stimuli when participants were aware of the transitive associations. The number of associations between the control stimuli was 3.6 ($SD = 4.3$) for the aware participants and 2.55 ($SD = 3.7$) for those categorised as unaware. The ANOVA table is shown in Appendix 3.15.

Table 3.17: Number of participants in each condition categorised as "aware of the transitive association between the stimuli in the training tasks and the association task

Condition	Aware	Unaware
Condition 1 *Vocabulary training, Picture association training, Filler vocabulary training, Word association test*	8	7
Condition 2 *Vocabulary training, Word association training, Filler vocabulary training, Picture association test*	7	8
Condition 3 *Filler vocabulary training, Picture association, training, Vocabulary training, Word association test*	9	6
Condition 4 *Filler vocabulary training, Word association training, Vocabulary training, Picture association test*	4	11
Condition 5 *Filler vocabulary training, Filler picture association, Vocabulary training, Word association test*	0	15
Condition 6 *Filler vocabulary training, Filler word association, Vocabulary training, Picture association test*	0	15

A mixed ANOVA was then carried out to determine whether there was an effect of condition on awareness and stimulus set (control or experimental). The dependent variable was the number of correct associates selected. This comparison is illustrated in Figure 3.17. There was a main effect of awareness ($F = 67.6$, $df = 1{,}80$, $p < .0001$), and a main effect of stimulus set ($F = 52.88$, $df = 1{,}80$, $p < .0001$) but there was no main effect of condition. There was no interaction between awareness and condition. The ANOVA table and means table for this analysis are given in Appendix 3.15b.

A χ^2 test of independence analysing the difference in the number of people aware in each condition.

The number of people aware in each condition is shown in Table 3.17. A χ^2 test of independence was carried out to determine whether there was a significant difference in the numbers participants categorised as aware or unaware in each experimental condition. There was no significant difference.

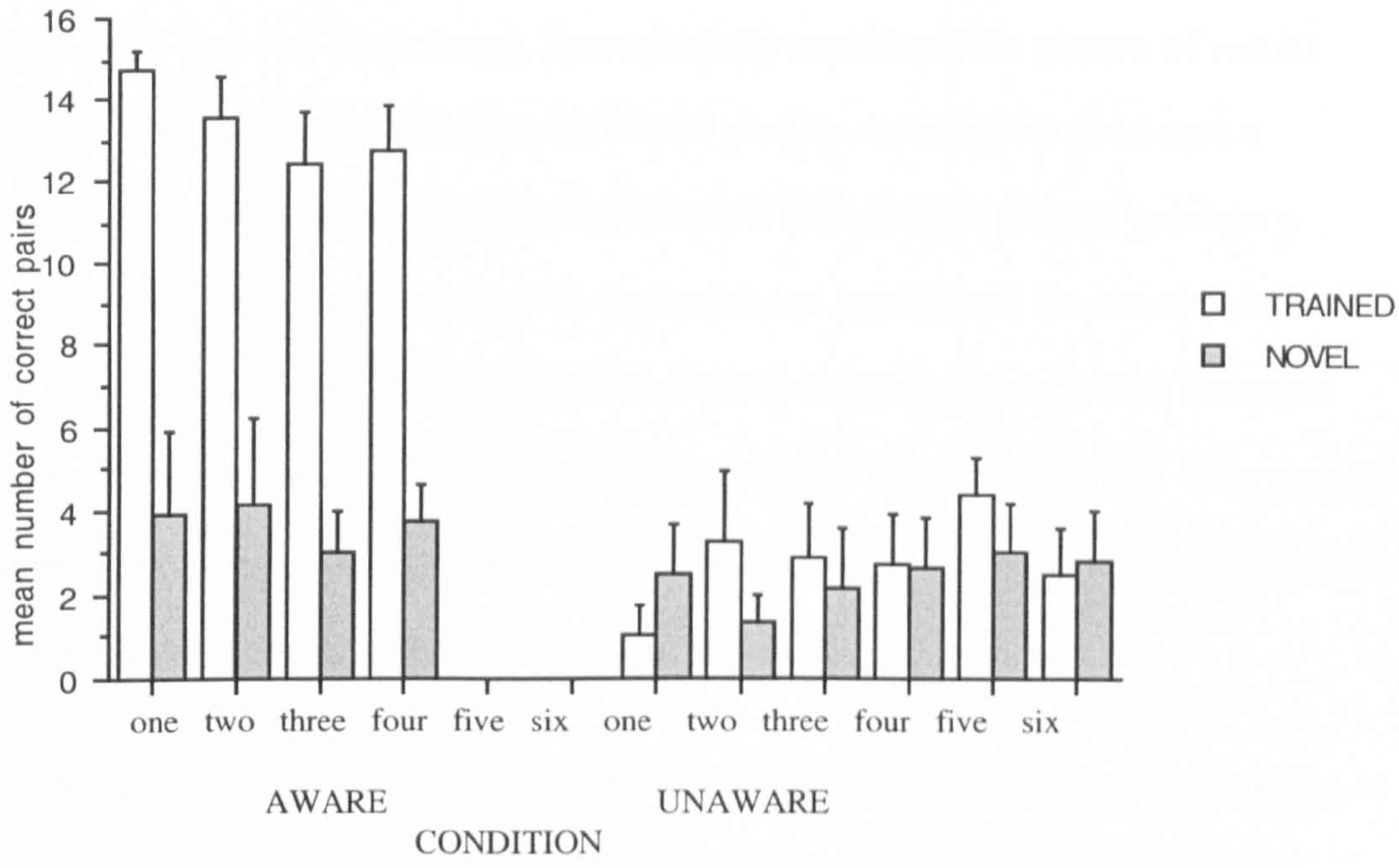


Figure 3.17: Number of correct responses (with standard deviation bars) for each stimulus set produced by those participant's categorised as "aware" or "unaware of the transitive associations between the stimuli in the training tasks and the test tasks in each condition.

Discussion

Picture Associations Transfer from Word Associations if the Words Are Names at Time of Association

Experiment 3 demonstrated that associations between novel words could produce a corresponding association between their picture referents, but only when the name relation between the words and their referents was learned before the word association task. Associations between named novel pictures produced a corresponding association between their names, regardless of the order in which names and associations were acquired. This result suggests a fundamental asymmetry between pictorial and lexical stimuli in their ability to sustain referential transfer of association. Does this cast any light on the nature and development of word meanings?

Conditions 3 and 4 of Experiment 3 successfully replicated the pattern of results obtained in Experiment 1 (Chapter 2). Novel picture associations produced a corresponding word association, but novel word associations did not produce a corresponding picture association. In both of these conditions, the novel paired association training task preceded the vocabulary training task in which the name relations between the novel pictures and novel words were established. This suggests an interesting possible explanation for the failure to transfer associations from novel words to novel pictures in Experiment 1 (Chapter 2).

The pattern of results obtained in Conditions 3 and 4 of Experiment 2 was similar to that of Experiment 3 and Conditions 1 and 2 of Experiment 1. There was some evidence that novel words were associated because of an association between their referent pictures (Condition 3). There was no evidence to suggest that picture associations can arise from associations between novel words that have no picture.

The transfer of association found here does not depend on subvocally naming the picture pairs when they are presented, nor on activating the appropriate stored picture referents as the word pairs are studied: transfer of associative information occurred in Conditions 3 and 4, in which the corresponding picture-word association was acquired after the picture-picture or word-word associations were learned.

The results of Experiment 3, and the methodological framework developed to expose these effects, seem to be worthy of further investigation (see Chapter 4 and Chapter 6). As a partial adaptation of the stimulus equivalence paradigm to address fundamental cognitive issues, it may be particularly useful in bringing to bear insights from both the behaviourist and cognitivist traditions.

Do these results have any bearing on the question of how words and meanings develop, interact, and are represented? How can these results best be expressed and accommodated in the terms of existing theories and established phenomena? In the next sections, we interpret the results within existing frameworks.

Single Semantic Stores

Single semantic store models propose that all semantic knowledge, whether verbal or perceptual in origin, is stored as propositional representations in a single store. Some models (e.g., Biggs & Marmurmek, 1990; Snodgrass, 1984) assume a depth of processing effect: information can be processed at the level of surface features -- for example, spelling to sound translation -- or at a deep level of amodal propositional analysis within the semantic store. Visual representations are assumed to have limited access to the semantic store. Access to abstract information is limited to lexical stimuli.

In a single semantic store model, the transfer of associations across stimulus modalities would occur as a result of amodal propositional processing. The patterns of association between the novel words and novel pictures, and the associations entailed in the name relation, are all stored within the same propositional structure. A symmetrical pattern of relationships between the representations of picture and word associations is predicted. Nor should the order in which associations are acquired have any major impact on the amodal propositional structures representing the associations. Because of the assumption that deeper semantic access to abstract representations is reserved for verbal material, a bias favouring the availability of verbal associations to the picture processing system might be predicted. None of these three predictions was supported by our results. Novel word associations that had no visual referent at the time of study did not produce corresponding picture associations. Picture associations only originated from word associations if the name relations were established prior to learning word associations. Word associations arose from picture associations regardless of the order in which the name relations were acquired. In the terminology of single store models, our results imply that novel words are not represented in the semantic system unless and until they have become associated with an image.

Single semantic store models could accommodate the pattern of data obtained if the novel word associations learned prior to the vocabulary task were represented at a purely surface level. However, this account would sit uneasily with an assumption of higher semantic access for lexical processes. The single semantic store model could also accommodate the data if it is assumed that verbal associations are stored within the lexical processing system and visual representations within the semantic system. But this proposal would result in two semantic stores, a position indistinguishable from dual coding.

Dual Coding

Dual coding models propose separate representational systems for verbal and imaginal material; they are principally concerned with differences of properties between these systems. Paivio (1971) posits that processing concrete words, or images that have strong referential links, can result in activation in both systems. The same degree of association, however, does not necessarily exist between the representations of two related concepts in the two systems (Paivio, 1986). He concludes from a series of experiments (Paivio & Dilley, 1966; Dilley & Paivio 1968) that pictures are superior as retrieval cues when compared with highly imageable words for both picture and word associates. Paivio and Csapo (1973) give evidence that the facilitating effect of pictures is greater when they serve as retrieval cues rather than as responses. Dual coding models allow that the acquisition of concepts may effect the properties of their representations. Paivio (1971) assumed that the relative strengths of the associative links within a processing system, and the referential links between processing systems, reflect an individual's history.

A dual coding account has no difficulties in accommodating the asymmetrical pattern of results obtained in Experiment 3. Dual coding theory predicts stronger associations between concrete (or imageable) words than between abstract words, due to its assumption that imageable words cause parallel activation of the verbal and the visual systems. It could be predicted that stronger associations would arise in Condition 2, in which the novel words were concrete (in the sense of having a picture referent when associated), compared with Condition 4, in which the novel words were effectively abstract during the word association task.

Another prediction of dual coding would follow from the assumptions that pictures are superior retrieval cues compared with even highly imageable words, and that imageable words are superior retrieval cues compared with abstract words. Novel word associations should arise from picture associations more readily than novel picture associations arise from associated words. Both tasks involve the recall of a chain of associations. The associative chain produced in Condition 3 is dependent on the probe word stimulus cueing the recall of its picture referent, which acts as a cue for its associated picture, which in turn cues the recall of its name. The chain of associations that must be recalled in Condition 4 relies on a probe picture stimulus cueing its name, which cues the recall of its paired word associate, which in turn cues the recall of its picture referent. The transfer of associations in Condition 3 relies on two picture cues and one concrete word cue, whereas the transfer of associations in Condition 4 relies on one picture cue, an abstract word cue and a concrete word cue.

Analysis of the vocabulary training task in Experiment 3 showed that the names for the novel picture stimuli were selected significantly faster than the corresponding pictures were selected for the novel word stimuli. Dual coding predicts that pictures are superior retrieval cues compared with words.

Perceptual Symbol Systems

Single semantic store models seek to provide a hypothetical explanation of how semantic representation could occur. In these models, conceptual meaning is embedded in associations between propositional representations. Dual coding explains the association between a word and its referent image as a referential link between processing systems. Dual coding focuses on the properties of the two symbolic processing systems rather than on the interactions between these systems. Conceptual meanings are expressed as patterns of association both within and between these systems, but there is no account of how these links are acquired or represented. With his perceptual symbol system, Barsalou (1999) develops Paivio's notions of separate representational systems and provides a theoretical model that combines perceptual experiences with verbal experiences to develop conceptual representations. Barsalou's model grounds the acquisition of conceptual representations in perceptual experiences. Perceptual experiences provide the basis of the representational complex which Barsalou refers to as a simulator. Words are meaningful through their integration with a conceptual simulator.

The asymmetry between the transfer of associations across symbol modalities follows the developmental sequence that Barsalou ascribes to the acquisition of a conceptual simulation. The acquisition of an association between two novel words that have no perceptual referents is an insufficient basis for the acquisition of a new concept. An association between two novel pictures is a sufficient basis for establishing a new conceptual simulator whether or not those pictures have names.

Are Novel Picture Associations Acquired More Easily than Novel Word Associations?

To explain the asymmetry in the pattern of results obtained in Experiment 1 (Chapter 2), we hypothesised that associations between novel pictures were acquired more readily than associations between novel words. The results of Experiment 3 did not support this hypothesis. Analysis of the paired association training tasks in Experiment 3 showed that there was no difference in the number of trials required, or in the mean response time, between novel picture association training and novel word association training. However, significantly more training trials were required in Condition 2 (word training) than in Conditions 1 or 3 (picture training). There was no significant difference in the numbers of word trials required between Conditions 2 and 4. In Conditions 1 and 2, the vocabulary task was presented first, while in Conditions 3 and 4 the vocabulary task came after the paired association task. This refutes the second hypothesis that word associations are more easily learned between words that have a picture referent than between novel words that have no pre-existent picture referent.

Transfer of Associations across Stimulus Modalities: Is Consciousness Required?

A post hoc analysis of participants' reasons for choosing pairings in the test association task of Experiment 3 suggested a difference in participants' performance depending on their ability to describe the contingencies between the stimuli in the training tasks and the test tasks. Participants who told the experimenter that they had used the associations learned in the training trials to select the associated stimuli were categorised as "aware of the transitive associations" between the stimuli in the training tasks and the test task. Participants who were "aware" produced more correct responses than did participants who were categorised as "unaware of the transitive associations" between the stimuli in the training tasks and the test task. There was no significant difference in the numbers of participants who were categorised as "aware" between conditions. It is interesting to note that Condition 4, in which the least number of people were categorised as "aware", was the condition in which the least number of correctly associated stimuli were selected in the test task, and was also the only condition in Experiment 3 that did not demonstrate a significant difference between the control and the experimental stimuli.

The findings here are reminiscent of Wittgenstein's (1953) observations about forming a name for a sensation so novel it has no verbal definition. He describes the need to concentrate his attention on the sensation whilst saying or writing down the new symbol, to impress on himself the connection between the two so that it can be recalled correctly in the future.

Name relations are more than chained associations

In Experiment 3, participants learned the novel paired associations and the picture–word associations to a criterion of correctness. All the necessary links in the chain of associations required for the test task had been forged, but participants who were unaware of this were unable to exploit the information entailed in the chain of associations when performing the association test task.

Barsalou (1999) asserts that a perceptual symbol is a record of a subset of the pattern of neural activation instanced by a given perceptual state. He proposes that the subset of the pattern of activation is "extracted via selective attention" (p.577). It seems evident from the results obtained in these experiments that attention is required to encode the novel associations as representations that can be used for symbolic processing.

Definitions of attention and consciousness are notoriously slippery and hard to pin down. The role of consciousness in vocabulary acquisition is a much debated topic.

Posner and Snyder (1975) outline three operational indicators of automatic processing that allow a distinction to be made between "automatic" and "conscious" processes. Automatic processes occur without intention, without giving rise to conscious awareness, and without producing interference in any ongoing mental activity. Conscious and unconscious learning have been broadly characterised as explicit and implicit learning. If a person is able to relate a verbal rule or describe a complex stimulus environment, explicit learning has taken place. Implicit learning is said to occur if abstract knowledge is learned without the ability to articulate a verbal rule or to provide a description of the stimulus environment.

Ellis (1994a) argued that explicit learning (or conscious processing) is required for acquiring word meanings and for developing an understanding of new vocabulary items. Other aspects of vocabulary acquisition can be produced by implicit processing, for example, recognising the surface form of new words, or acquiring the underlying patterns of contextual regularity.

Bentall and Dickens (1994) claim that explicit learning is a specifically human ability, and they argue that language development and explicit learning abilities are closely related. Explicit learning is closely linked to "rule governed behaviour" and implicit learning to classical and operant conditioning. Animals have been trained on all the component relations for a stimulus equivalence task, but they have never shown the emergent relations of symmetry, transitivity, or equivalence. It is argued that the processing required for the emergence of equivalence relations belongs in the domain of explicit learning.

There is much evidence that words that are imageable are more meaningful (measured in terms of the number of verbal associates that are generated from a word in a given time period).

Awareness or forgetting?

Although novel picture associations and novel word associations were learned equally easily in the association training tasks, it is possible that the novel word associations were forgotten faster than the novel picture associations. Paivio (1991) reported better associative recall for picture stimuli than for word stimuli. Walker and Hulme (1999) have reported an advantage for concrete words compared with abstract words in a series of short-term serial recall tasks. It is possible that the word associations learned in Condition 4 were forgotten faster than the word associations learned in Condition 2. In Condition 2 the novel word associations could be processed as concrete word associations because they had a corresponding picture referent. In Condition 4 the novel word associations were established in the absence of picture referents and so must be classified as abstract picture pairs. There was no independent measure of recall in Experiments 2 and 3, so this explanation could not be investigated.

Conclusions

The data presented here show that a transfer of information occurred between the verbal and visual systems, mediated by a picture-word name association.

Our results suggest an asymmetry in the patterns of transfer across stimulus modality. Picture associations can be transferred to corresponding word associations more readily than word associations can transfer to picture associations.

Order of association training had an impact on cross-modal transfer of association; this effect interacted with the asymmetry noted above. Picture to word transfer was most likely when picture-picture associations were acquired before vocabulary training. Word to picture transfer only occurred when word-word assocation training followed vocabulary training.

It can also be argued that the transfer of associations across stimulus modalities requires explicit processes, as only participants who could verbalise the association produced correct responses in the test task. The performance of the participants who were unaware of, or could not verbalise, the connection was no different to the performance of those in the control conditions. This was despite all participants having learned the novel paired associations and vocabulary training to a criterion of correctness. It is possible that participants were unable to recall the associations even if they had been aware of the transitive relations between the associations in the training tasks and the test task. This possibility will be investigated in Experiment 4.

Summary

- Experiment 1 had demonstrated an asymmetrical relationship between corresponding word and picture associations. Associations between novel pictures produced corresponding word associations, but associations between novel words did not produce corresponding picture associations.
- Experiment 3 replicated and extended this pattern of results.
- Novel word associations can produce corresponding picture associations if there is an established name relation between the words and the pictures at the time the novel words are associated.
- Associations between novel pictures can produce corresponding word associations regardless of whether the name relation is acquired before or after the association.
- There was no evidence that this pattern of results can be accounted for by a difference in the ease with which the novel picture associations and novel word associations were originally learned.
- The pattern of results is accommodated more readily by a dual coding account than by single semantic store models.
- The results can be usefully interpreted within the framework of perceptual symbol grounding.
- There is some evidence that awareness of the contingencies between the training and the test tasks is necessary for the transfer of associations to occur.

Chapter 4

Is Awareness Necessary for the Transfer of Associations between Stimulus Modalities?

This chapter focuses on the role of awareness in mediating the transfer of associations between stimulus modalities. Experimental evidence is provided to suggest not only that awareness of the trained associations is required, but also that awareness of the contingencies operating between the training tasks and the test task is necessary. In Experiment 3 (Chapter 3), we demonstrated that associations between novel pictures can produce corresponding word associations regardless of whether the name relations are learned before or after the picture association. In contrast, our results suggest that word associations can produce corresponding picture associations only if name relations are established before the word associations are learned.

As was also seen, inspection of the data revealed considerable individual variation: several participants responded correctly to the picture association test task when they had learned the word associations before the name relations. In the other conditions, there were participants who showed no evidence that picture associations could produce corresponding word associations. A post hoc analysis of the data, and of participants' comments about the tasks, led us to propose that the transfer of associations between stimulus modalities requires awareness of the contingencies among the original trained associations, the name relations, and the test association task. We shall refer to this as our *naming awareness hypothesis*. The primary aim of this chapter is to test this hypothesis.

The data obtained from the priming task employed in Experiment 1 (Chapter 2) also exhibit considerable individual variation in the patterns of response by participants within each condition. There were participants in each condition who showed evidence of transferred associations across stimulus modality (picture priming after corresponding word associations had been learned or word priming after picture associations had been trained). However, no data was collected in Experiment 1 to determine whether participants were aware of the contingencies between the training tasks and the test task. Nonetheless, similarities between the patterns of data obtained in Experiments 1 and 3 lead us to extend the naming awareness hypothesis to cross modal priming. We postulate that cross modal priming occurs only when participants are aware of the contingencies between the training and the test tasks. A priming task is included in Experiment 4 to test this secondary hypothesis.

In Experiment 3, there was no measure of participants' abilities to recall the trained associations. It is possible that participants who performed badly in the test task were merely unable to recall the trained paired associates or the name relations. In Experiment 4, recall tests are introduced to test the secondary hypothesis that poor test performance is due to poor recall of the associations learned during the training tasks.

What Do We Mean by "Awareness"?

The terms *awareness*, *consciousness*, and *conscious awareness* are often used interchangeably (see, e.g., Gardiner, 1996; Nunn, 1996; Kihlstrom, 1996; Velmans, 1996). Debates about the role of consciousness and awareness often founder because of the diversity and confusion of definitions employed. Velmans (1996) describes the shortcomings of some of the common definitions. Consciousness used synonymously with "mind" gives rise to too broad a definition since it is apparent that not all mental states or mental processes are conscious. Conversely, defining consciousness to mean only awareness of self is too narrow since it is evident that we are aware not only of ourselves but also of events in the external world. The term consciousness has also been used to refer to a state of wakefulness; this definition is inadequate both because it is possible to be conscious of dream experiences and because it is equally possible to be unaware of sensory or cognitive experiences occurring while awake. For our purposes, we shall use the term *awareness* to refer to those events, processes, and memories that are people's self-reported experiences.

It is evident both from our experience of the world and from the experimental literature, that learning takes place and memories are laid down, following both conscious and nonconscious experiences. The terms adopted to describe this dissociation in memories, cognitive processes, and tasks include *explicit/implicit*, *procedural/ declarative*, *incidental/intentional*, and *direct /indirect*. The distinction is not always easy to discern because many tasks involve both kinds of processing, and the definitions applicable to the different although overlapping terms are not completely interchangeable. It is necessary to clarify these differences to bring the processes implicated by our naming hypothesis into focus.

Learning without Awareness

The canonical example of nonconscious learning is classical, or Pavlovian, conditioning. A stimulus (*the conditioned stimulus*) that is neutral with respect to a given behaviour (*the unconditioned response*) can, if repeatedly paired with a stimulus that evokes that behaviour (the *unconditioned stimulus*), evoke a similar response (the *conditioned response*) in the absence of the unconditioned stimulus. This type of learning has been demonstrated in organisms as primitive as molluscs (e.g., *Aplysia* -- see Kandel & Schwartz, 1982). Implicit learning has been demonstrated in human beings. Warrington and Weiskrantz (1979) produced classical conditioning in two amnesic patients. By pairing the sound of a buzzer with a puff of air directed in to one of each patient's eyes, they conditioned an eye blink response to the sound of a buzzer alone. Ten minutes after having learned the response, the patients were unable to recall any details of the conditioning procedure, yet they continued to show the response for the rest of the day.

Reber (1989, 1992) characterises implicit learning as an unconscious process that yields abstract knowledge. He carried out a series of experiments using a paradigm based on *miniature artificial grammars* (MAGs). These have produced clear evidence of implicit learning. Reber's participants were presented with strings of letters (training strings) that had been generated using an underlying rule system. The participants were instructed either (a) to deduce rules for predicting the letter order, or (b) to memorise the examples for a memory test. After several hours of these trials, they were asked to determine whether a series of new letter strings were grammatical or ungrammatical (whether they adhered to the same rules as those in the training strings). Many of the participants' abilities to discriminate between the new strings were above chance, despite the fact that they were unable to verbalise underlying rules. Further, there was no difference between the performance of participants who were searching for a rule and that of participants who were memorising the letter strings. Reber concludes that this demonstrates unconscious and incidental learning, which occurs whether or not participants have the intention of learning regularities. In other words, in MAG paradigms, the formation and testing of conscious hypotheses does not affect the experimental outcome. Thus, "The pick up of information takes place independently of consciousness or awareness of what is picked up" (Reber, 1989, p. 231). Reber goes on to claim that the contents of implicit memory are too complex and rich to be expressed in words. Our operational definition of awareness (Experiment 3, Experiment 4, this chapter) requires participants to verbalise the relationships between the stimuli. We are not focusing on how the information is learned but on how available to conscious inspection it is after it has been acquired.

Conscious learning

Conscious learning occurs when we study for an exam, when we attend to the details of a painting that we wish to recall, or when we listen to someone giving us instructions. The training tasks in our experiments are all examples of conscious learning.

Attention has long been held to be the gateway to conscious learning and memory. James' (1950 /1890) storehouse model of memory has influenced psychologists for more than a century. He proposed that the contents of current consciousness are contained in a "primary store". Stimuli or events reach consciousness only if they are the focus of attention. Memories are housed in a "secondary store", where they are not conscious unless they are recalled. James (1892) described these memories as

> The knowledge of a former state of mind after it has dropped from consciousness; or rather it is the knowledge of an event or fact, of which in the meantime we have not been thinking, with the additional consciousness that we have experienced it before. (p. 287),

An example of a task requiring explicit learning is paired associate learning (PAL). Participants are instructed, during a study phase, to learn lists of paired associations between arbitrarily selected pictures or words. A recall test is then given in which one of the paired stimuli serves as a cue for its paired stimulus. PAL can be classified as requiring explicit learning since participants are able to report the strategies they have used (Paivio, Smythe & Yuille, 1968). Moreover, participants' performance in PAL tasks has been enhanced by instructions to adopt specific encoding strategies, for example to visualise the two items interacting, or to construct a sentence containing the two words (Paivio & Foth, 1970). These experiments demonstrate explicit learning during the study phase and explicit processing (processes open to conscious inspection) during the recall test. Participants approach their tasks with the *intention* of learning the pairs for a future memory test, they *consciously attend* to the presented stimuli, and they *consciously employ* a mnemonic strategy for encoding and recalling the paired associates. The training tasks presented in our experiments are procedurally similar to the study phase of PAL tasks, and can be classified as explicit learning because participants consciously attend to the stimuli with the intention of learning the paired associations. Our naming awareness hypothesis assumes that the mnemonic strategies participants employ for the test task are conscious, and proposes that an awareness of the relationship between the trained stimulus pairs and their names is required for the transfer of associations.

Another means of defining conscious processes is the distinction between *conscious* and *automatic* processes (Posner & Snyder, 1975). Automatic processes are those that occur without intention, without giving rise to conscious awareness, and without interfering with ongoing mental activities. Conscious processes are intentional, give rise to conscious awareness, and produce interference in competition with other mental activities. This distinction is not always easy to observe because the two processes can be combined in many cognitive tasks. The interference recorded in a Stroop task, for instance, can be explained in terms of automatic processing; automatic processing of the colour word occurs in parallel with the intentional processing of the colour name. Automatic reading of the colour name interferes with output processing for naming the colour because of competition between the two activated colour words.

Posner and Snyder's (1975) model proposes that stimulus information automatically activates those internal representations that have been habitually associated with it. It follows that the automaticity of a particular pathway is closely related to the degree of learning that the individual has experienced between these associations. If conscious attention is employed in a task involving stimulus processing, other signals are inhibited and do not reach active attention; because of this, the benefit of automatic activation is increased. New items might continue to automatically activate pathways, but they are not easily associated to nonhabitual patterns of response. This produces enhanced responses to expected stimuli and slower responses with increased errors for unexpected stimuli. Automatic processing has been invoked by proponents of semantic network theories to explain the facilitation observed in priming tasks (e.g. Collins & Loftus, 1975; Williams, 1996). In Experiment 4, we employ a priming task to investigate the nature of the transitive relations. Once acquired, can transitive associations produce priming like paired associations do?

It has been proposed that both automatic and intentional processes affect the way priming tasks are performed (Neely, 1991). Posner and Snyder (1975) suggest that people consciously employ strategies. By this they mean that people can choose to selectively attend to a particular input modality; they can program selective attention to a specific area of memory; and they can program it to perform a particular operation on receipt of a certain stimulus. Strategies can have an effect on conscious perception, on subjects' responses, and on what is available for later report. Conscious processes can result in the activation of specific memory representations. Conscious processes not only result in selectivity; they can also enhance the rate at which information enters the processing system. Strategies are independent of automatic activation. The distinction is important in a priming task if the facilitation is to be attributed to automatic processes. Steps were taken in the design of the priming task in Experiment 4 to reduce the chances of participants' employing conscious strategies during the task.

Declarative knowledge and awareness

Squire (1987) proposed two discrete memory systems: the *procedural system* and the *declarative system* (or *propositional system*). The procedural system is an action system in which perceptual and motor skills are stored; it is expressed in behaviour, not in words, and it is not open to consciousness. The declarative system, by contrast, is expressed in words and is open to consciousness. It is the system that is employed in explicit tasks, those tasks in which participants are aware, or become aware, that their performance is influenced by specific events or experiences from the past. Our operational definition of awareness is not derived from participants' performance in the association test task but from a declarative knowledge of the relations tested by the association test task.

We aim to determine whether (a) the transfer of associative information between memory systems requires explicit awareness of each link in the associative chain, or (b) the transitive relations emerge from unconscious or implicit processing of these associations.

The Role of Awareness in Vocabulary Acquisition

In Experiment 3 and Experiment 4 (this chapter), transitive relations between the trained associations and the test associations are mediated by the picture-word associations presented in the vocabulary training task. The roles of implicit and explicit processing are tightly enmeshed in the domain of vocabulary acquisition. Ellis (1994a) examined evidence for incidental vocabulary learning from several fields of research. He concluded that the surface forms of new vocabulary — the phonology and pronunciation, and the graphemes and orthography -- are acquired implicitly; the performance of these skills is automatic. Performance is improved with practice and is affected by frequency, recency, and regularity. Ellis does not dismiss the role of verbal declarative learning -- rules for spelling can be of assistance -- but he argues it is ultimately the experience of writing, speaking, or listening that results in automatised recognition and production of, new vocabulary items. Learning word meanings (the correspondence of words with semantic representations, relations with other words), he goes on to claim, is an explicit process dependent on cognitive strategies. The meanings of new words can be inferred from their context, from their juxtaposition with objects, or from surrounding text or speech.

Ellis (1994a) presents compelling evidence for his arguments, drawing on studies of anterograde amnesia among other sources. The definitive symptom of anterograde amnesia is a difficulty in recalling experiences after an underlying brain insult. For example, Milner's (1966) patient HM was able neither to recall the day's events nor to find his way around the hospital in which he was staying, but he had normal recall of autobiographical events and semantic knowledge acquired before the onset of the amnesia. His vocabulary appeared normal and he had an above average IQ. Notably, his ability to acquire information implicitly appeared unaffected, but his explicit learning ability was severely impaired. His implicit learning was demonstrated by a stem completion task. In this task, a list of words or word pairs is given to the participant to study. At recall each word is prompted by a display of its first three letters and the participant is told to complete the fragment with the first word that comes to mind. HM's behaviour was like that of normal controls: words that appeared in the study phase were selected in the test phase faster and more frequently than words that had not recently been studied. However, when given explicit learning tasks, his performance was poor: he was unable to select 12 faces from an array that he had seen 90 seconds previously; likewise, he was unable to learn new associations between words, scoring zero on a PAL test. Ellis argues that this suggests that learning the conceptual associations required for comprehension of new vocabulary is an explicit process.

Following Ellis (1994a), our naming awareness hypothesis predicts that the artificial vocabulary trained in Experiment 4 would mediate the transfer of associations between stimulus modalities only if the conceptual links between the stimuli have been explicitly processed. Furthermore, evidence such as HM's failure to learn new paired associations suggests that explicit processing might have been be required at each of the PAL phases in our Experiment 3. To distinguish whether the locus of the effect of "awareness" in Experiment 3 was the individual trained associations or the transfer of associations, we introduce recall tests for the trained associations in Experiment 4 (this chapter).

Evidence produced by Schacter (1986) suggests that established associations can be activated through implicit processes. He presented amnesics and controls with a study list of word pairs associated through common idiomatic speech, for example, "sour-grapes". The amnesic participants showed the same priming effects as the controls in a subsequent free association test, so when they were presented with the word "sour" they responded with the word "grape". Shimamura and Squire (1986) report similar implicit priming effects in amnesic participants when the study list comprises highly associated word pairs -- "table and chair", for instance.

In the training tasks presented in Experiment 3 and Experiment 4 (this chapter), participants are instructed to learn associations between a picture and its name, and between two pictures or words, and performed training until they had reached a criterion of correctness. The trained associations can be considered to be explicit knowledge; they are intentionally encoded and recalled. The test task requires participants to use the transitive relations between the training tasks and the test task, to exploit their knowledge of the corresponding name relations. The question of interest is whether these transitive relations have to be explicitly mediated or whether they can be implicitly abstracted. Can the correct response be selected without participants being able to verbalise the reasons for their choice? The matching to sample task employed in Experiment 4 is a measure of intentional processing. To determine whether there was an implicit transfer of associations, a task that relies on automatic processing was required. Decision tasks, such as lexical decision or object decision, have been held to be a measure of automatic processes (Draine & Greenwald, 1998; Fischler, 1977b; Meyer & Schvaneveldt, 1971; Schacter, 1987; Williams, 1996).

Is Explicit Learning Verbal Behaviour?

In Experiment 3 and Experiment 4 (this chapter) we have adapted a behaviourist matching to sample paradigm often used in stimulus equivalence studies to examine transitive relationships. Researchers in the behaviourist tradition have used studies of stimulus equivalence to examine questions pertaining to the ontogenesis of language and of symbolic reference. Although the terminology employed by behaviourist and cognitivist researchers is typically confined to their own tradition, it is evident that the same core questions are addressed. Further light might be shed on our naming awareness hypothesis by examining how these questions have been addressed by behaviourist researchers.

Bentall and Dickens (1994) note that the absence of awareness has been taken as a hallmark of implicit learning in human adults and, like McLaren, Green, and Mackintosh (1994), suggest that associative learning in animals provides a good model of implicit learning in humans. Bentall and Dickens argue that there is no parallel of explicit learning to be found in nonhuman species. Following Piaget (1959), who proposed that language is the precursor to explicit learning and consciousness, Hayes and Hayes (1992) argue that there is a close relationship between the emergence of language and the development of explicit learning from both phylogenic and ontogenic perspectives. Hayes and Hayes give a behavioural account of explicit learning. They describe it as verbal or rule governed behaviour characterised by the use of instructions, or the ability to construct hypotheses about contingencies.

Skinner (1957) defined verbal behaviour as behaviour reinforced through the mediation of other people in accordance with the practices of the verbal community. He defined verbal stimuli in terms of their functional relations with a given behaviour (see Chapter 3, Introduction). Although he acknowledged that tacts are not the same as names, he did not use *naming* as a technical term. Skinner's account fails to distinguish between operant behaviour and verbal behaviour (Horne & Lowe; 1996). Horne and Lowe (1996) claim that the basic unit of verbal behaviour is *naming*. They give an account of how a name might be learned and how it develops its symbolic function. Horne and Lowe (1996) define naming as a

> ...higher order bidirectional behavioural relation that a) combines conventional speaker and listener behaviour within the individual, b) does not require reinforcement of both speaker and listener behaviour for each new name to be established, c) relates to classes of objects and events. (p. 207)

By *speaker behaviour* Horne and Lowe mean that the presence of an object acts as a discriminative stimulus that will produce the appropriate utterance from a child without prompting or reinforcement from another person. This, they claim, is the final stage in acquiring a speaker-and-listener behaviour within the individual. It is the result of a history of hearing the name of an object being spoken, combined with orienting towards that object, of echoing that name in the presence of the object, and of the child hearing itself echo the name in the presence of that object. They term this relationship a *higher order behavioural relation* because, once the naming behaviour of listening, echoing, and tacting is established, children can short circuit the process and learn names for new objects after hearing the names only once or twice. Once naming is established, the child can acquire intraverbal behaviours (conceptual associations) by successively naming two or more objects in the environment (or properties of those objects). They use Skinner's example of a child who has learned to name a spoon and a fork individually, who will then come to say "spoon fork" or "fork spoon" when she sees the table set for meals. In this manner, a bidirectional relationship is established between the two; thus, saying "fork"will prompt saying "spoon". This in turn affects other aspects of the child's behaviour, for, if a child sees a spoon and then says "spoon fork", he or she will then look for the presence of the fork (Skinner, 1957).

Horne and Lowe's (1996) account suggests that once naming is established, chained associations between objects and their names produce new behaviours, and that naming as a behaviour accounts for the emergent relations evinced in stimulus equivalence phenomena. The design of Experiment 4 provides a test of these predictions; by using adult subjects with a history of naming behaviour. Teaching them to name new items by training bidirectional links between novel pictures and novel words, and establishing bidirectional associations between the novel words, should be sufficient to produce corresponding associations between the named pictures. Our naming awareness hypothesis proposes that naming requires more than a bidirectional relationship; naming requires an awareness of the relationships entailed by the name.

Can Explicit Instruction Result in Explicit Learning?

Our naming awareness hypothesis suggests that the transfer of associations across stimulus modalities is an explicit process. By extending this prediction, it is possible that participants who are unaware of the relations between the training and the test stimulus pairs mediated by a naming relationship might acquire this association after verbal instruction.

Ellis (1994a) refers to the role of deliberate learning strategies for acquiring new vocabulary items. He cites the effectiveness of keyword mediation techniques requiring semantic and imagery elaboration as evidence for intentional or explicit learning (Desrochers & Begg, 1987; Ellis & Beaton, 1993). Ellis also describes how readers can be trained to use metacognitive strategies in order to infer the meaning of a new word either by means of its context or by word analysis such as identifying its part of speech (e.g. verb or noun), or thinking of any *cognates* (words sharing the same root. e.g., "unicycle" and "bicycle") with which they are already familiar.

An example of the role of verbal instruction on the emergence of equivalence relations is given by Lowe and Beasty (1987). They gave a matching to sample training task to 29 young children (aged 2 – 5 years) in which the children learned the following four associations: (a) A1-B1, a vertical line matched to a red rather than a green comparison stimulus; (b) A2-B2, a horizontal line matched to a green rather than a red comparison stimulus; (c) A1-C1, the vertical line matched to a triangle rather than a cross; and (d) A2-C2, the horizontal line matched to a cross rather than a triangle. Tests of equivalence (i.e., B1-C1 and C2-B2) were then presented. During the training and the testing, recordings of the children's spontaneous verbal behaviour were made; this was so that notes could be taken of *how* they named the stimuli (e.g., "up" for the vertical line or "hat" for the triangle). Interestingly, only those participants who had named the sample–comparison pairs (e.g., "up green" or "up hat") during the training trials were successful in the equivalence tests. Some of these participants responded by naming all three members of a stimulus class (e.g., "up green up hat") in the presence of any two of the stimuli. Those children who failed the equivalence test were subsequently taught to name the stimulus-comparison pairs during the training phase (e.g., "up-green" in the presence of the vertical line and the green comparison). All but one of the children successfully learned these verbal pairings, and all of them proceeded to pass the equivalence test. The one child who failed the equivalence test after this intervention had also failed to say the associated names.

It appears that the emergent relations demonstrated in the stimulus equivalence paradigm are a product of verbal or rule governed behaviour; in cognitivist terminology, the transitive relations are a product of explicit processing and can be influenced by verbal instruction. In Chapter 3, we outlined the similarities between the emergent transitive relations in Experiment 3 and those emergent relations demonstrated in stimulus equivalence tasks. It is hypothesised that, if the transfer of associations between stimulus modalities is an explicit process, explicit knowledge of the contingencies will allow participants who have previously failed the association test task to select the correct responses in a subsequent test. To investigate this hypothesis, the test tasks were presented both before and after an explanation of the relationship between the training tasks and the test tasks.

Measuring Awareness

At the end of Experiment 3, participants were asked general questions about the way they had approached the experimental tasks. Although participants' self reports may be suggestive of their mental process, if we are to draw inferences about hypothetical inner events, it is necessary to devise an operational procedure that establishes a link between an inner event and an observable event (Paivio, 1991; also see Gardiner, 1996, p. 59). For the purposes of this experiment, it is not enough to discover that a participant expresses awareness *per se*. The crucial question is not "are they aware?", but "what are they aware *of*?" (Bentall & Dickens, 1994, p. 347; emphasis added).

To these ends, an improved protocol and questionnaire for interviewing the participants was introduced. Participants were questioned after each training task in order to determine what they had learned, and after each test task to establish whether (a) they recalled seeing the experimental stimuli before, and (b) whether they were aware that the stimuli in the test task could be associated according to the corresponding paired associations learned in the training task and mediated by the name relation. By interviewing participants after each task, it was hoped that we would obtain data that indicated which relationships participants were aware of and at what juncture participants developed awareness.

Experimental Aims

Experiment 4 is designed to extend the findings of Experiment 3 by determining whether the transfer of paired associate information between the verbal and the visual systems is a product of explicit processing. The naming awareness hypothesis proposes that awareness of the contingencies between the training tasks and the test task is necessary for the transfer of associative information between the visual and the verbal processing systems.

If we are to conclude that awareness is necessary for making the connection between the two trained associations and the emergent associations illustrated in Figure 4.1, the following question needs answering: is awareness more than good recall of the trained associations? Is there a difference in the ability to recall the trained associations between those who are aware of the connections and those who are unaware? To test for this, a recall task for both picture-word association learning and trained-pair association learning was introduced in Experiment 4. This task will also allow us to determine whether "aware" acts via the learning or the transfer of paired associations.

If the transfer of associations requires explicit processing defined as the ability to explain the transitive relations between the training tasks and the test tasks, the question arises whether an explicit explanation of these relations will improve participants' performance on the test tasks. To investigate this possibility, participants performed the test association task twice, once before and once after a verbal explanation had been presented.

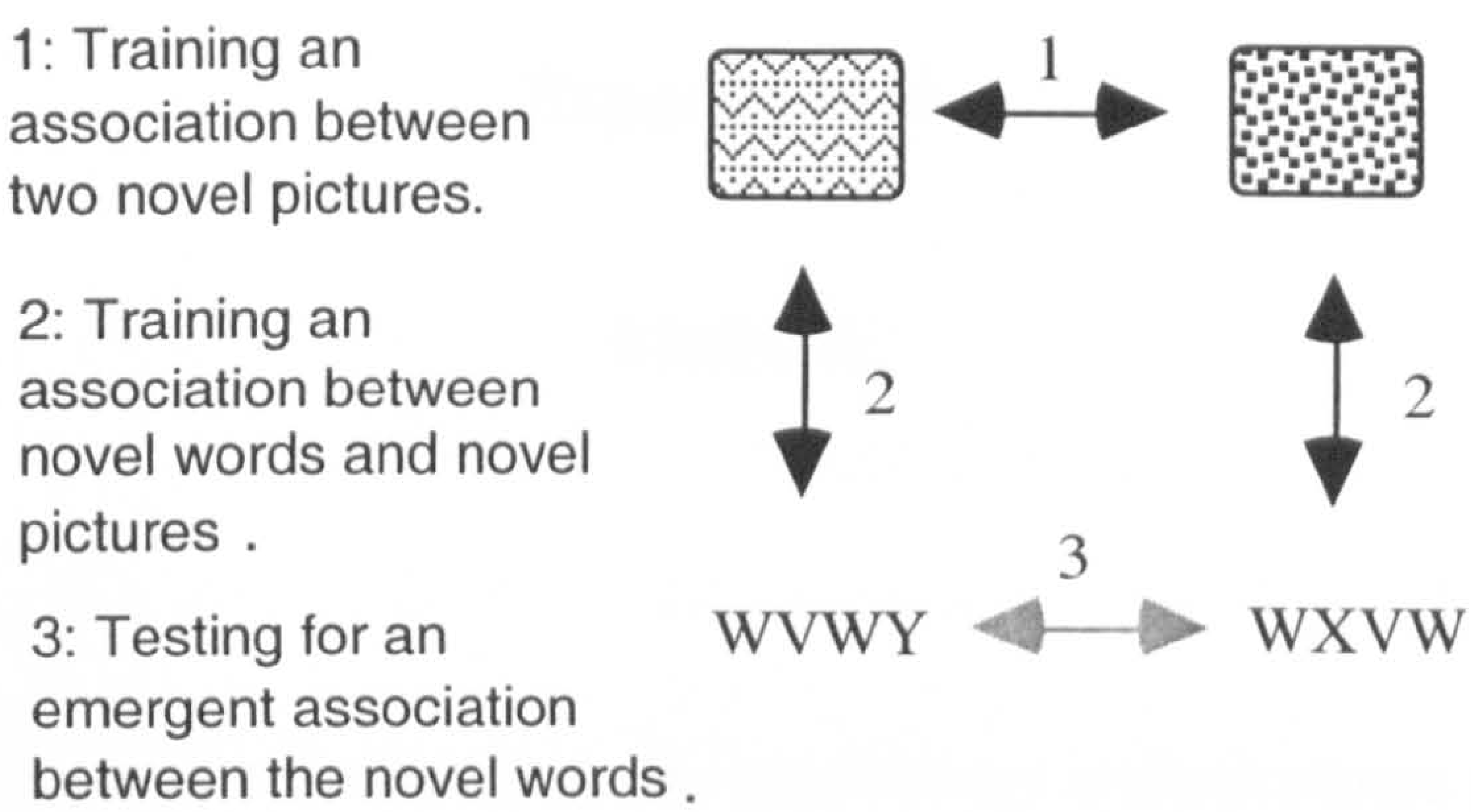


Figure 4.1: The transitive relations between the training tasks and the test task

In Experiment 3 the order of training had an effect on the transfer of association from words to pictures. There was some evidence suggesting that the order of the training phases had an effect on the numbers of people who were able to make the link between the training and the test trials. Learning the word association prior to the picture names corresponded with the least number of subjects being aware of the connection; learning the picture pairs before the names of the pictures were learned corresponded with the most subjects being aware of the connection. However, this result did not reach statistical significance, possibly due to insufficient statistical power. The present experiment increased the numbers of participants to examine this further.

A second aim of Experiment 4 is to determine whether the associations required to produce facilitation in a priming task are the product of explicit processing; it did this by examining the performance of participants, each rated as aware or unaware of the associations, both before and after they had been given an explicit explanation of the transitive relations between the associative training tasks and the association test task.

Experiment 4

Method

Participants

Eighty participants were recruited from the psychology undergraduate panel and from the community participant panel of the University of Wales, Bangor. Undergraduates received two course credits; members of the community panel were given £7.00 for their time. Participants were pseudorandomly assigned to one of four conditions according to the order in which they arrived. No attempts were made to balance either the number of men and women, or the participants' ages, in each condition. The age range of the participants was 16 - 64 years. None of the participants had participated in Experiments 1, 2, or 3.

Stimuli and Apparatus

Association tasks

Twelve novel word and twelve novel picture stimuli were taken from Experiment 3 (Chapter 3). They were designated for use in experimental and control stimulus sets for the associative training, vocabulary training, and association test tasks in the same manner as used in Experiment 3. The stimulus array in which materials were presented was also the same as that of Experiment 3 (see Figure 3.12).

Priming tasks

Four priming tasks were introduced in Experiment 4: two object decision tasks (ODT)s for the picture stimuli, and two lexical decision tasks (LDTs) for the word stimuli. For the ODTs, an additional 56 pictures of nonobjects were taken from Kroll and Potter (1984) (see Appendix 4.1.b). These were divided into two sets of 28, to be used as foils in the two ODTs. For the LDTs, two additional sets of 28 words were selected from the corpus of 7 letter nonwords that had been generated for Experiment 3 (see Appendix 4.1.a). All of the nonwords were of three syllables in a consonant vowel consonant pattern. They were used as foils in the two LDTs. The experimental and control stimuli from the association tasks were also used as stimuli in the priming tasks.

In the ODTs, participants were asked to decide whether they had seen a target picture in an earlier experimental task. In the LDTs, participants had to decide whether they had seen a novel word in an earlier task. The stimuli from the association tasks, together with the additional stimuli, were arranged as prime-target pairs for each priming task. The number of "yes" and "no" responses were balanced: there were 16 of each. A "yes" response was as likely to have been preceded by a familiar prime as by an unfamiliar prime.

Primes and targets for the decision tasks were chosen as follows (see Table 4.1): four prime-target pairs were generated by pairing each of the experimental stimuli (stimuli used in the trained association task) with its trained associate, each stimulus serving once as prime and once as target. Four pairs were generated by pairing each of the experimental stimuli with a stimulus from the other trained associate pair, again using each stimulus once as prime and once as target. Eight pairs were generated by pairing each experimental stimulus, once as a prime and once as a target, to previously unseen foils. Eight pairs were generated by pairing each of the four control stimuli (from the association test task) once with another control stimulus and once with a previously unseen foil. Eight prime-target pairs were designated from 16 of the remaining unseen foils. (See Appendix 4.1b).

Each of the decision tasks was preceded by five practice trials. The prime-target pairs for these practice trials were generated as follows. One of the experimental associate pairs was also used in a practice trial (a yes response). The other two experimental stimuli were paired with unseen foils, one as target (a yes response), and one as prime (a no response). One of the control stimuli was paired (as a target) with an unseen foil (a yes response). The remaining two unseen foils were used to generate the fifth pair (a no response).

All of the word stimuli were displayed in Chicago font, point 18, screen resolution 640 x 480 pixels. The picture stimuli were displayed as approximately 3 cm^2. All of the stimuli were displayed in the centre of the screen.

All experimental tasks were generated using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993) and run on a Power Macintosh 4400/160 with a 15" colour Apple monitor. Responses were made on the keyboard in the association training tasks and association test tasks. A Psyscope button box was used for recording keystrokes and latency of the responses in the priming tasks.

Table 4.1: The prime-target stimulus pairings and correct responses for each prime task.

Prime Stimulus	Target Stimulus	n	Yes / No
Experimental	Experimental (*trained associate*)	4	Y
Experimental	Experimental (*not trained associate*)	4	Y
Foil (*previously unseen*)	Experimental	4	Y
Experimental	Foil (*previously unseen*)	4	N
Control	Control	4	Y
Control	Foil (*previously unseen*)	4	N
Foil (*previously unseen*)	Foil (*previously unseen*)	8	N

Awareness debriefing

A semi-structured interview sheet was printed for every participant. After each training task, the participants were asked if they thought they had learned the associations and what, if any, mnemonic strategies they had employed. After each association test task, participants were asked to explain their rationale for the pairs they had selected. They were also asked if they had noticed the presence of the control stimuli and whether they had treated the control and experimental stimuli in the same way. The experimenter recorded their responses on the interview sheet. A copy of an interview sheet is given in Appendix 4.2. The participant's responses are given in Appendix 2.24.

For each condition, a diagram was prepared to illustrate the relationship between the stimuli in the training tasks and the test tasks. They were designed to show the abstract relationships, not to refresh participants' memories of the stimulus pairs they had studied. Each diagram was printed on A4 paper and laminated. The diagram for Condition 1 is shown in Figure 4.2.

Recall tests

Recall tests were generated using the same stimuli employed in the training association and vocabulary training tasks. These tests were presented by computer programs identical to those used in the training tasks, except that no feedback was given to subjects about the correctness of their responses.

Explanation of the rationale for the correct choice pairmates in condition 1

1st : In the first of the training trials, you learned an association between some novel words and pictures - the names of some new objects.

2nd In the second training trials, you learned an association between the pictures.

3rd You then did a word pairing task without feedback. The connection between the correct pairs can be seen via the associations in the previous training trials.

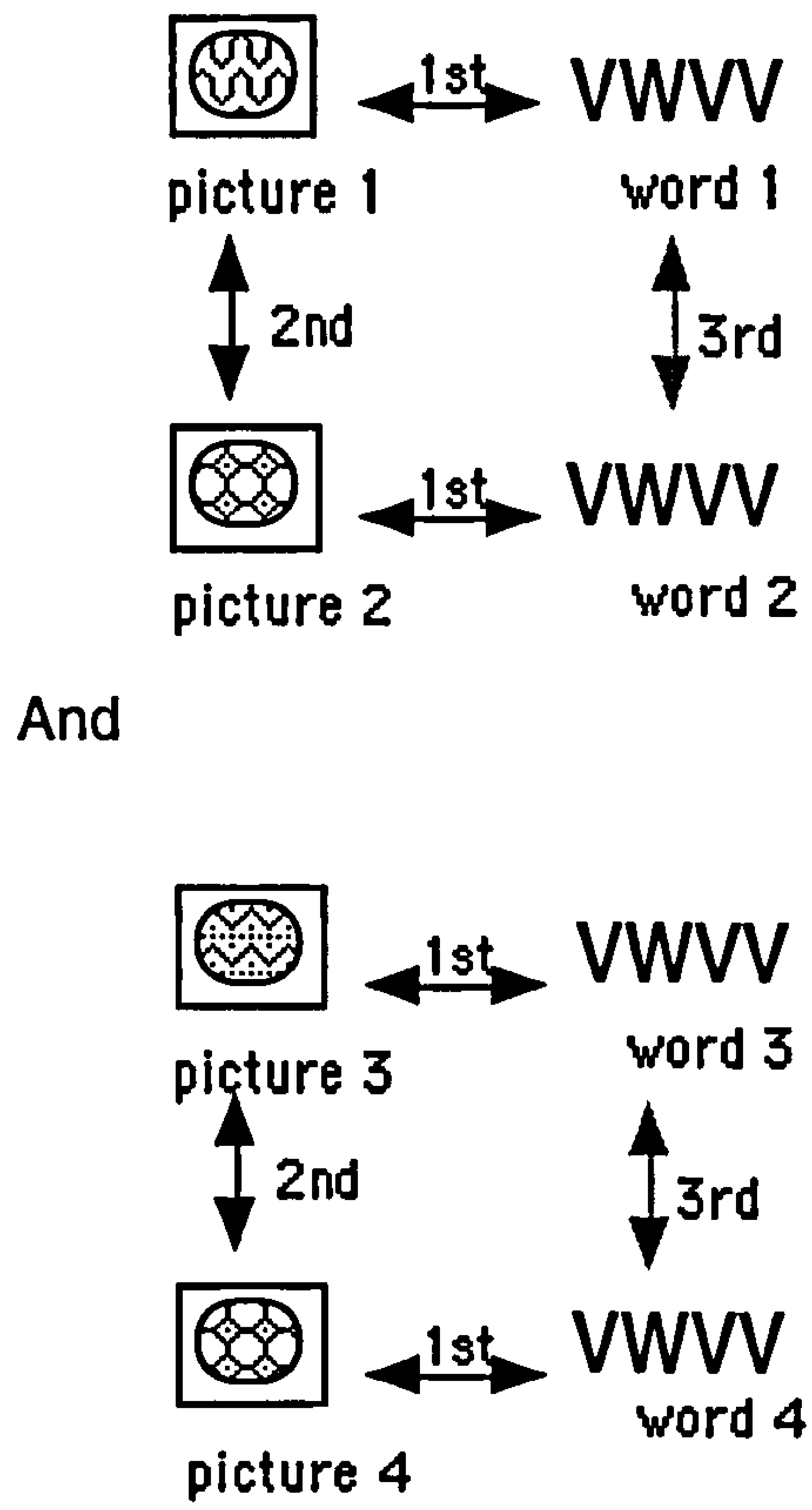


Figure 4.2: The awareness debriefing sheet for Condition 1, Experiment 4.

Design

A mixed design was employed in this experiment. The sequence of training tasks was manipulated between the four between subject conditions. In each condition, participants performed two association training tasks, then an association task followed by a priming task. After the priming task, participants were given an explanation of the transitive relations between the training tasks and the test task. The test association task was repeated, followed by the second priming task. Finally, participants were tested on their ability to recall the trained associates and the name relations that they had learned at the start of the experiment. There were no control conditions since the stimuli and training tasks employed in this experiment were identical to those employed in Experiment 3 (Chapter 3). That experiment established that the stimuli within a stimulus set were functionally equivalent, that the stimulus sets (pictures and words) were equally easily learned, and that subjects' improved performance on the trained materials, as opposed to controls, in the test tasks was not attributable to similarities with real world objects or words.

The association training, vocabulary training (in which participants learned picture-word relations), and associative test tasks were the same as those used in Experiment 3. The tasks were run in the same sequences employed in the experimental conditions of Experiment 3 (excluding the filler tasks). Depending on the experimental condition in which they were placed, participants learned either novel picture associations or novel word associations. The paired association training task was presented either before or after the vocabulary training task. In each training task, participants were trained to a criterion of correctness of 16 consecutive correct trials. A trial qualified as correct only if the correct response had been made before feedback was displayed. The training tasks were followed by an association test task in the modality opposite to that of training. In the word association conditions, training tasks were followed by a novel picture association test and the first ODT. In the picture association conditions, training tasks were followed by a novel word association test task and the first LDT. After participants completed the first priming task, the experimenter showed them a diagram explaining the contingencies between the training tasks and the association test task. The test association task was then repeated, followed by the second priming task. Finally, participants were tested on their ability to recall the associations they had learned in the paired association training tasks. The sequence of tasks in the different conditions is shown in Table 4.2.

As in Experiment 3 (Chapter 3), Conditions 1 and 2 commenced with the vocabulary training task. In Condition 1, the vocabulary task was followed by the picture association training task, and in Condition 2 by the word association training task. In Conditions 3 and 4 the vocabulary task was presented after the novel paired associations had been learned. Condition 3 commenced with the picture association training task and Condition 4 with the word association training task. Comparisons were planned between stimulus type (picture or word) and order of association training (whether the name relation was learned before or after the paired associations). Participants in Conditions 1 and 3 performed the word association test task followed by the first LDT. Participants in Conditions 2 and 4 were given the picture association test task followed by the first ODT. The test associations had no time limit; the purpose of the task was to establish whether any transitive associations across stimulus modalities had emerged. The priming task was included to determine whether the new associations behaved similarly to real words and objects in semantic priming tasks.

After the decision task, the experimenter explained the relationship between the training tasks and the test task. This was designed to determine whether explicit knowledge of the rationale would change the performance of participants who had previously been unaware of the transitive relations. The test association tasks were repeated, then the second priming task was given. The last two tasks were cued recall tests of the paired associations and picture–word associations learned at the start of the experiment. The final tasks were included so that it could be determined whether poor performance on the test tasks could be accounted for by poor recall of the trained associations.

Table 4.2: The sequence of tasks within each condition

Tasks	Condition 1	Condition 2	Condition 3	Condition 4
1 Training Task	Vocabulary Training		Association Training	
			Picture	Word
2 Training Task	Association Training		Vocabulary Training	
	Picture	Word		
3 Test Task	Association Test 1			
	Word	Picture	Word	Picture
4 Decision Task 1	Decision Task 1			
	Lexical	Object	Lexical	Object
5 Debrief	Explanation of the relation between the training tasks and the test association task			
6 Test Task 2	Association Test 2			
	Word	Picture	Word	Picture
7 Decision Task 2	Decision Task 2			
	Lexical	Object	Lexical	Object
8 Recall Task	Test Recall of Trained Associations			
	Picture	Word	Picture	Word
9 Recall Task	Recall Test for Trained Vocabulary			

The dependent variables in the test association task were the numbers of correct responses recorded for the experimental versus control stimuli. The dependent variable in the decision tasks was latency of response from onset of target stimulus; the within subjects variable was the relationship between the prime and the target in each trial. The between subjects variable in both tasks was the order of training tasks in each condition. This order is illustrated in Table 4.2.

Procedure

Association tasks

The procedure used for the novel paired association training task, vocabulary training task, and association test tasks was the same as that employed in Experiment 3 except that participants were asked whether they felt they had learned the associations, and to describe any strategies they had used. After each task was completed, the relevant questions were read from the awareness debriefing sheet, and participants' replies were recorded on the sheet.

Decision tasks

Two LDTs were presented to participants in Conditions 1 and 3. Two ODTs were presented to participants in Conditions 2 and 4. The procedure for all four tasks was the same, except that different stimulus lists were used in each task. The sequence in which the stimuli from each list were presented was random and different for all subjects. In the decision tasks, participants were asked to decide whether they had seen the target word (or picture) earlier in the experiment. The task started with the following instructions displayed on the screen:

> In this part of the experiment you will see a series of "new" words [pictures *], some of which have appeared in earlier tests and others that are brand new. Your task is to say whether you have seen them before.

Each trial starts with a beep sound and a fixation mark in the middle of the screen. This is followed by a word [picture*] that is displayed very briefly before the target word [picture*] is shown. You need to make a decision about the TARGET [picture*].

If you HAVE seen the target word [picture*] before, press the GREEN key on the response box. If you HAVE NOT seen the target word [picture*], before press the RED key. Please respond as fast and as accurately as you can.

There are 5 practice trials and 32 test trials.

When you are ready to begin, tell the experimenter to start the practice trials.

[Note: * In the LDTs, "word" appeared here; "picture" appeared in the ODTs.]

The experimenter ensured that participants had understood the instructions and watched them performing the practice trials before initiating the experimental trials. Each trial commenced with a "beep" sound (the Macintosh correct beep) and the display of a fixation mark (an asterisk) in the centre of the screen for 250 ms. The fixation mark was then replaced by the prime stimulus that remained on view for 250 ms. After an ISI of 750 ms, the target appeared on the screen and remained until the trial was terminated by the participant pressing one of the response keys. The red and the green buttons on the Psyscope Button Box were used to record the "yes"/ "no" responses. The latency of response from the onset of the target stimulus was recorded using the Button Box timer. There was an interval of 2000 ms between the completion of one trial and the onset of the next.

Awareness debriefing

Participants were asked to study the explanation of the rationale for the correct test association task choices in their experimental condition (see Figure 4.1). The experimenter read through the explanation and pointed out the relationships using the diagram. Actual experimental stimuli were neither discussed nor displayed during this phase of the experiment.

Recall of trained associations

These tasks were included to test participants' ability to recall the associations they had learned in the paired association training and vocabulary training tasks. All the tests were presented using the same stimulus array used in the training task. The only procedural differences between the training tasks and the test tasks were the removal of feedback (correct responses were not highlighted) and the limited number of trials: there were 8 for the trained association recall test and 16 for the vocabulary recall test.

Trained association recall test

The word association test task was given to participants in Conditions 2 and 4, the picture association test to participants in Conditions 1 and 3. The association tests started with the following instructions displayed on the monitor:

> In this part of the experiment, you are asked to select the word [picture*] pairs that you learned at the beginning of this experiment. As in the earlier task a word [picture*] will appear in the centre of the array and remain there until you press the space bar. It will then be replaced by four words [pictures*] in the outside squares.
>
> Your task is to press the key that corresponds to the word pair that you learned earlier. These are the same keys that you used in the previous phases of the experiment. On this task there is no feedback.

If you have any questions, ask the experimenter now. Otherwise press the space bar.

Note: * "word" was shown in the word association recall task; "picture" was shown in the picture association recall task.]

Each experimental stimulus was presented as the probe stimulus twice. The order of presentation was random. Participants' responses were recorded by computer.

Vocabulary recall test

This test task was presented to participants from all conditions. Presentation started with the following instructions displayed on the monitor:

> In this part of the experiment, you have to select the picture word pairs that you learned at the beginning of the experiment. The words and pictures are presented in the same way as in the earlier task and the response keys are the same. On this task there is no feedback.
>
> If you have any questions ask the experimenter now. Otherwise press the space bar to begin.

Each picture stimulus and each word stimulus appeared twice as the probe stimulus. The order of presentation was random. The response keys selected were recorded by computer.

Results

In all of the following analyses the alpha level is $p < .05$.

Analysis of Test Association Task 1

The dependent variable in all of the test association tasks was the number of correct responses returned for the each stimulus set (experimental or control). There were 16 experimental trials and 16 control trials.

Stimulus set (experimental vs. control) by condition.

The mean number of correct responses produced by participants in each condition for each stimulus set (experimental versus control) is shown in Table 4.3.

A mixed ANOVA was performed on these data. The within subjects variable was stimulus set (experimental vs. control); the between subjects variable was condition (the sequence of the training tasks).The main effect of stimulus set was highly significant ($F = 39.1$; $df = 1, 73$; $p <. 0001$). There were more correct responses for the experimental stimuli than for the control stimuli. There was no main effect of condition, nor was there an interaction between stimulus set and condition (see Appendix 4.3.a).

Table 4.3: The mean number of correct responses (+ SD) for each stimulus set (experimental and control) in each condition of Experiment 4.

Condition	*n*	Control	Experimental
Condition 1 *vocabulary training, picture association training, word association test 1*	19	2.9 (4.9)	6.4 (6.1)
Condition 2 *vocabulary training, word association training, picture association test 1*	19	1.9 (2.5)	7.3* (6.2)
Condition 3 *picture association training, vocabulary training, word association test 1*	19	2.5 (4.2)	10.8* (6.1)
Condition *4* *word association training, vocabulary training, picture association test 1*	20	2.5 (4.5)	5.7 (6.9)

Note: * denotes a significant difference between control and experimental stimuli shown by simple main effects.

The effect of stimulus set in each condition was examined using simple main effects. The ANOVA tables for these analyses are given in Appendices 4.3.b – e. There was no effect of stimulus set for Condition 1. The effect of stimulus set was significant for Condition 2 ($F = 14.62$; $df = 1, 18$; $p = .0012$) and Condition 3 ($F = 25.67$; $df = 1, 18$; $p < .0001$). There was no effect of stimulus set in Condition 4.

Awareness of the contingencies between the training and test tasks

After the first test association task, participants were asked to explain their rationale for the pairs they selected. Their responses were categorised by three independent raters as "aware of the transitive relations between the training and test tasks" (*Aware 1*), or as "unaware of the transitive relations between the training and test tasks" (*Unaware 1*) (Cronbach's Alpha for the inter-rater reliability = 0.79). The number of participants who were categorised as Aware 1 and Unaware 1 in each condition is shown in Table 4.4. A χ^2 test of independence was performed on the number of people in each condition who were categorised as Aware 1 or Unaware 1. The difference was significant ($\chi^2 = 7.96$; $df = 3,1$; $p = .047$). The tables for the expected frequencies and summary table are presented in Appendix 4.4.

The effect of "awareness of the transitive relations" on stimulus set and condition was examined using a mixed ANOVA. The between subject variables were awareness and condition, and the within subject variable was stimulus set. The dependent variable was the number of correct responses for the control and the experimental stimuli. There was a significant main effect of awareness ($F = 51.23$; $df = 1, 69$; $p < .0001$) and a significant main effect of stimulus set ($F = 61.77$; $df = 1, 69$; $p < .0001$). The interaction between awareness and stimulus set was significant ($F = 33.83$; $df = 1, 69$; $p < .0001$), but there was no interaction between awareness and condition. (See Appendix 4.5).

Table 4.4: The number of participants in each condition categorised as Aware 1 or Unaware 1 of the transitive relations between the training and the test tasks.

Condition	Aware	Unaware
Condition 1 *vocabulary training,* *picture association training,* *word association test 1*	8	11
Condition 2 *vocabulary training,* *word association training,* *picture association test 1*	7	12
Condition 3 *picture association training,* *vocabulary training,* *word association test 1*	13	6
Condition 4 *word association training,* *vocabulary training,* *picture association test 1*	5	15

An analysis of simple main effects revealed a significant difference between the control and experimental stimulus sets for Aware1 particpants ($F = 78.27$; $df = 1, 29$; $p < .0001$). There was no significant difference between the control and experimental stimulus sets for Unaware 1 participants. The mean scores for the experimental and control stimuli was 13.2 ($SD = 3.6$) and 3.1 ($SD = 4.7$) respectively for participants categorised as Aware 1 and Unaware 1 the mean scores were 3.3 ($SD = 4.9$) for the experimental stimuli and 2 ($SD = 3.6$) for the control stimuli. The mean scores for Aware 1 and Unaware 1 in each condition are shown in Figure 4.3. The ANOVA tables are given in Appendix 4.5.

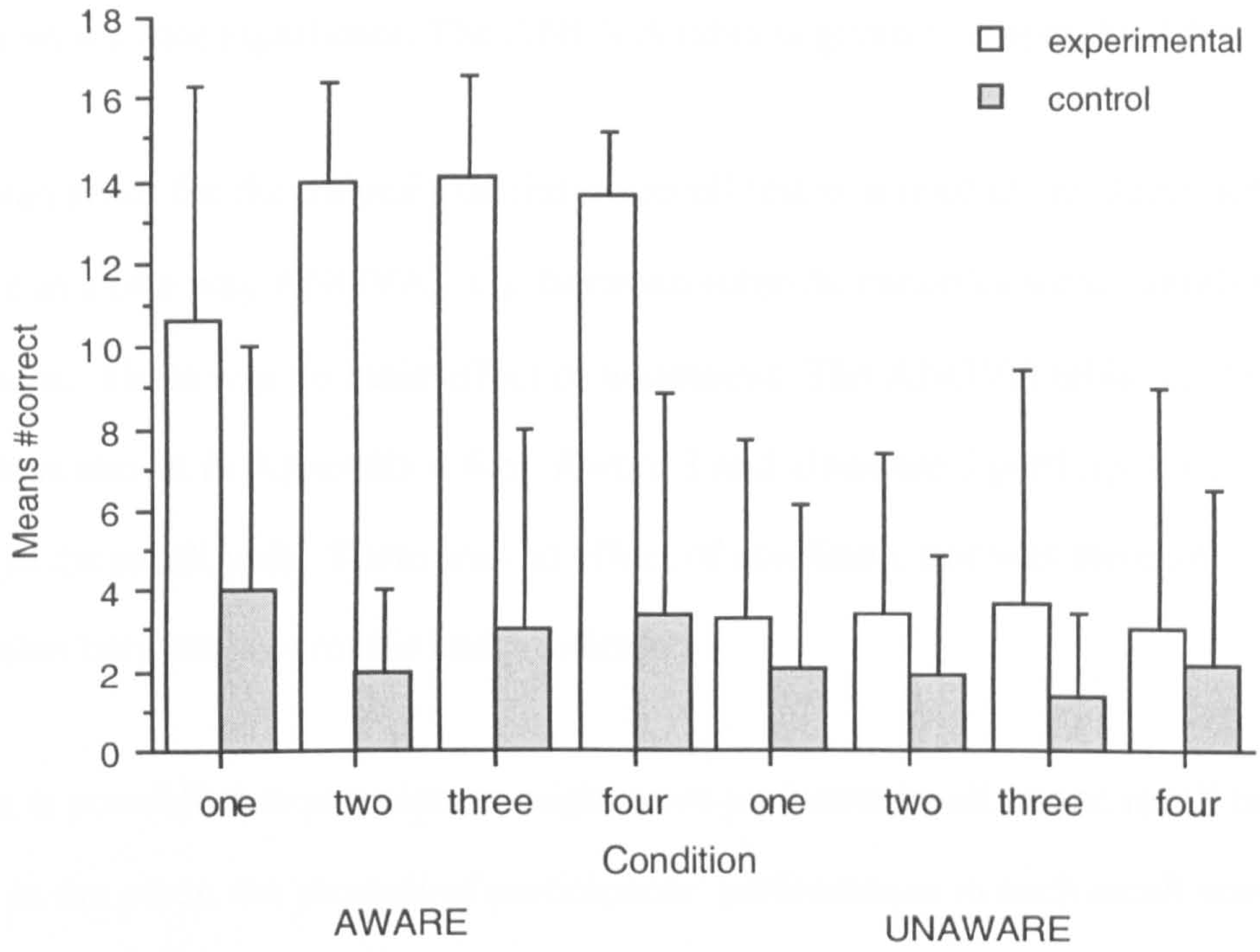


Figure 4.3: Mean number of correct responses (+ SD) in Association test Task 1 for the effects of awareness of the transitive relations, stimulus set (experimental or control) and condition (sequence of training tasks). The maximum score was 16.

Awareness or Poor Recall?

The recall scores for each participant in the vocabulary recall test and the trained association recall test were calculated. The mean scores for each task and each condition are shown in Table 4.5. The maximum score in the vocabulary recall test was 16 and in the trained association recall test the maximum score was 8.

A two way ANOVA was carried out on the number of correct responses in the vocabulary recall test. The between subjects variables were "awareness of the transitive relations between the training tasks" (after the first test task) and condition.

There was no significant difference in the mean recall scores of Aware 1 and Unaware 1 participants. Nor was there an effect of condition. The interaction of condition and awareness was not significant. The ANOVA table is given in Appendix 4.6.a.

The mean score for the trained association recall test was used as the dependent variable in a two way ANOVA. The between subjects variables were condition and awareness. There was no main effect of awareness. The ANOVA table for this analysis is shown in Appendix 4.6.b. Aware 1 and Unaware 1 participants had similar scores in the recall task. There was no effect of condition, nor was there an interaction between awareness and condition.

Since it is possible that participants might have performed well in one recall test and poorly in the other, the product of participants' performance in each recall test was calculated (vocabulary recall score x trained association recall score). This was used as the dependent variable in an ANOVA in which awareness and condition were the between subjects variables. There was no main effect of awareness or condition. There was no interaction between awareness and condition. The ANOVA table and means for this analysis are shown in Appendix 4.6.c.

Table 4.5: The mean number of correct responses (+ SD) for Aware 1 and Unaware 1 in each condition for the vocabulary recall test and the trained association recall test. The maximum score on the vocabulary test was 16 and for the trained association recall test was 8.

	Recall of Trained Associates		Recall of Vocabulary	
Condition	Aware	Unaware	Aware	Unaware
Condition 1: *vocabulary training,* *picture association training,* *word association test 1*	5.9 (3.1)	6.8 (2.3)	12.9 (5.5)	14.2 (4.7)
Condition 2: *vocabulary training,* *word association training,* *picture association test 1*	7 (1.9)	7.25 (2)	14.4 (1.3)	11.5 (5.6)
Condition 3: *picture association training,* *vocabulary training,* *word association test 1*	7.5 (0.9)	6.2 (2.6)	14.7 (4.1)	13.2 (4.4)
Condition: 4 *word association training,* *vocabulary training,* *picture association test 1*	7.8 (0.5)	6.3 (2.8)	15.4 (.9)	13.7 (4.7)

Analysis of Test Association Task 2

Participants performed the second association test task after they had been presented with a rationale for selecting the correct response. The number of correct responses for each participant was calculated.

Stimulus set (experimental vs. control) by condition

The mean number of responses for the experimental and control stimulus sets in each condition is shown in Table 4.6.

The number of correct responses for each stimulus set was the dependent variable in a mixed ANOVA. The within subjects variable was stimulus set and the between subjects variable was condition. There was a significant main effect of stimulus set ($F = 79.67$; $df = 1, 73$; $p < .0001$). There was no main effect of condition, nor was there an interaction between condition and stimulus set. (See Appendix 4.7).

Simple main effects showed there was a significant difference between the number of responses to the control and to the experimental stimuli in all conditions; thus Condition 1 ($F = 12.77$; $df = 1, 18$; $p = .0022$), Condition 2 ($F = 30.38$; $df = 1, 18$; $p < .0001$), Condition 3 ($F = 32.83$; $df = 1, 18$; $p < .0001$) and Condition 4 ($F = 13.11$; $df = 1, 19$; $p = .0018$). The ANOVA tables for these analyses are given in Appendices 4.7b and 4.7e.

Table 4.6: The mean number of correct responses (+ SD) to each stimulus set in each condition for Association Test 2.

Condition	*n*	Control	Experimental
Condition 1: *vocabulary training,* *picture association training,* *word association test 1*	19	2.7 (4.6)	9.3* (6.8)
Condition 2: *vocabulary training,* *word association training,* *picture association test 1*	19	2.2 (3.0)	10.6* (6.0)
Condition 3: *picture association training,* *vocabulary training,* *word association test 1*	19	2.6 (4.2)	11.5* (6.5)
Condition 4: *word association training,* *vocabulary training,* *picture association test 1*	20	2.1 (4.6)	9.1* (7.2)

Note: *significant difference between control and experimental stimuli demonstrated by simple main effects.

Awareness after Test Task 2

Participants were asked whether they had been able to relate the paired associations they had learned in the paired association training and vocabulary training task with the responses required for the second association test. Their responses were categorised "aware of the transitive relations between the training and test tasks"(Aware 2), or as "unaware of the transitive relations between the training and test tasks"(Unaware 2). The second set of responses was categorised by the three postgraduates, who had rated participants' responses after the first association test. As before, they had no knowledge of participants' performance in the test tasks. A reliability analysis for the three ratings of the 77 participants produced a Cronbach's alpha value of 0.76. In cases where there were differences between the ratings, the majority decision was followed. The number of participants rated as aware after association Test Task 2 is shown in Table 4.7.

Table 4.7: The number of participants in each condition rated as aware and unaware of the transitive relations between the training tasks and association test task 2.

Condition	Aware	Unaware
Condition 1: *vocabulary training,* *picture association training,* *word association test 1*	11	8
Condition 2: *vocabulary training,* *word association training,* *picture association test 1*	12	7
Condition 3: *picture association training,* *vocabulary training,* *word association test 1*	16	3
Condition 4: *word association training,* *vocabulary training picture* *association test*	11	9

Analysis of the number of participants rated as Aware 2 and Unaware 2

A χ^2 test of independence was performed on the number of people in each condition who were categorised as aware or unaware of the transitive relations between the training during Test Task 2. The difference was not significant. The tables for the expected frequencies and summary table are presented in Appendix 4.8.

The effect of Awareness 2 on Test Task 2

An analysis of awareness in Test Task 2 was carried out using a mixed ANOVA. Awareness 2 and condition were treated as between subject variables and stimulus set (experimental or control) as within subject variables. The number of correct responses was the dependent variable. The mean number of correct responses for experimental and control stimuli by participants rated as aware were 12.16 (SD = 5.78) and 2.08 (SD = 3.74) respectively. The means for each stimulus set for Aware 2 and Unaware 2 in each condition are illustrated in Figure 4.4.

For participants rated as unaware, the mean number of correct responses for the experimental and control stimuli were 6.26 (SD = 6.39) and 3.04 (SD = 4.59) respectively. There was a significant main effect of Awareness 2 ($F = 8.53$; $df = 1, 69$; $p = .0047$); aware participants produced more correct responses than unaware participants. There was a significant main effect of stimulus set ($F = 52.79$; $df = 1, 69$; $p < .0001$); a greater number of correct responses were made to experimental stimuli than to control stimuli.

There was a significant interaction between awareness 2 and stimulus set ($F = 16.58$ $df = 1, 69$; $p < .0001$). There was no main effect of condition, nor was there an interaction between condition and Awareness 2 nor an interaction between condition and stimulus set ($p > .05$). The ANOVA table for this analysis is shown in Appendix 4.9.

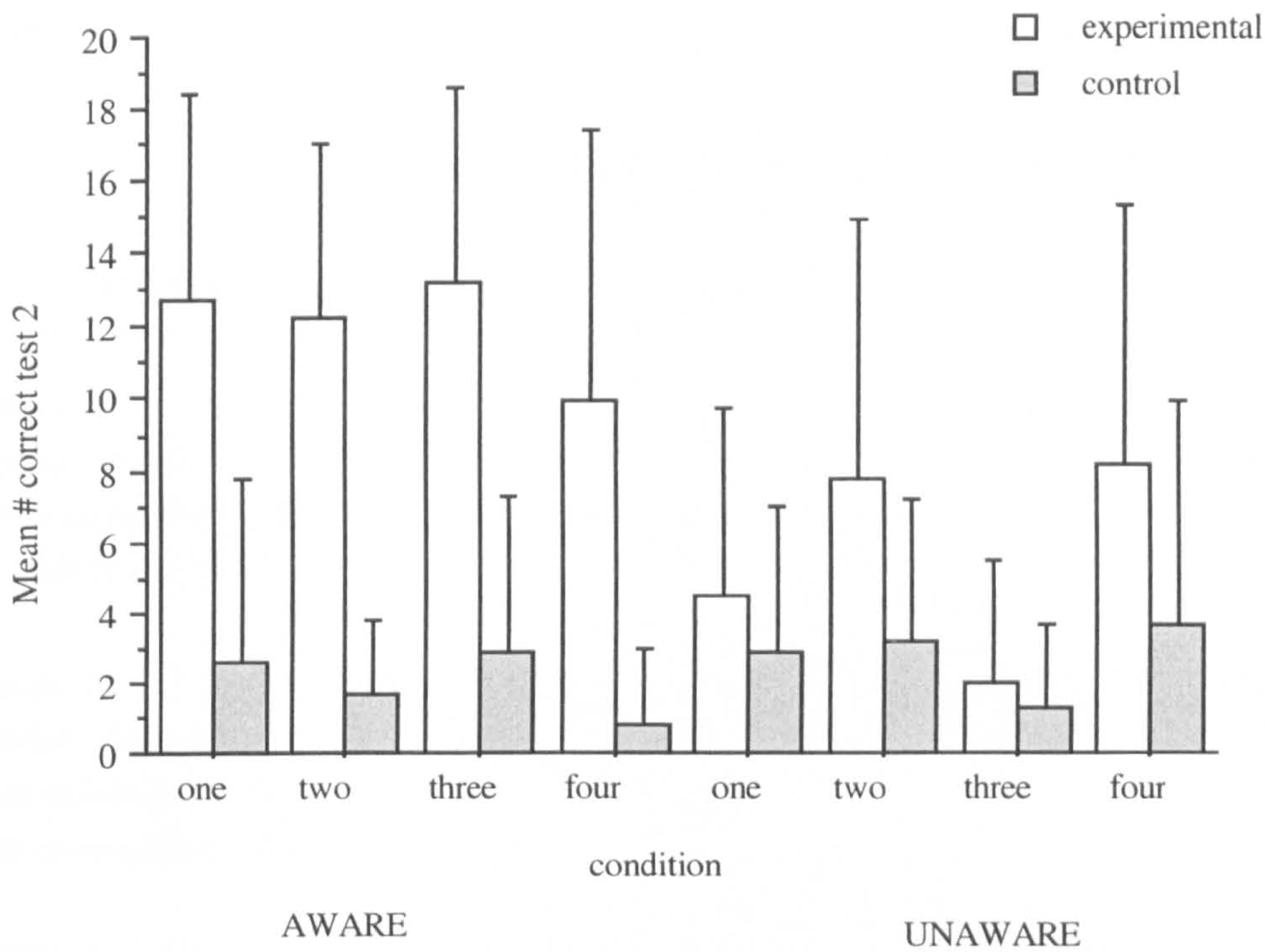


Figure 4.4: Mean number of correct responses (+ SD) for the effects of stimulus set (experimental or control) sequence of training tasks (condition) and awareness of the transitive relations after Association Test Task 2.

Is "Awareness After Test Task 2" Due To Good Recall?

A comparison was made between the recall test scores of participants who were rated unaware and participants who were rated aware. The mean scores for the vocabulary recall test and the trained association recall test are shown in Table 4.8.

Table 4.8: Mean number of correct responses (+ SD) for aware and unaware after Test Task 2, in each condition for the vocabulary recall test and the trained association recall test. The maximum score on the vocabulary test was 16; for the trained association recall test, the maximum score was 8.

	Recall of Trained Associates		Recall of Vocabulary	
Condition	Aware	Unaware	Aware	Unaware
Condition 1: *vocabulary training,* *picture association training,* *word association test 1*	6.3 (6.6)	6.6 (7.3)	13.6 (4.8)	13.6 (5.5)
Condition 2: *vocabulary training,* *word association training,* *picture association test 1*	7.3 (1.5)	6.9 (2.6)	12.6 (4.3)	12.6 (5.7)
Condition 3: *picture association training,* *vocabulary training,* *word association test 1*	7.3 (1.2)	5.7 (3.2)	14.4 (4.1)	13.0 (5.2)
Condition 4: *word association training,* *vocabulary training,* *picture association test 1*	7.4 (1.8)	5.8 (3.1)	13.0 (5.4)	15.6 (0.5)

Awareness after Association Test 2 and vocabulary recall

The number of correct responses in the vocabulary recall test was the dependent variable in a two way ANOVA. The between subjects variables were awareness and condition. There was no main effect of awareness after Association Test Task 2 (Awareness 2), nor of condition. There was no interaction between Awareness 2 and condition. (See Appendix 4.10.a.)

Awareness 2 and trained association recall

The number of correct responses in the trained association test task was analysed. A two way ANOVA was performed using the number of correct responses as the dependent variable; condition and Awareness 2 were treated as between subject variables. There was no main effect of awareness, nor of condition. There was no interaction between awareness and condition on the number of correct responses in the trained association recall task (see Appendix 4.10.b).

Awareness after test association task and the product of vocabulary and trained association recall

As recall of both training tasks was necessary if correct responses were selected, the product of each participant's performance for vocabulary recall and trained association recall was calculated. This was used as the dependent variable in a two way ANOVA. Condition and Awareness 2 were the between subjects variables. There was no main effect of condition, nor of Awareness 2. There was no interaction between condition and Awareness 2 (see Appendix 4.10.c).

Analysis of Decision Tasks

The dependant variable in both of the LDTs and both of the ODTs was the latency of response from onset of the target stimulus. The relationship between the prime and the target was manipulated as a within subjects variable. The comparisons of interest were the reaction times to the experimental stimuli when primed by their trained associates (associated) compared with when they had been primed by an experimental stimulus from the other trained associate pair (categorical), or when the prime was a previously unseen foil (unrelated). Participants in Conditions 1 and 3 performed the ODTs; and participants in Conditions 2 and 4 performed the LDTs. Mean reaction times for each participant were calculated. Only correct responses were included in the analysis. Trials that exceeded 2000 ms or were less than 200 ms were excluded, as were trials that fell outside three standard deviations of each subject's mean response time.

Decision Task 1.

The data were sorted according to the protocol described above. Incorrect responses occurred in 2.8 % of trials in which an experimental stimulus was the target. A total of 3.68% of the experimental stimulus trials were excluded. The mean response times and mean number correct for each prime type in each condition are shown in Table 4.9.

The number of correct responses was analysed. A mixed ANOVA was performed, in which condition was the between subjects variable, and prime type (associated, categorical, or unrelated) was the within subjects variable. There was no main effect of condition nor prime type. There was no interaction between prime type and condition. The ANOVA table is shown in Appendix 4.11. No further analysis of error scores was undertaken.

Table 4.9: Mean response times (+ SD) and mean number correct for each target type in each condition of the first decision task. The maximum score for each prime-target type was 4

	Prime-Target Relations					
	Mean RT			Mean No. Correct Responses		
Condition	Associated	Categorical	Unrelated	Associated	Categorical	Unrelated
One	594.4 (151.2)	586.3 (134.6)	595.7 (161.2)	3.95 (0.2)	3.84 (0.7)	4.0 (0.0)
Two	627.9 (138.4)	607.4 (113.1)	654.2 (182.5)	3.79 (0.4)	3.8 (0.4)	3.68 (0.7)
Three	560.4 (121.4)	606.1 (116.5)	568.9 (120.8)	3.84 (0.4)	3.9 (0.3)	3.74 (0.6)
Four	589.1 (131.4)	589.1 (98.7)	585.9 (120.1)	3.85 (0.4)	3.9 (0.3)	3.90 (0.5)

Note : Conditions 2 and 4 performed the Object Decision Task and Conditions 1 and 3 performed the Lexical Decision Task

Analysis of effect of "Awareness 1" in Decision Task 1.

To determine the effect on the decision task of "awareness of the transitive relations between the training tasks and Test Task 1" (Awareness 1), a mixed ANOVA was carried out. The between subjects variable was Awareness 1; the within subject condition was prime type. The dependent variable was response time. There was no main effect of awareness nor of condition, but there was a significant interaction between awareness and condition ($F = 6.45$; $df = 1, 75$; $p = .002$) (see Appendix 4.13.a). Participants who were aware were faster responding to the target following the associated prime than were unaware participants. The interaction can be seen in Figure 4.5. Simple main effects analysis showed that there was a main effect of prime type for aware participants ($F = 5.49$; $df = 2, 64$; $p = .006$) (Appendix 4.13.b) but not for unaware (Appendix 4.13.d). Planned means contrasts for aware participants showed that the difference between the associated prime and the unrelated prime was significant ($F = 7.33$, $df = 1, 64$; $p = .009$), as was the difference between the associated prime and the categorical prime ($F = 9.04$; $df = 1, 64$; $p = .004$); the difference between the categorical prime and the unrelated prime was not significant (see Appendix 4.13.d). There was no effect of prime type for participants who were unaware (see Appendix 4.13.e). A priming effect was demonstrated only for participants who were aware when the prime and the target were associated pairs.

Interaction of awareness and prime type with condition

A mixed ANOVA was performed to determine whether the effect of awareness interacted with condition in the first decision task. The dependent variable was response time; the between subjects variable was condition and the within subjects variable was prime type (associated, categorical, and unrelated). The ANOVA showed a significant interaction between awareness and prime type ($F = 5.89$; $df = 2{,}138$; $p = .004$), but there was no main effect of condition, nor was there an interaction between condition and prime-type (see Appendix 4.14.a). The pattern of results is illustrated in Figure 4.5.

Analysis of simple main effects showed that there was no significant effect of awareness, nor prime type, nor an interaction between prime type and awareness for Conditions 1 and 2 (see Appendices 4.14.b-c). In Conditions 3 and 4 there was no main effect of awareness, nor a main effect of condition, but the interaction between awareness and prime type was significant (condition 3: $F = 3.8$; $df = 2, 34$; $p = .03$; condition 4: $F = 3.46$; $df = 3, 36$; $p = .04$) (see Appendices 4.14.d-e). Planned means comparisons between prime types in Condition 3 for aware participants showed a significant difference in responses to the experimental stimuli when they were preceded by an associated prime compared with a categorical prime ($F = 15$; $df = 1, 36$; $p = .0007$). The differences between the associated and the unrelated primes, and the categorical and the unrelated prime, were not significant. The same pattern was observed for aware participants in Condition 4: planned means comparisons between prime types showed a significant difference between targets when preceded by the associated prime compared with the categorical prime ($F = 6.18$; $df = 1, 36$; $p = .038$). The differences between the associated and the unrelated and between the categorical and the unrelated were not significant. The interactions are illustrated in Figure 4.6. (The ANOVA tables are shown in Appendices 4.14.h-i).

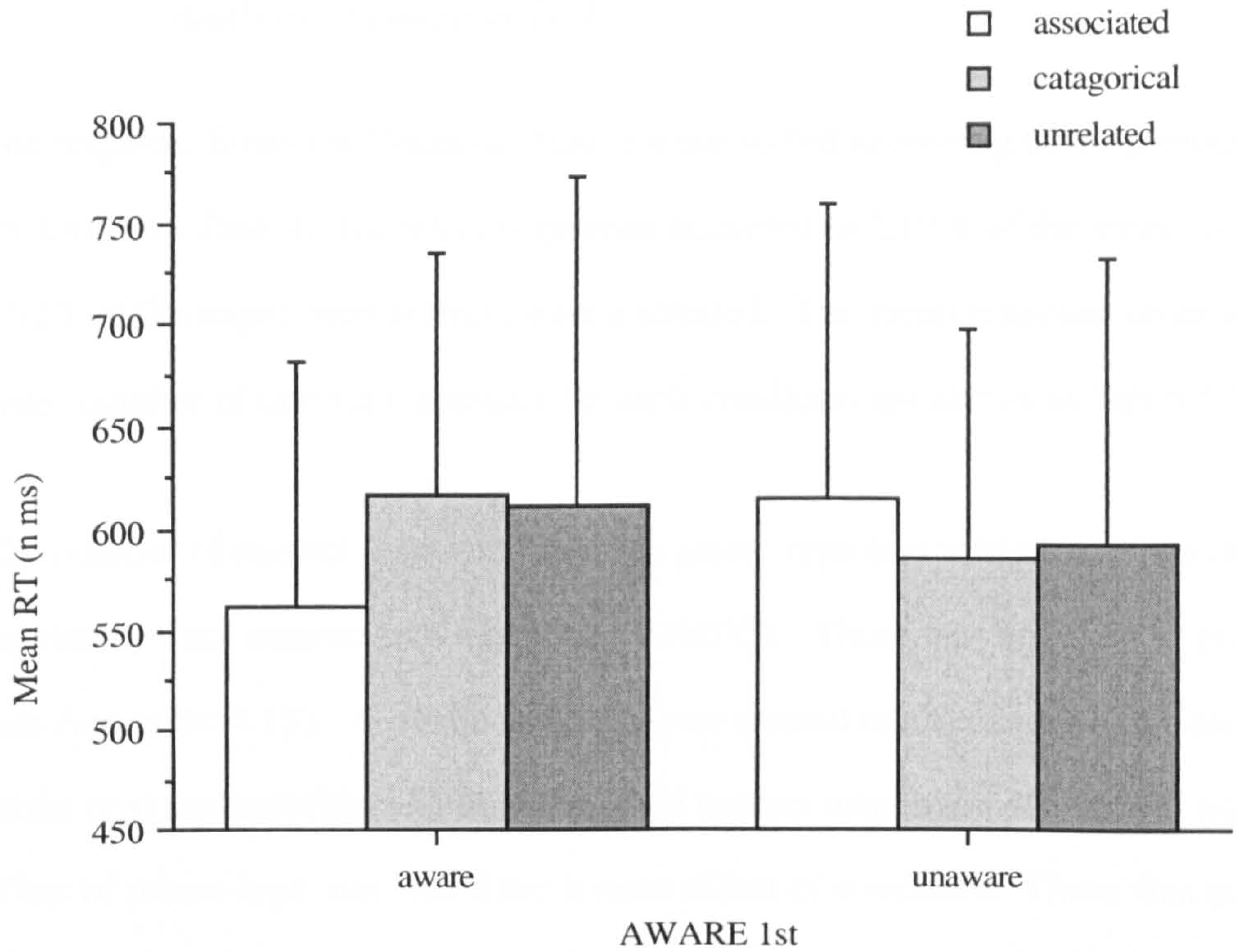


Figure 4.5: The effect of awareness on the mean response time (+ SD) when the prime-target relationship was manipulated

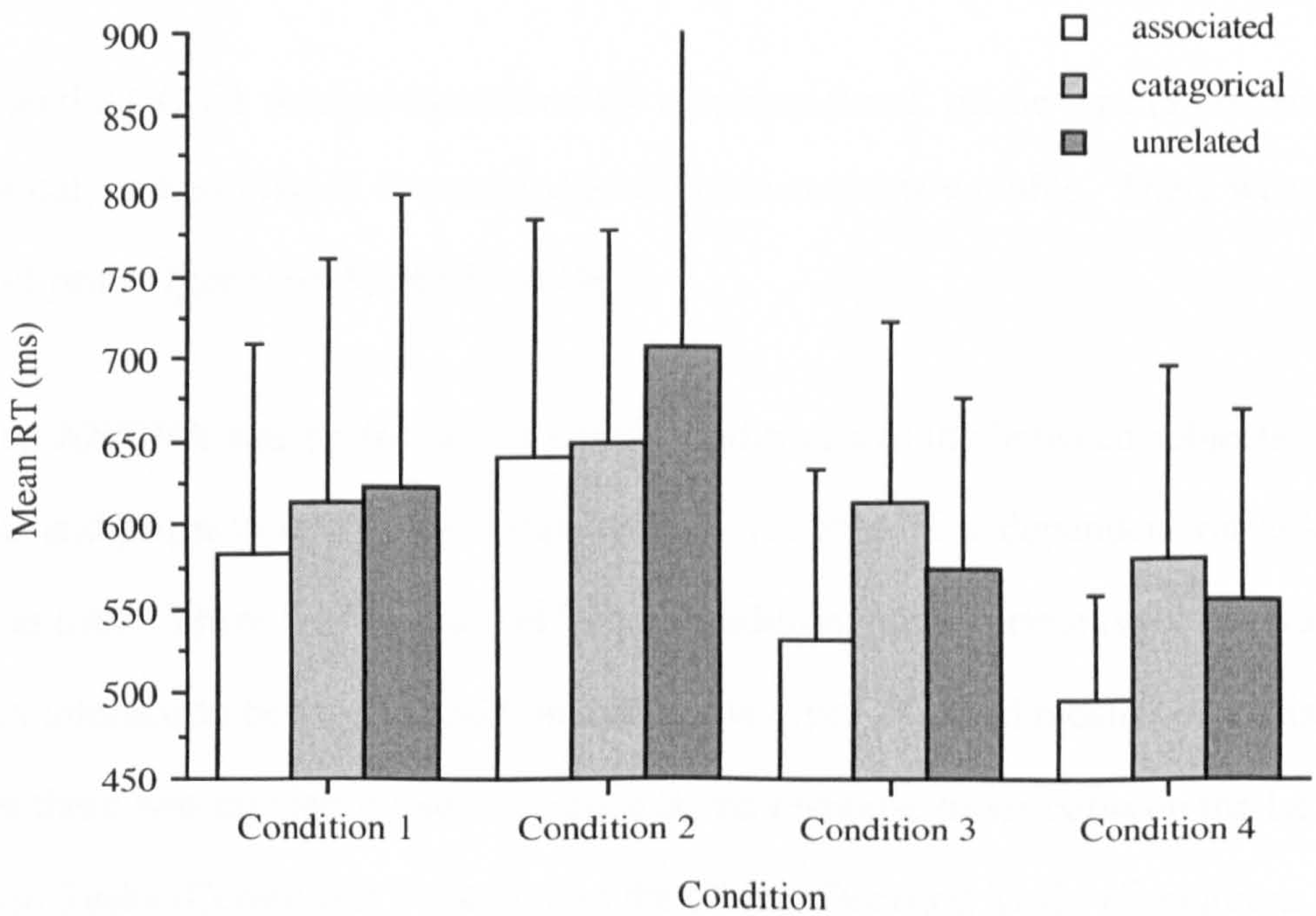


Figure 4.6: The effect of prime type and condition on response times (+ SD) in Decision Task 1 including only participants who were categorised as Aware 1

Analysis of Decision Task 2

The response times for Decision Task 2 were sorted according to the protocol outlined for Decision Task 1. Incorrect responses occurred in 2.19% of the trials. A total of 2.92% of the experimental trials were excluded. The mean response times and the mean number of correct responses for each condition are shown in Table 4.10.

The number of correct responses for each prime type (associated, categorical, and unrelated) were entered into a one way ANOVA. There was no effect of prime type (see Appendix 4.15). A mixed ANOVA was carried out to examine the interaction of prime type and condition on the number of correct responses. There was no main effect of prime-type, nor was there a main effect of condition. There was no interaction between prime type and condition. Planned means comparisons showed that there was no difference in the number of correct responses returned for the Lexical Decision Task (Conditions 1 and 3) and Object Decision Task (Conditions 2 and 4) (see Appendix 4.16).

A repeated ANOVA was performed on the response times; prime type (associated, categorical, and unrelated) was treated as a within subjects variable. There was no effect of prime type (see Appendix 4.16c).

A mixed ANOVA was performed in which condition was the between subjects variable and prime type was the within subjects variable. The dependent variable was response time. There was no main effect of condition, nor of prime type, nor was there an interaction between condition and prime type. Planned means comparisons showed there was no significant difference in the response times between the Lexical Decision Tasks (Conditions 1 and 3) and the Object Decision Tasks (Conditions 2 and 4) (see Appendix 4.17)

Analysis of effect of awareness after Test Task 1 on Decision Task 2.

The effect of awareness of the transitive relations between the training tasks and Test Task 1 on the response times of Decision Task 2 was analysed using a mixed ANOVA. Awareness was treated as a between subjects variable and prime type (associated, categorical, or unrelated) was the between subjects variable and response time was the dependent variable. The mean response times and the mean number of correct responses for each prime type are shown in Table 4.11. There was no main effect of awareness after Test Task 1 nor of prime type, but there was a significant interaction between prime type and awareness after Test Task 1 ($F = 3.73$; $df = 2, 150$; $p = .026$). This interaction is illustrated in Figure 4.7.

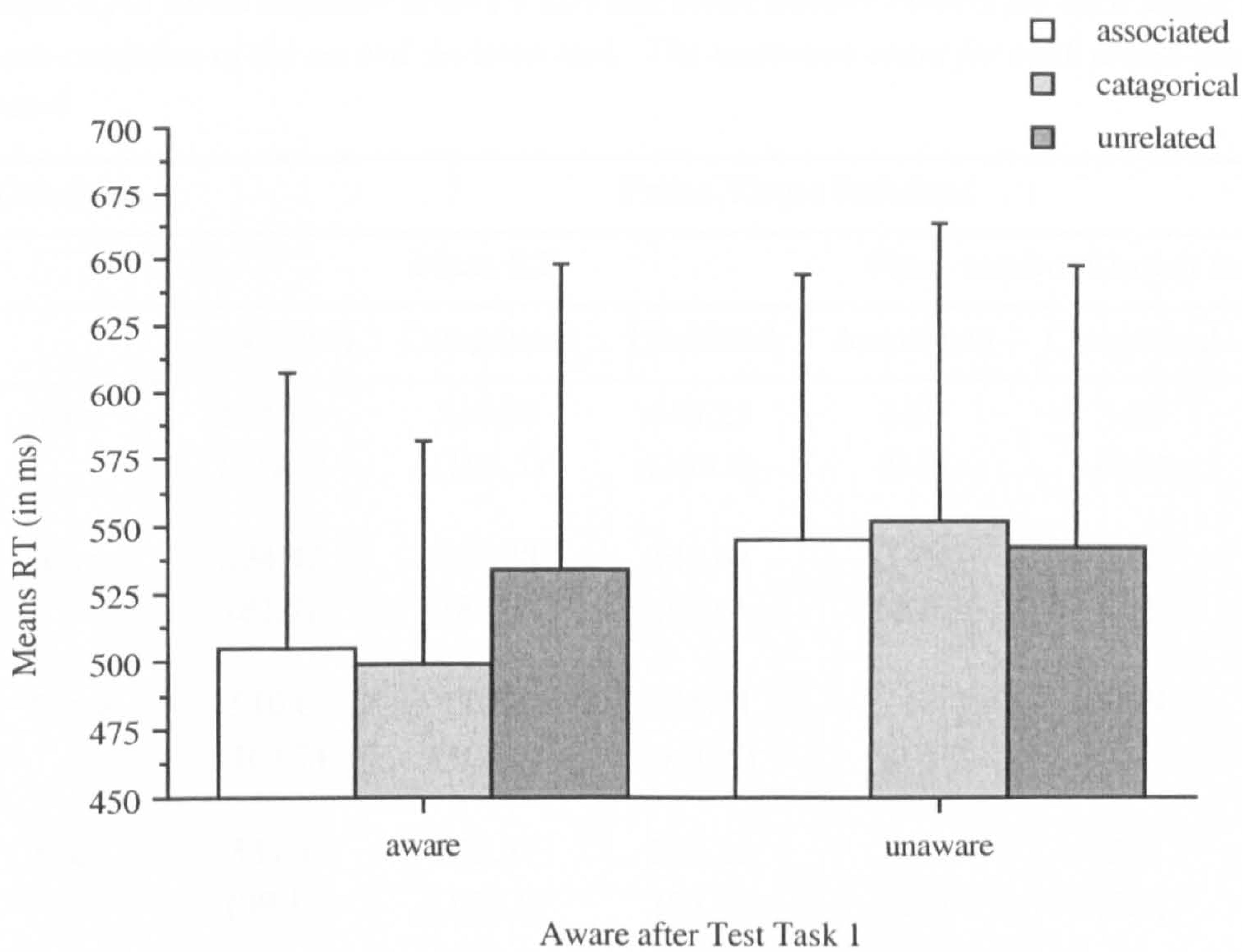


Figure 4.7: The effect of "Awareness after Test Task 1" on prime type (+ SD) in Decision Task 2.

Simple main effects showed there was no effect of prime type on response time for participants who were categorised as unaware after Test Task 1. Simple main effects showed a significant effect of Awareness after Test Task 1 on prime type ($F = 5.38$; $df = 2, 64$; $p = .007$). Planned means comparisons showed that response times were significantly faster when targets were preceded by an associated prime compared with an unrelated prime ($F = 6.35$; df 1, 64; $p = .014$). Response times were significantly faster when a categorically related prime preceded the target compared with an unrelated prime ($F = 9.47$; df 1, 64; $p = .0031$). There was no significant difference between the associated and the categorical prime. The tables for these analyses are shown in Appendices 4.18.a – e.

Table 4.10: Mean response times (+ SD) and mean number correct for each target type in each condition of the second decision task. The maximum score for each prime-target type was 4

Condition	Prime-Target Relations					
	Mean RT			Mean number Correct Responses		
	Associated	Categorical	Unrelated	Associated	Categorical	Unrelated
One	514.26 (121.3)	516.86 (106.5)	545.25 (109.9)	3.89 (0.3)	3.95 (0.2)	3.95 (0.2)
Two	534.42 (81.7)	540.35 (81.8)	548.64 (98.6)	3.79 (0.4)	3.95 (0.2)	3.89 (0.3)
Three	510.6 (103.7)	504.2 (100.4)	531.74 (140.5)	4 (0)	3.79 (0.5)	3.84 (.4)
Four	551.1 (99.1)	553.47 (120.1)	528.31 (87.9)	3.9 (.31)	3.9 (0.3)	3.75 (0.4)

Note: Conditions 2 and 4 performed Object Decision Tasks and Conditions 1 and 3 performed Lexical Decision Tasks.

Effect of awareness after Test Task 2 on Decision Task 2

After the second Test Task, participants were asked to explain the rationale they had employed for selecting the stimulus pairs. Their responses were categorised as "aware or unaware of the transitive relations between the training tasks and the test tasks". This variable was dubbed "Awareness 2". The effect of Awareness 2 on response times in Decision Task 2 was examined. The mean RTs for participants rated as aware or unaware after test task 2 for each prime type is shown in Table 4.11.

Table 4.11: Mean response time (in ms) for Decision Task 2 for participants rated as aware after Association Test Task 1 and after Association Test Task 2.

Awareness x Prime Type	RT (ms) for Awareness after Test Task 1			RT (ms) for Awareness after Test Task 2		
	N	mean	SD	N	Mean	SD
associated, unaware	44	545.01	98.8	27	545.6	104.9
associated, aware	33	505.10	102.5	50	518.35	99.7
categorical, unaware	44	551.69	111.7	27	557.03	120.4
categorical, aware	33	498.85	82.8	50	513.94	90.31
unrelated, unaware	44	533.38	105.6	27	530.35	99.9
unrelated, aware	33	533.38	114.4	50	542.67	114.1

A mixed ANOVA was used in which Awareness 2 was the between subjects variable and prime type was the within subjects variable; the dependent variable was response time. There was no main effect of Awareness 2, nor of prime type, but the interaction between Awareness 2 and prime type was significant ($F = 5.61$; $df = 2, 150$; $p = .005$)

(see Appendix 4.19). This interaction is illustrated in Figure 4.8. Analysis of simple main effects showed that there was no significant effect of prime type on the response times for participants who were unaware after test task 2, but there was a significant effect of prime type for participants who were aware after test task 2 ($F = 5.03$; $df = 2, 98$; $p = .008$). Planned means comparisons were performed on prime type for Awareness 2. There was a significant difference between the associated and the unrelated primes ($F = 6.21$; $df = 1, 98$; $p = .014$) and between the categorical and the unrelated primes ($F = 8.67$; $df = 1, 98$; $p = .004$). Responses to targets following the unrelated primes were slower in both cases. There was no significant difference between the associated and the categorical primes. The tables for these analyses are shown in Appendix 4.19.

Analysis of Errors and Awareness 2

The number of excluded trials in Decision Task 2 was analysed to determine whether unaware particpants made more errors than unaware participants. A one way ANOVA was perfomed in which the number of excluded trials was the dependent variable and the between subjects variable was Awareness 1 (participants rated as aware or unaware of the transitive relations between the training tasks and association test task 1). There was no effect of Awareness 1. The ANOVA was repeated for the between subjects variable of Awareness 2 (participants rated as aware or unaware of the transitive relations between the training tasks and Association Test Task 2). There was no effect of Awareness 2. The ANOVA tables and means for these analyses are given in Appendices 4.20 – 4.21. No further analyses of the errors was performed.

Effect of condition in Decision Task 2 and of awareness

The effect of awareness and priming was examined by analysing the response times in each condition of Decision Task 2 for participants who were rated as aware after Test Task 1 and after Test Task 2. Since there was no evidence that priming had been produced by participants who were unaware, the data from these participants was excluded from the following analyses.

A mixed ANOVA was performed on data from awareness participants. Prime type was the within subject variable and condition was the between subjects variable. The dependent variable was response time. The mean response times for prime type in each condition are shown in figure 4.8. There was no main effect of condition, nor of prime type. There was no interaction between condition and prime type. Simple main effect analysis of each condition showed that there was no effect of prime type in Conditions 1, 2, and 4. There was a significant effect of prime type in Condition 3 ($F = 5.25$; $df = 2, 24$; $p = .013$). Planned means comparisons between the prime types showed that response times were faster following an associated prime compared with an unrelated prime ($F = 7.89$; $df = 1, 24$; $p = .0097$). Response times were faster following a categorical prime than an unrelated prime ($F = 7.85$; $df = 2, 24$; $p = .0099$). There was no significant difference between the response times following an associated and a categorical prime. The tables for these analyses are shown in Appendix 4.22.

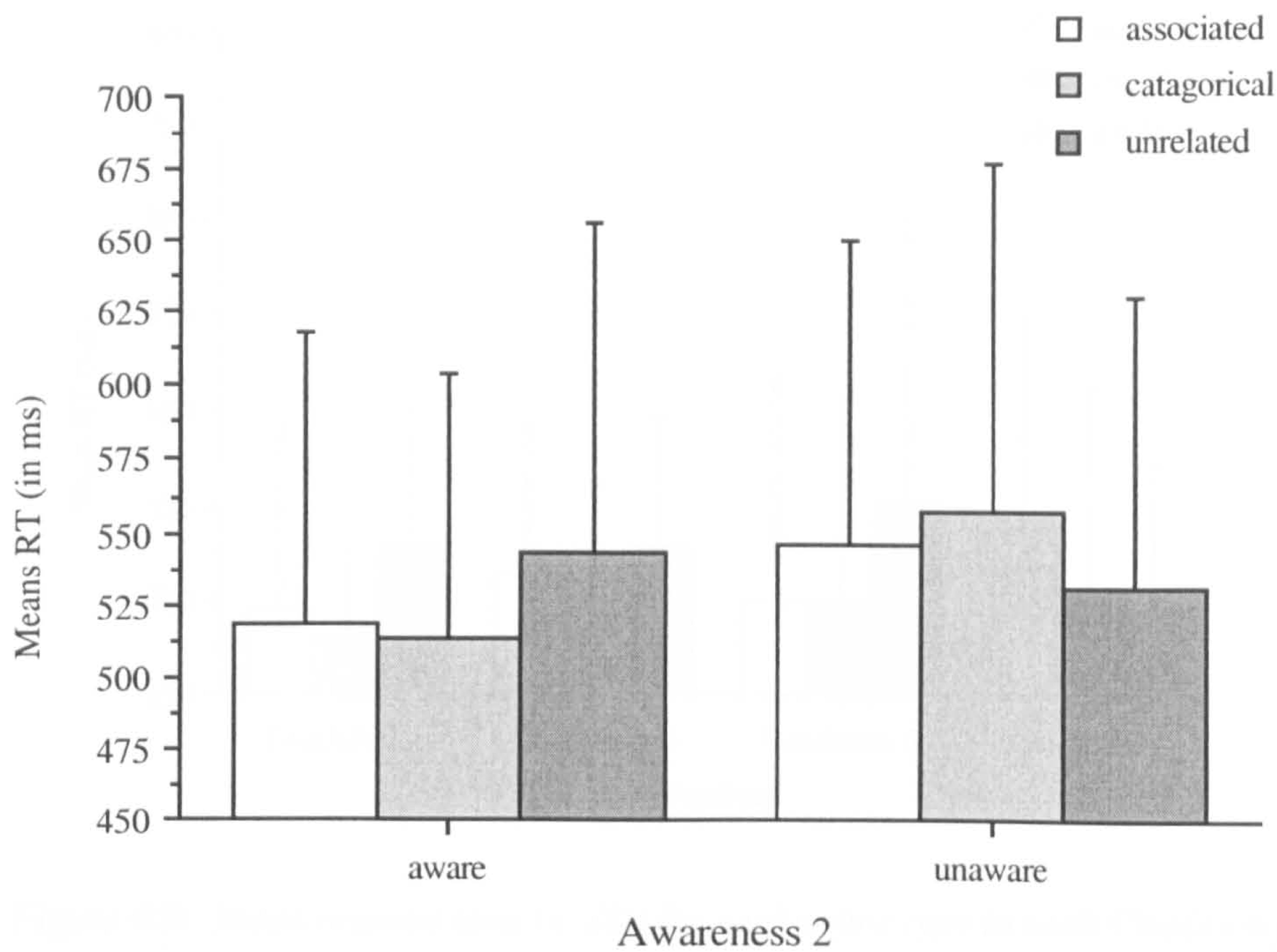


Figure 4.8: The effect of "Awareness after Test Task 2" on the response times (+ SD) to each prime type in Decision Task 2.

The response times of participants rated as Aware 2 were analysed using a mixed ANOVA: condition was the between subjects variable and prime type was the within subjects variable. The mean response times are shown in Figure 4.9. There was a significant main effect of prime type ($F = 4.55$; $df = 2, 92$; $p = .013$), but there was no main effect of condition. There was no interaction between prime type and condition.

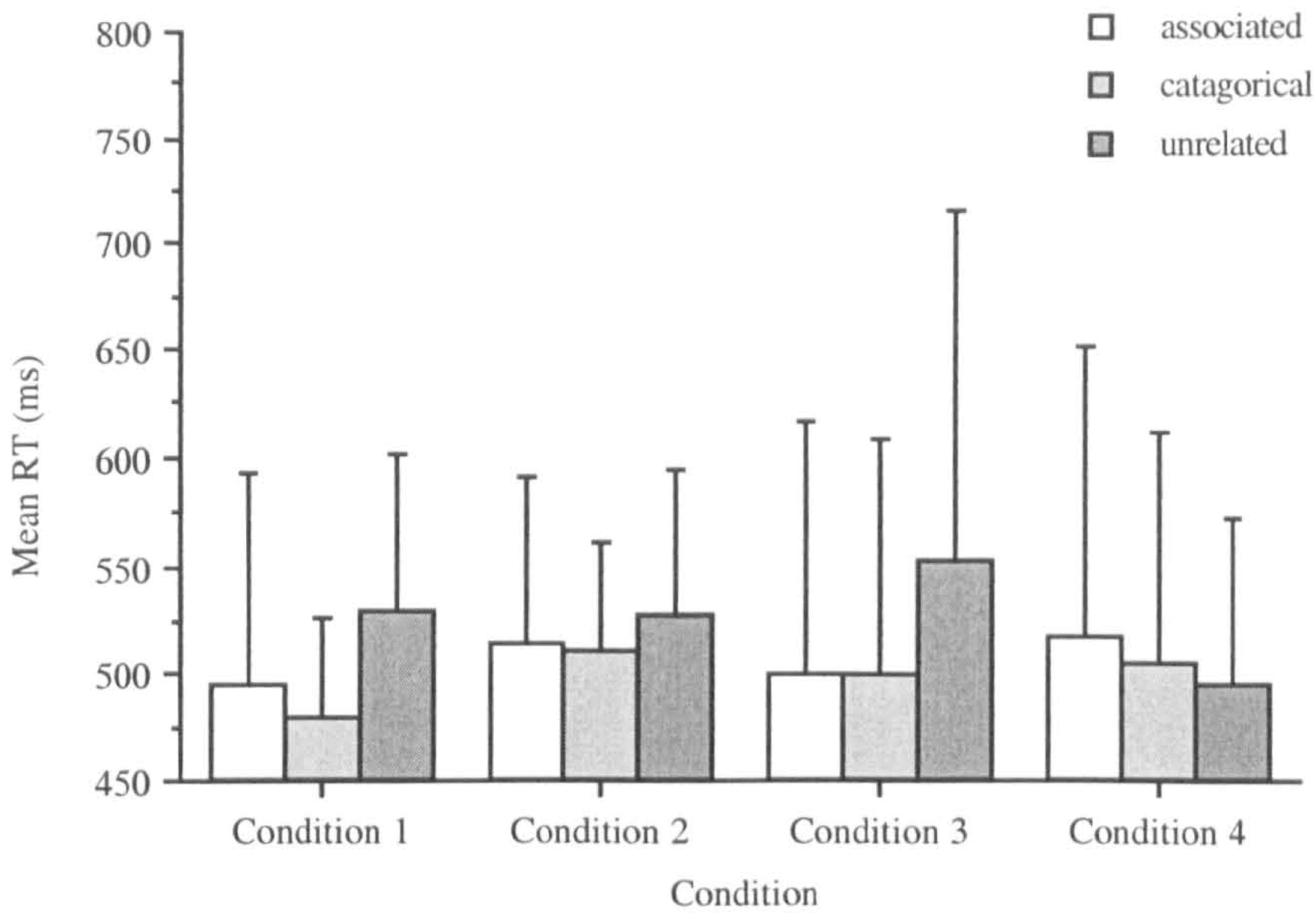


Figure 4.9: Mean respone time (+ SD) for each prime type in each Condition for participants who were rated as Aware 1

Analysis of simple main effects showed that there was a significant effect of prime type in Condition 1 ($F = 4.76$; $df = 2, 20$; $p = .02$). Planned means comparisons showed that the response time following an associated prime was significantly faster than after an unrelated prime ($F = 5.73$; $df = 1, 20$; $p = .027$), and the response time following a categorically related prime was significantly faster than after an unrelated prime ($F = 8.37$; $df = 1, 20$; $p = .009$). There was no significant difference in the response times to targets following an associated prime compared with a categorical prime. Analysis of simple main effects showed there was no effect of prime type in Conditions 2, 3, or 4. These comparisons are illustrated in Figure 4.10. The tables for these analyses are shown in Appendix 4.23.

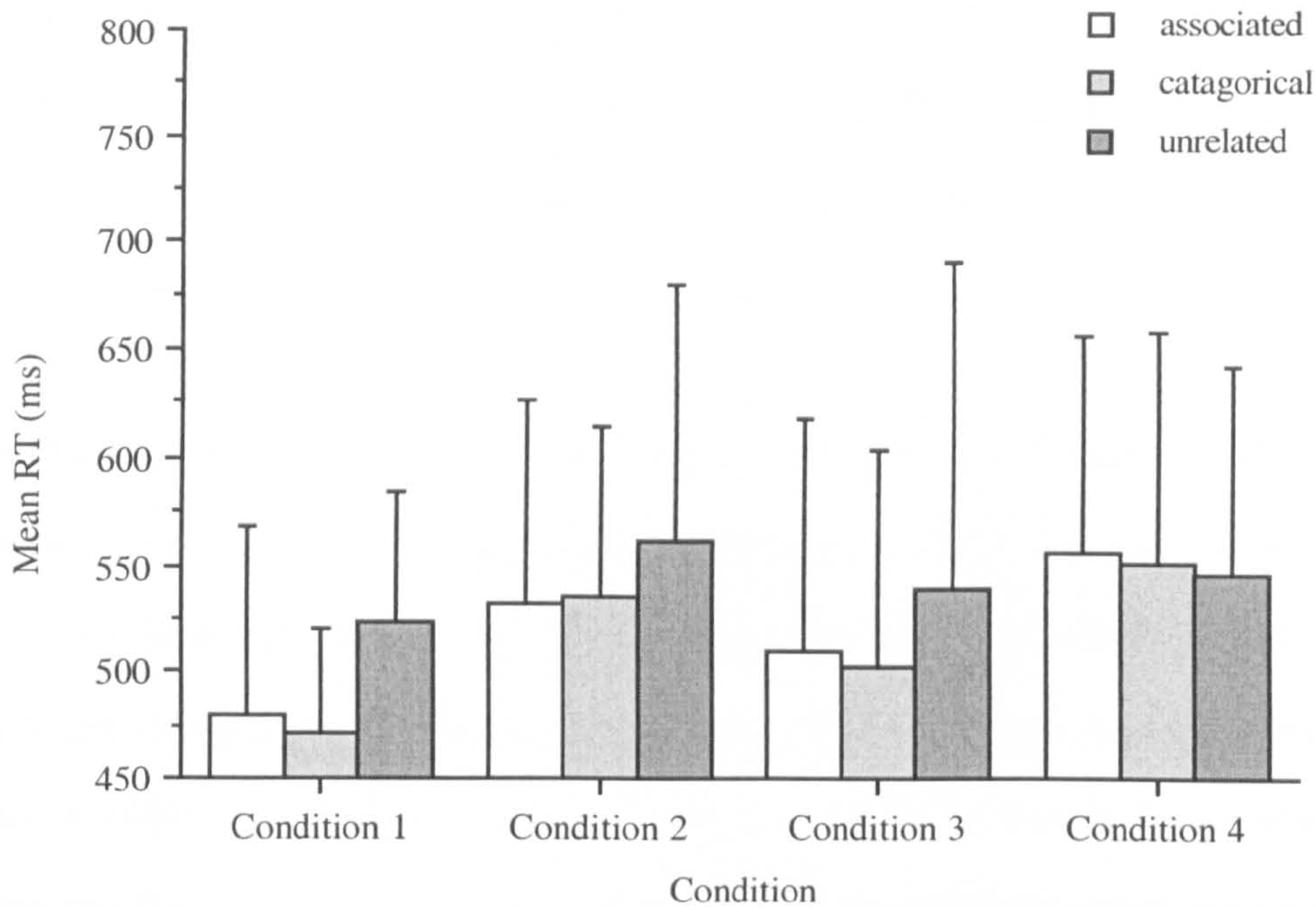


Figure 4.10: Mean response time (+ SD) for each prime type in each condition for Aware 2.

Analysis of Participants Who Became Aware after Instruction

The data from only those participants who were aware after instruction (those participants who were rated as unaware after Test Task 1 and aware after Test Task 2) were analysed to determine the effect of the explicit instructions about the contingencies operating between the training tasks and the test task.

Analysis of association test tasks

The mean number of correct responses produced by participants who were aware after instruction in Test Task 1 was 4 (SD = 5.4) for experimental stimuli and 1.17 (SD = 1.89) for control stimuli. A repeated measures ANOVA showed this difference to be significant (F = 5.11; df = 1, 17; p = .037).

The mean number of correct responses produced by participants who were aware after instruction in Test Task 2 was 10.72 ($SD = 7.02$) for experimental stimuli and 0.83 ($SD = 1.25$) for control stimuli. A repeated measures ANOVA showed this difference to be significant ($F = 34.72$; $df = 1, 17$; $p < .0001$).

A repeated measures ANOVA was performed to compare the performance of participants who were aware after instruction in Association Test 1 and Association Test 2. The repeated measures were Test Task and stimulus set (experimental or control) and the dependent variable was number of correct responses. There was a significant effect of Test ($F = 13.54$; $df = 1,17$; $p = .0019$), and a significant effect of stimulus set ($F = 24.52$; $df = 1, 17$; $p < .0001$). The interaction between Association Test and stimulus set was significant ($F = 22.91$; $df = 1, 17$; $p = .0002$).

Analysis of Decision Task 2

There was no evidence of any facilitation effect caused by different prime types. The mean response times were 529.29 ms. ($SD = 84.41$) for associated primes, 526.07 ms ($SD = 82.35$) for categorical primes, and 531.49 ms ($SD = 105.97$) for unrelated primes. A repeated measures ANOVA showed there were no significant differences.

Discussion

In Experiment 4, associations were successfully transferred between stimulus modalities, but only when subjects were aware of the link created by the naming relationship. Participants were able to learn the individual paired associations without awareness, but not to transfer these associations across stimulus modalities. Semantic priming effects were found between transferred associations, but only when participants had been aware of relationships between the stimuli without being given explicit instructions.

These results may cast a new light on, and raise some new experimental questions about one of the central and intractable questions of psychology for researchers in both the behaviourist and cognitivist traditions: the ontology of symbols, the process of symbol grounding, the core skill in stimulus equivalence competence.

In Experiment 4 we also replicated the picture superiority effect we observed in Experiments 2 and 3. Participants who learned picture associations prior to learning names for those pictures performed better in the word association test task than participants who learned the names of the pictures before they learned associations between those pictures. In contrast, participants who learned word associations prior to learning picture referents performed worse in the picture association task than participants who learned the picture referants prior to learning the word associations. The performance of participants who learned picture associations first was superior to that of participants in any of the other conditions. Performance on the test association task was linked to awareness of the relationship between the training and test tasks.

Awareness and Symbolic Function

Our data showed a difference in performance on the test association task for participants who were rated as aware versus unaware of the contingencies between the training tasks and the test task. Aware participants produced more correct responses on the test association task than participants who were unaware. This difference in performance can not be attributed to a difference in recall ability since there was no difference in the performance of the aware and unaware participants on the recall task. This suggests that awareness of the mediating role of the name relation is necessary for the transfer of associations across stimulus modalities.

Awareness and naming

Naming, according to Horne and Lowe (1996), is a higher order behavioural relation which, once acquired, allows the bidirectionality established in a name relation to extend across other verbal behaviours. They propose that because names both evoke and are evoked by classes of stimuli, naming is the mechanism that brings about the emergent relations demonstrated in stimulus equivalence studies. Naming is the foundation of symbolic behaviour. Horne and Lowe (1996) suggest that, once an individual has a history of naming behaviour, new names can be learned after hearing a name only once or twice in the presence of an object.

Participants in our experiment were all verbally proficient adults with histories of naming behaviour. When they commenced the vocabulary training task, participants were explicitly instructed to learn the names of the pictures. A bidirectional association between the novel word and picture pairs was trained to a criterion of correctness. Following Horne and Lowe's (1996) account of the role of naming in symbolic behaviour, it might be expected that the training tasks would be sufficient to produce a name relation between the picture and word stimuli that was capable of mediating the transfer of associations between stimulus modalities. This was not the case, it appears that a history of naming and learning a bidirectional relationship between a word and a picture is not sufficient for the emergence of transitive relations between the verbal and the picture processing systems. Our data show that only participants who were aware of the relationship between the stimuli performed correctly in the test association task, the ability to recall the names of the stimuli and to recall the trained paired associations was not sufficient to produce correct responses.

We propose that a name does not function symbolically unless there is awareness of the contingencies entailed by the bidirectional relationships. Further evidence for our argument comes from the results of our decision tasks. A priming effect was produced between the transitively related stimuli for participants who were aware of the relationship mediated by the name relation . Participants who were unaware of this relationship produced no priming effect. Priming in decision tasks has often been used as an index of a semantic relationship between the prime and the target (e.g. Lupker, 1988; McKoon & Ratcliffe; 1992; Meyer & Schvaneveldt, 1971; Williams 1996). Since semantic relationships require symbolic processing, we suggest that awareness is required for the transition between a bidirectional relationship between items and a symbolic relationship between items.

Role of awareness in stimulus equivalence

Our data shows a difference between participants who were aware after Test Task 1 (Aware 1) and participants who were aware only after explicit instructions about the mediating role of the name relation between the trained associations and the test associations (Aware 2). Aware 1 participants produced correct responses on the matching to sample (MTS) association test tasks and showed priming on the decision task. Aware 2 participants showed an improvement and responded above chance in Association Test Task 2, but they did not show a priming effect in decision Task 2.

Bentall and Dickens (1994) re-evaluated evidence obtained by themselves and their colleagues in their chronometric studies of stimulus equivalence. Following MTS training with sets of unrelated pictograms or sets of abstract stimuli, participants completed tests of symmetry relatively faster than tests of equivalence or transitivity. After further testing this difference in latency decreased. Participants who were trained using pre-associated stimulus sets (e.g., plants) showed no differences in the response times for symmetry and equivalence tests (Bentall, Dickens, & Fox, 1993). Bentall and Dickens (1994) conclude that symmetrical relations come effortlessly to linguistically able human beings but that the transitive inference necessary for the emergent relations demonstrated in stimulus equivalence requires effortful, attention demanding, explicit processing.

In Experiment 4 priming was shown by Aware 1 participants. Priming was not shown by participants who became aware of the relationship only after explicit instruction, although these participants were able to perform correctly on the association test. This suggests that there is a difference in either the amount of explicit processing required, or that a different type of process is involved. We suggest that there is a processing difference between a transfer of associative information between stimulus modalities mediated by a symbolic relationship, compared with information mediated by a chain of associations.

Equivalence relations in symbolic reference

The phenomenon of stimulus equivalence is an example of symbolic behaviour (Bentall and Dickens, 1994). The critical test in establishing whether there is an equivalence relationship between stimuli is a test of transitivity that also requires symmetry (A -> B, therefore B -> A) and reflexivity (matching to self e.g. A -> A and B->B). In Experiment 4, the picture-word name relationship mediates the transitive relationship between the visual and the verbal associations in the training and test tasks. This is another example of symbolic behaviour. The procedures involved in establishing an equivalence relationship, and the processes implicated in the transitive relationships demonstrated in Experiment 4, appear very similar to the processes described by Deacon's (1997) model of symbolic reference. We argue that our data provide evidence of the role of awareness in acquiring symbolic relations. By examining our results in the complementary frameworks of stimulus equivalence and symbolic reference, we hope to address at which step in the learning processes a departure from straight associative learning to a deeper explicit processing is required.

Deacon's account of symbolic reference

The data obtained in our Experiment 4 correspond with Deacon's (1997) distinctions between symbolic and indexical reference. Deacon focuses on the differences between the human phenomenon of language and the nonsymbolic reference found in nonhuman communication (and in many other forms of human communication). He employs the classification of referential associations originally proposed by Peirce (1903/1955), distinguishing between three categories: *icon, index*, and *symbol. Iconic reference* is mediated by physical similarity between the sign and the referent. A picture of an object is *iconic* of the object; we can see resemblances between them. Indices are mediated by a physical or temporal connection with the referent. A thermometer is an *indicator* of temperature; an index is a causal link between a sign and its referent. These relationships are illustrated in Figure 4.11. *Symbols* are mediated by a formal or arbitrary link, irrespective of physical similarity or contiguity. A wedding ring symbolises marriage vows; a letter symbolises a certain sound; a word symbolises not only a referent object, but also the sense of that object represented by related information learned from various sources. The essence of a symbolic relationship is that the relationship between a sign and its referent is not a function of their correlated appearance; it is a function of the relationship between that sign and other signs. (See figure 4.12.)

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Figure 4.11: A schematic diagram depicting the internal relationships between iconic and indexical reference processes. The probability of interpreting something as iconic of something else is depicted by a series of concentric domains of decreasing similarity and decreasing iconic potential among objects. The form of a sign stimulus (S) elicits awareness of a set of past stimulus memories (e.g., mental "images") by virtue of stimulus generalisation processes. Thus, any remembered object (O) can be said to be re-presented by the iconic stimulus. Similarly, each mental image is iconic in the same way; no other referential relationship need necessarily be involved for an iconic referential relationship to be produced. Indexical reference, however, requires iconic reference. In order to interpret something as indexical, at least three iconic relationships must be also recognised. First, the indicating stimulus must be seen as an icon of other similar instances (the top iconic relationships); second, instances of its occurrence must also correlate (arrows) with additional stimuli either in space or time; and third, past correlations need to be interpreted as iconic of one another (indicated by the concentric arrangement of arrows). The indexical interpretation is thus the conjunction of three iconic interpretaions, with one being of a higher-order than the other two (i.e., treating them as parts of a whole). This is essentially the kind of reference provided by a conditioned response. (Taken from Deacon 1997, p.79)

The relationships trained and tested in our Experiment 4 can be accommodated by Deacon's framework as follows: the stimuli that participants studied in the training tasks demanded an iconic reference for recognition. Indexical reference was established in the trained associates related by contiguity. The test association task requires symbolic reference: the transitive relations we tested require an awareness of the relationship between the test association stimuli and their names and the trained-paired associations. Deacon's classification of relationships corresponds with the three types of relationship required for stimulus equivalence. Equivalence relations demand reflexivity, symmetry, and transitivity (see Introduction to Chapter 3) within a logically closed stimulus set. Deacon's iconic reference requires reflexivity; the indexical reference demands symmetry; and symbolic reference could not occur without transitive relations.

Deacon's account of the development of symbolic reference provides an apt account of the processing demanded for acquiring the transitive relations tested in our Experiment 4. He describes three stages in the acquisition of symbolic reference: the *indexical*, the *transitional*, and the *symbolic* (see Figure 4.12). The indexical stage establishes associations among signs and referent objects. The transitional stage maps interconnecting associations between sign stimuli or *tokens*, maintaining the indexical associations between signs and their referent objects. These interconnecting associations between tokens are, in turn, indices of combinatorial and exclusion relationships that form a closed group of logical possibilities. The associations of the transitional stage are *simple*; they relate to elementary paired associations between tokens. The symbolic stage demands a shift of cognitive processing. Symbolic relationships are not learned in the same way as indexical associations between tokens, a symbolic relationship is discovered or recognised in the pattern of relationships between existing indexical relationships. The process of recognition involves making links with something that is already learned, so a matrix of associations must be in place before any one symbol token can function symbolically. This is not an added learning step, it is a shift in learning strategy;. When adopted, it takes no more time than perceptual recognition. This strategy, however, requires an effortful restructuring of previously learned associations to allow the system-level correspondences between token-token relationships and object-object relationships to become apparent. Note that our Condition 3, in which picture associations were learned before vocabulary training, produced the best performance of any of the conditions in Experiment 4. It is an intriguing possibility that the reason for subjects' good performance in Condition 3 is that they had a matrix of existing associations in which the vocabulary training could be enmeshed.

It is interesting to observe the correspondence between the distinction Deacon makes about the shift in processing strategy that is required before transitive relations become symbolic relations, and the distinction between implicit and explicit learning made by Maclaren, Green, and Mackintosh (1996). Maclaren et al. suggest that implicit learning can be seen as associative learning; in contrast, explicit learning requires additional cognitive processing. It is this combination of explicit cognitive processing and associative learning that gives us insight into the contingencies operating between associations, and the ability to explain the contingencies.

Figure 4.12: A schematic depiction of the construction of symbolic referential relationships from indexed relationships. This figure builds on the scheme depicted in figure 4.10, but here the iconic relationships are only implied and the indexical relationships are condensed into single arrows. Three stages in the construction of symbolic relationships are shown from bottom to top. First, a collection of different indices are individually learned (varying strength indicated by darkness of arrows). Second, systematic relationships between index tokens (indexical stimuli) are recognised and learned as additional indices (grey arrows linking indices). Third, a shift (reversal of indexical arrows) in mnemonic strategy to rely on relationships between tokens (darker arrows above) to pick out objects indirectly via relationships between objects (corresponding lower arrow system). Individual indices can stand on their own in isolation, but symbols must be part of a closed group of transformations that links them in order to refer, otherwise they revert to indices. (Taken from Deacon(1997, p. 87)

Awareness and symbolic reference

The results of Experiment 4 make an intriguing example of what Deacon explains as a shift in learning strategy between the transitional stage and the symbolic stage. It could be argued that participants who were "unaware" but able to recall the trained associations had acquired only indexical relations between the stimuli. Participants who were "aware" only after instruction attained only the transitional stage; they had learned the relations between tokens, and between tokens and signs, but these associations remain bound to the original experiences. Their understanding had the cognitive status of chained associations. Participants who were "aware" without further instruction could be said to have acquired functional symbolism: they were not only aware of all the trained associations, but also that the names referred to the associations in both the training and the test task.

Deacon suggests that it is the process of recognising the symbolic relationship that is effortful. Once a symbolic relationship has been acquired, symbolic associations can be processed as easily and quickly as transitively related associations. Priming data from the decision tasks in our Experiment 4 show a pattern that supports Deacon's suggestion. Participants who were rated as Aware 1 (aware without further instruction) showed a priming effect between the associations transferred across stimulus modalities, but participants who became aware only after further instruction showed no priming effect. Many participants who became aware after further instructions, and produced correct responses on the test association task, reported that they found the task difficult, or that it required a lot of effort. As we have observed above, the different response times between newly trained relations and well established relations reported by Bentall and Dickens (1994) in their chronometric analysis of stimulus equivalence also correspond with this difference. We argue that in Deacon's terms, awareness is an index of the explicit processing that is required for the shift from transitive to symbolic reference and that this shift in cognitive processing underpins the emergent equivalence relations demonstrated in stimulus equivalence tests.

Awareness and dual coding

Although the role of awareness in developing symbolic function appears to be particularly specified in Deacon's model, it is not incompatible with Paivio's (19991) dual coding model. In the dual coding model, word meaning is achieved through the referential links that connect the two symbolic systems (the verbal system and the imagery system). Like Deacon's, Paivio's model suggests that a word's meaning is not necessarily represented by one-to-one mappings between the representations of one word and one item; the model can accommodate "many-to-one" and "one-to-many" relations. Thus, one imagen might be related to several logogens (or one logger might be connected to several Imogenes). For example, "Yowzah", "puss", or "cat" might all refer to one particular pet, and "cat" can refer not only to any domestic cat but also to creatures of related species such as lions and tigers.

In Paivio's (1986) dual coding model, the contents of the imagery and verbal systems retain the combined functional properties of the sensorimotor systems from which they originate. The sound of a word and the orthography of that word comprise an integrated representation in the verbal system. The two systems are interconnected through referential links between individual logogens and imagens. Paivio assumes these interconnections to be partial; interconnections occur only between certain representations in each system. The referential connections between the systems result from experiential learning, and appear to depend on co-occurrence. A simple example is pointing to an object and simultaneously naming it (Paivio, 1986). According to dual coding theory, semantic learning occurs by establishing referential links between verbal and perceptual representations; Paivio does not however, specify how images are learned for concrete words, nor how one learns to describe images.

> What is the nature of the control processes or the controlling variables involved in such interchanges, and how do they originate developmentally? Such skills must originate with associative experiences between language and the child's oriented perceptual-motor reactions to things, but precisely how? The mechanisms are not obvious. Classical and operant conditioning have been proposed. The field is wide open and it is important because, until we have answers to the kinds of questions I have raised here, we will have an inadequate understanding of the structural and functional nature of mental representations (Paivio, 1991, p. 205).

Our data show that merely learning a bidirectional link between a novel picture and a novel word is insufficient to allow symbolic processing: awareness of the representational nature of this link is required for symbolic function. We argue that this is an explicit process. If awareness of the contingencies surrounding the referential link is "the controlling variable", then mechanisms other than operant or classical conditioning must be posited.

Awareness and Perceptual Symbol Systems

Like Deacon, Barsalou asserts that word meanings are not represented by one-to-one mappings between a word and an object; meanings are distributed across sensory areas of the brain that have associated patterns of activity. For example, the word "lavender" might evoke an image of a smell, a colour, and a visual image of a shrub. Perceptual symbols for words develop in the same way as perceptual symbols for other sensory experiences. In Barsalou's model, perceptual symbols are used to construct multi-modal simulations of perceptual experiences. Simulators are

Barsalou's equivalent of concepts; they are the means by which an entity or an event can be represented.

Central to the formation of simulators is attention. Attention is the mechanism by which an experience is parsed into schematic perceptual components; it provides the means of contrast between a focal concept and its contextual background. Entry to long term memory follows attention, but once a concept has been encoded as a simulator, that simulation when activated can control attention to focus on the salient details, resulting in faster perception and recognition. Barsalou suggests that the construction of a novel simulator requires strategic processing, whereas highly compiled simulators produce simulations automatically. According to Deacon, the transition between indexical and symbolic relations is effortful, but once symbolic associations have been established they are activated as readily as indexical associations. Barsalou suggests that during recall simulations are produced of the original entity or event are activated. These simulations can occur unconsciously as in implicit memory, or consciously as in explicit memory. In a perceptual symbol system, conscious experience follows unconscious or preconscious processing of sensations and actions; different neural mechanisms support the two processes. This is similar to Deacon's (1997) proposal that symbolic reference results from recoding conceptually related indexical relationships. Barsalou posits that simulators, stored in long-term memory, can become active unconsciously in implicit memory or consciously in explicit memory. Simulations are implemented in working memory. Sensory specific buffers simulate sensations just experienced, currently imagined, or anticipated. Barsalou makes no specific claim about the implicit/explicit nature of simulations activated in working memory.

Barsalou views priming as perceptual anticipation: the top-down activation of a simulation (activated by processing the prime) facilitates identification of a matching perceptual input.

In Experiment 4, we obtained priming when participants were aware of the name mediated association between the prime and the target (Aware 1), but we did not obtain priming when participants were unaware of this association. Nor did we obtain priming when participants became aware following instruction about the relationships between the trained and the test stimuli (Aware 2). This pattern of data is consistent with Barsalou's proposal of two different neural mechanisms. Barsalou specifies that attention is the key to encoding perceptual symbols in long-term memory, but these representations can be implicitly or explicitly represented. We suggest that conscious-awareness is required before perceptual symbols are available for the construction of simulations to represent word meaning. Furthermore, priming will only occur when associations between perceptual symbols (for the prime and target) have been compiled within a simulation sufficiently frequently to become automatic.

The Transfer of Associations between Stimulus Modalities is an Explicit Process

Our data show a difference in the performance on the association test task between participants who were rated as aware and those rated as unaware. Aware participants produced more correct responses than unaware participants, despite there being no difference in their performances on the recall task. Aware participants were not only able to recall the trained associations, they were also able to report that the names learned in the vocabulary task referred to both the trained associations and the stimuli in the association test task. It seems that the transfer of associations between stimulus modalities is mediated by the symbolic relations between the pictures and the words. Experiment 4's results suggest that a symbolic relationship is more than a chain of bidirectional relationships; a view supported by theories such as Deacon's and Barsalou's. At some point there must be explicit knowledge of the relationships entailed between elements in that chain. Unaware participants were able to use the chain of associations encapsulated by the symbolic relations once they were aware of the relationship entailed in the training tasks, as demonstrated by their performance on Association Test Task 2. Evidence that conscious retrieval processes were required for this task can be found in the records of participants' descriptions of their rationale for the task; many of these participants reported that they had found the process effortful. This is also reflected in the data from Decision Task 2; participants who were aware after instruction showed no priming effects, unlike participants who were aware after Test Task 1, who did show priming. This suggests that explicit knowledge about symbolic relations achieved by chained association does not confer symbolic function. It also suggests that the acquisition of symbolic relations *does* require explicit processing.

Awareness and Priming

The data we obtained showed that awareness of the contingencies between the training and the test tasks is necessary before priming across stimulus modalities is produced. It appears, however, that awareness is not sufficient: automaticity is also required. The participants who became aware after instruction did not show any priming effect between the related primes and targets despite their improved performance on the association test task. Priming is thought to be the product of automatic rather than intentional processing (Draine & Greenwald, 1998; Fischler, 1977; Meyer & Schvaneveldt, 1971; Schacter, 1987; Williams, 1996).

Our results are similar to those of Dagenbach, Horst, and Carr (1990). In their experiment, they demonstrated that episodic learning of new vocabulary items produces good recall in a cued memory test (over 99% correct), but in a LDT no facilitation was produced between episodically related prime target pairs. In a follow-up experiment (their Experiment 3), they intensified the training procedure. In the initial training procedure, participants studied 24 unfamiliar words and their definitions until they could correctly define every word. The 24 unfamiliar words were then paired with synonyms. Participants studied these word pairs for 15 minutes. They were then given a 10 page booklet, in which the first word of each of the 24 word pairs appeared in random order on each page. Participants were asked to write in the second word for each pair. The experimenter corrected any mistakes or missing words before the participant commenced the next page. In the intensive training procedure, participants were trained once every week for 5 weeks. In addition to training, outlined above, participants were required to produce sentences correctly employing the new vocabulary words. After the 5th training session, participants' recall of the word pairs was tested and they participated in a LDT. .A priming effect of 43 ms was produced between the episodically related word-pairs. Cued recall of the word pairs was over 99% correct. Interestingly, in a follow up experiment employing the same intensive training procedure for pairs of familiar but unrelated words, Dagenbach et al. failed to produce a priming effect.

Dagenbach et al. (1990) interpret their results as evidence that extensive episodic association can, in some instances, result in automatic semantic priming of a lexical decision. However, their failure to produce priming between familiar but unrelated words suggests that purely episodic associations formed in experimental conditions are not functionally equivalent to semantic associations. This indicates that semantic memory is more than a purely associative system. Participants' performance reflects the function of semantic memory in mapping meaningful relationships between items in the world. In Dagenbach, et al.'s experiment, only associations between synonymous words were incorporated into semantic memory. In our experiment, symbolic associations between novel words were formed more readily if they had a referent picture at the time of association. It appears that the contents of semantic memory are selectively encoded.

Further evidence of selectivity can be seen in the pattern of the data obtained in Decision Task 1 from aware participants: a priming effect was produced only for the associated prime target pairs; no priming effect was produced by the categorically related primes (from the other experimental stimulus set). This was despite the fact that the corresponding stimuli for both prime types had appeared with equal frequency in the same stimulus arrays.

Posner and Snyder's (1975) model of attention suggests that conscious processing enables selectivity and can enhance the rate of information processing. As might be predicted by their model, participants in our experiment who were rated as aware before explicit instruction showed a priming effect on the Decision Tasks, whereas participants who were unaware before explicit instructions did not show a priming effect. Both sets of participants had learned the associations to the same criterion and showed similar recall abilities. Participants who became aware after instruction were able to select the correct responses in the Association Test Task, but did not demonstrate priming in the decision task. This suggests that the different encoding strategies result in associative pathways of different strengths. If the patterns of association are treated symbolically (through the name relation), the resulting associations will allow automatic activation of related representations. Patterns of association that are not united by a higher order relationship do not produce automatic activation of related representations; the process of retrieving these representations remains intentional.

Symbolic Relations Develop more Readily from Picture Associations than Word Associations

In Experiment 4, the sequence of exposure to new associative information was manipulated between conditions. This manipulation caused differences in the number of correct responses recorded in Association Test Task 1. The mean number of correct responses was greatest in Condition 3, in which novel picture associations were trained before names for the pictures were learned. The mean number of correct responses was lowest in Condition 4, in which novel word associations were trained before the picture word associations were learned. The same pattern was observed for the number of aware participants in each condition: the condition in which the most participants were aware (after Test Task 1) was Condition 3, and the condition with the least number of aware participants was Condition 4. This raises the question: why might the sequence in which the association training tasks are presented affect the ease with which symbolic relations are acquired.

The data we collected in Experiment 4 replicates the pattern of results obtained in our previous experiments. There was an advantage conferred by learning picture associations before the name relations We propose that pictures have an inherant or implicit symbolic quality due to conveying details of the physical form and shape of the object they portray, whereas the relationship a word has with its referent is entirely arbitrary; no meaning can be deduced from a novel word presented without a context.

Pictures have inherent symbolic status

Gelman and Ebeling (1998) demonstrated that both children and adults readily interpret pictures as symbolic material. Their data suggest that a picture needs only a very approximate similarity in shape to its referent object provided it is understood that the creator of the shape intended it to be representational. In their experiment, participants were presented with a series of line drawings that were roughly shaped like nameable objects. Half of the participants were told that these drawings had been deliberately created by someone painting a picture, the other participants were told that the drawings depicted accidentally created shapes, caused by someone spilling paint. The participants who believed the shapes were created intentionally named them according to their similarities with objects (e.g., "sun") significantly more often than participants who believed them to be accidentally created.

In our experiment, participants were told that they would be learning associations between pictures of novel objects. These instructions imply that the pictures are representative of the shape and appearance of an unfamiliar object. To this extent, the pictures convey some meaningful information; conversely, the novel word associations without picture referents would not appear to convey any meaningful information.

Paivio and Csapo (1973) presented evidence showing a difference between the recall of pictures and words following either intentional or incidental learning. Participants were told that the experiment was concerned with the accuracy of picture and word identification following a short exposure of about 60 ms. They were asked to write down the words or names of the pictures after each stimulus was presented. Participants in the incidental learning condition received no further instructions. Participants in the intentional learning condition were told that that they would later be given a recall test. Learning condition had no effect on their participants' abilities to recall the pictures, but it did affect their recall of the words. Participants recalled significantly more words in the intentional learning condition than in the incidental learning condition.

Paivio and Csapo's results suggest that visual information can be learned without intentional learning. This implies that less effort or processing capacity is required to learn and to recall associations between items that are easily recognised. The less processing capacity required to activate the associations between the pictures, the easier it will be to assimilate the name relations into this associative structure. This idea will be discussed at greater length in Chapter 6.

Theoretical implications of the picture superiority effect

As we discussed in Chapter 3, dual coding predicts such a modality asymmetry in the pattern of results. However, the differences predicted by that model are dependent on the assumption that chained associations underlie the processes employed during the association test task. Results from the decision tasks in Experiment 4 support the notion that semantic associations underpin the priming effect we observed. The data from participants who were not rated as aware until the relationship between the training tasks and the test task had been explained to them (Aware 2) showed evidence of associations transferred across stimulus modalities in the test association task, but no evidence of priming in the first or the second decision tasks. It appears that Aware 2 participants were able to perform the association test task by means of chained associations; but since they showed no semantic priming for these associations, we suggest that more than a chained association is required for symbolic function.

Barsalou's perceptual symbols model proposes that language representations are integrated with other perceptual representations within a conceptual simulator. Unlike Deacon (1997), whose emphasis is on the mnemonic power of words that allows associations between words to implicitly refer to a relationship between objects or events (bypassing the matrix of indexical relations that sustain each symbolic relationship), Barsalou's emphasis is on the role of perceptual representations underpinning cognitive function. Barsalou proposes that word meanings are grounded in neural records of perceptual activation. Abstract words are grounded in complex simulations of combined physical and introspective events. It might be predicted from this model that novel word associations with picture referents would be associated more readily than those without picture referents.

Barsalou (1998, 1999) proposes that the ontogeny of language begins with the acquisition of "perceptual simulators"; these form the substance of conceptual knowledge which will support the acquisition of new words. New words can be mapped onto this conceptual structure. The order in which the associations were presented in Condition 3 would be optimal for this developmental sequence. We note in passing that the ontological order of acquisition of conceptual versus verbal knowedge implied by Barsalou appears to be the opposite of that implied by Bentall and Dickens (1994). This issue is taken up again in our General Discussion (Chapter 6).

Following Deacon's account of symbolic function, it would seem that the sequence in which associative relationships are acquired could affect the development of a symbolic relationship. Because symbols embody higher order relationships, they cannot be acquired one at a time, as simple associations can. The first stage in acquiring a symbolic relationship is the object-symbol correlation, but the importance of this relationship becomes subordinate to the associations between symbols once symbolic function is acquired. The relationships between symbols form a systematic network of associations that is isomorphic with objects and events in the world. It could be argued that patterns of associations between icons/objects would map more readily onto novel words than patterns of associations between letter strings would reflect associations between icons/objects.

It is interesting to observe that there was no difference in the response times to the pictures in the ODT compared with the words in the LDT.

This suggests that once a symbolic relationship has been acquired there is no preferential direction to the referential association between the picture and the word; picture associations can be accessed by the verbal system as readily as word associations can be accessed by the imagery system. This finding lends support to Deacon's model of symbolic reference which posits that once symbolic reference is established, symbolic associations are accessed as readily as indexical associations established through contiguity. This pattern of responses is contrary to the proposition of a common semantic store that is more readily accessed by pictures than by words (Carr et al., 1982; Durso & Johnson, 1979; Guenther et al., 1980).

Summary

- The transfer of associations across stimulus modalities depends on awareness of the contingencies existing among the trained-paired associations, the name relations, and the cross modality test association task. Participants who were unaware of these contingencies showed no differences between their responses to the control and to the experimental stimuli. It is argued that awareness corresponds with symbolic function, a qualitatively different relationship to that of simple chained associations.

- There was no evidence to support the suggestion that awareness of the contingencies is a direct product of the ability to recall the trained associations. There was no difference in the mean recall scores of participants who were rated as aware compared with those participants who were rated as unaware, both after the first and after the second test association task.

- There was no evidence that awareness was necessary for acquiring the paired associations. Awareness had no effect on recall of trained associates, only on transferred associates.

- Analysis of Decision Task 1 showed no evidence of facilitation produced by associated primes in any of the conditions when the data from all of the participants was included. When data from only those participants who were rated as aware after Test Task 1 was analysed, a significant effect of prime type was demonstrated. Responses to targets following an associated prime were significantly faster than responses following a categorically related or an unrelated prime. It was concluded that priming requires both explict knowledge of the associations and automatic activation of theses associations. Both these attributes are conveyed by symbolic functioning.

- The asymmetry in the relationship between corresponding picture and word relationships demonstrated in Experiment 1 and Experiment 3 was reproduced. Picture associations established in the absence of a name could produce corresponding word associations when the name had been learned, but word associations that were established without an existing visual referent did not produce picture associations after the word picture associations were learned. There was a corresponding difference in the numbers of people rated as aware in each condition after Test Task 1. Condition 3 produced the greatest number of participants rated as aware (in Condition 3 the picture association-training task was presented before the vocabulary-training task). This difference was no longer significant after the explanation of the contingencies between the training and the test tasks had been presented. This is further evidence that explicit processing is required for the transfer of associations across stimulus modalities.

- It is argued that picture associations are more readily learned than word associations, because pictures are inherently more meaningful. Iconic relationships between pictures are established more easily than between words.

Chapter 5

Semantic Priming: a Measure of Symbolic relations?

The results of Experiment 4 (Chapter 4) suggest that the priming effect observed in the decision tasks required automatic access to explicit knowledge of the relations between the prime and the target. We propose that the facilitation observed in Experiment 4 is an example of semantic priming rather than priming mediated by chained associations. Associations transferred between visual and verbal systems produce priming only when a functional symbolic relationship between the symbol tokens has been established. The aim of Experiment 5, presented in this chapter, is to determine whether explicit knowledge of a relationship between words is necessary to obtain priming in a lexical decision task (LDT).

In Experiment 5 (this chapter), prime-target pairs were selected that conformed to different permutations of relationships defined by categorical norms, associative norms, and collocates drawn from a large corpus of text. After completing the LDT, participants were asked to describe the relationship (if any) between each of the prime–target pairs. Analysis of the data collected supported the hypothesis that explicit knowledge about the relationship between the prime and target underpins the facilitation produced in a LDT. In keeping with the predictions of dual coding and perceptual symbol grounding models, it was shown that verbal associations grounded in perceptual experiences produced greater facilitation than those derived from purely verbal experience.

In Experiment 4 (Chapter 4), a priming effect was produced only by those participants who were rated as "aware"; that is participants who could explain the relationship between the prime and the target. We argue that priming occurs only when the relationship between an associated prime and target is functionally symbolic. The associations between the related prime and target in Experiment 4 could have been derived only from knowledge of the relations entailed between the trained paired-associates and the names of the associations; the relationship was not derived from direct experience of paired associations. Participants who became aware of the relationships only after the experimenter had explained the contingencies did not show a priming effect. It was concluded that merely learning a chain of associations between a prime and target is insufficient to facilitate the identification of a target following the presentation of an associated prime. If the results of Experiment 4 are interpreted in the framework of Deacon's (1997) model of symbolic referential relationships; priming effects are produced only when the relationship between the prime and the target is symbolic. According to Deacon, there is a qualitative difference between a symbolic relationship and an associative relationship between symbol tokens. Symbolic relationships are learned by a different cognitive strategy; they are acquired when an implicit pattern within a logically complete system of relationships between symbol tokens is recognised. These self-contained symbol systems are in turn incorporated into higher order relationships with other self-contained symbol systems. These are the building blocks of semantic reference which, in turn, are organised in hierarchical systems within a distributed network. Once symbolic relations have been established within a logically complete symbol system, any token is readily accessible to another regardless of whether there was a direct paired associations between those tokens; this, we propose, is the mechanism that underpins semantic priming.

In Chapter 4 we concluded that the priming measured in the decision tasks presented in Experiment 4 requires both that the relationship between the prime and the target is available to conscious inspection and that the prime produces automatic activation of the related target. However, these conclusions were grounded in participants' performance following a restricted training protocol that bears little similarity to natural language acquisition. Our Experiments 1, 2, 3, and 4 required participants to learn paired associations between limited sets of novel word and novel picture stimuli. A possible weakness in the design of the previous experiments might be the specific nature of the relationship between the word and the picture. A word's meaning is not generally restricted to a specific relationship between one letter-string/phoneme string and the representation of one item; a word refers to a class of items (Shepard, 1975; Vygotsky, 1934/1986). A word's meaning is bound in the pattern of similarities between items within a given class and differences with items belonging to a different class (Rosch, Mervis, Gray, Johnson, & Boyes-Braen, 1976; Rosch, Simpson, & Scott Miller, 1976). The artificial nature of our experiments might have prompted the use of imagery and other mnemonic strategies resulting in the conscious recall of the picture stimuli, giving the impression that awareness of the relationship is a prerequisite for the transfer of associations across stimulus modalities. In this chapter we intend to examine the nature of the relationship required for facilitation to occur between familiar word pairs employed in a LDT.

Is Automatic Associative Priming Semantic?

In Chapter 4 we concluded that the priming effect observed during the decision tasks was mediated by symbolic associations. If we are correct, it follows that priming effects observed in LDTs are an index of semantic relations between the word pairs. However, there has been much debate in the literature about whether priming observed in a LDT is an index of associative or semantic relations between the prime and target (e.g., Fischler 1977 a or b; Shelton & Martin, 1992; Williams, 1996). The frequent problem presented by a failure to establish shared operational definitions within the psychological community has resulted in a confusing literature. The definition of semantic relations between concepts that has been employed in priming studies varies: some researchers have used membership of the same category class as a measure of semantic relations (e.g., Lupker, 1984); others use free associates (e.g., Meyer & Schvaneveldt, 1971). Dark and Benson (1991) asked their participants to name a word that would make somebody else think of the target word (these were not the subjects who later took part in their experiments). Because it is possible that word associations might originate from accidents of contiguity (Fischler, 1977 a), it has been claimed that priming obtained from word pairs taken from free associations might be derived from lexical rather than semantic representations (Lupker, 1984, Shelton & Martin, 1992). If priming were restricted to lexical rather than semantic representations it would follow that a LDT is not an appropriate tool for investigating the semantic system. In this experiment we aim to investigate not only whether awareness of a relationship is necessary for semantic priming, but also whether the source of a normative relationship (associative, categorical or category co-ordinate) effects the amount of priming produced.

Priming

Priming paradigms have long been used as an indication of a relationship between two words. Differences in priming effects have been attributed to differences in the strength of an association between two words (Fischler, 1977a; Seidenberg, Waters, Sanders, & Langer, 1984), differences in processing mechanisms, and differences in the type of stimuli being used,. In our discussion of Experiment 4, we concluded that the priming effect observed was the product of automatic processing; our aim in Experiment 5 (this chapter) is to determine whether awareness of a relationship is a measure of semantic association using priming as an index. To investigate the role of semantic activation in a LDT, it is necessary to determine whether facilitation occurs before the target is recognised as a word (pre-lexical processes) or whether the prime-target relationship facilitates the lexical decision after the target has been identified (post-lexical processes).

Evidence that different processing mechanisms are employed

The priming literature makes a distinction between automatic and attentional processing. Attentional processing is described as an intentional, capacity-limited process requiring awareness of the stimuli, whereas automatic processing is data driven with an unlimited capacity, occurring outside awareness (Dark & Benson, 1991).

A question that has spawned much research is whether semantic analysis is an automatic or an attentional process (Dark & Benson, 1991). In a review covering nearly twenty years of research using the priming paradigm in LDTs and pronunciation tasks, Neely (1991) has identified several patterns of apparent dissociation between lexical decision and pronunciation.

Neely (1991) suggests that three mechanisms are needed to account for the differences reported in the priming literature. The first, he proposes, is automatic processes causing a spread of activation through semantic memory (Collins & Loftus, 1975). The second mechanism is expectancy; this is an attentional process and requires identification of the prime so that expectancies about the target may be generated. The third mechanism is a post-lexical process which allows the presence or absence of a relationship between the prime and the target to aid the lexical decision. Neely claims that all three mechanisms operate during a LDT.

Automatic spreading activation

Siedenberg et al. (1984) argue that priming effects observed when the same stimuli are employed in both pronunciation tasks and LDT can be attributed to automatic spreading activation. They propose that the process of decoding the target words is facilitated either by constraining the cohort of possible alternative word representations, or by facilitating discrimination between words within that cohort. Siedenberg et al. proposed that spreading activation occurs only when the word pairs are highly related, either associatively or semantically. They attribute priming effects that are produced only in a LDT, and not in a pronunciation task, to post-lexical processes.

Automatic priming observed in a LDT has often been interpreted in the framework of Collins and Loftus' (1975) model of spreading activation. They propose that semantic knowledge is represented by a network of connected conceptual nodes. This model accounts for priming in the following way. The presentation of the prime results in the activation of its semantic representation; activation will then spread to semantically related representations, which in turn activate corresponding lexical representations. If the lexical representation of the target word is already activated, and if it is assumed that a certain degree of activation is required before recognition occurs, then primed target words will be recognised more readily. According to this account, priming occurs as a result of semantic associations between the prime and the target. But if priming occurs as a result of a relationship encoded as links between lexical level representations, this would obviate the requirement of semantic activation.

Compound-cue theory

Ratcliff and McKoon (1988) put forward an account of priming which assumes that the processes employed in pronunciation tasks versus LDTs are fundamentally different. They claim that responses to LDTs can be made on the basis of familiarity, whereas pronunciation tasks require the retrieval of one specific name from a lexicon containing tens of thousands of entries. Their theory suggests that a combination of prime and target serves as a cue to memory. The familiarity of the compound (prime + target) is used to make the lexical decision. It is assumed that because words are more familiar than nonwords, the higher the computed familiarity of a compound cue the faster a "word" response can be determined. If the target is a nonword, then the compound cue will result in a very low familiarity value and a "nonword" response can quickly be selected. Instances that produce only a moderate familiarity require additional processing, hence slower response times are recorded for unrelated word pairs. Although compound cue theory can account for much of the data reported in the priming literature, such as frequency effects, subliminal priming and inhibition effects, it does not account for priming between semantically related but non-associated word pairs, since the familiarity of a compound cue is a product of the associative strength between a prime and a target (Neely, 1991).

It is apparent that the priming phenomenon is not mediated by one process. Priming effects have been attributed to several of the processes putatively involved in a lexical decision task. In our experiment we have used an LDT to examine semantic associations; it is apparent that before we can draw conclusions about the properties of a semantic association we need to establish whether any priming observed has occurred as a result of automatic or intentional processing. We propose that semantic associations produce automatic activation and, that this facilitates the pre-lexical target recognition processes rather than post-lexical decision processes.

Target expectancy

Neely (1991) proposes that expectancies about the target are produced following identification of the prime. Expectancy generation occurs when participants are aware of the prime and generate possible targets. Evidence of expectancy can be seen in the proportion effect: the mean amount of priming produced increases with the proportion of related prime-target pairs (den Heyer, Briand, & Dannenbring, 1983). However, Seidenberg, Waters, Sanders, and Langer (1984) produced priming using asymmetrical prime-target pairs such as hop-bell; they argued that this effect is unlikely to be produced by an expectancy strategy because bell is not a free associate of hop.

Fischler (1977b) tried to induce target expectancy in a LDT by exposing participants to highly associated pairs prior to the critical trial, but the priming effect produced was not significantly different to the condition in which participants saw no associated pairs prior to the critical trial. At the end of the experiment, participants were asked if they had noticed that some of the word pairs were related. There was no difference between the performance of those who were aware that some pairs were related and those who were not. Fishler (1977b) obtained similar results with a single presentation task. He added an additional condition in which he specifically instructed participants that some of the successive items were related and that the purpose of the experiment was to determine whether people could take advantage of this information when making a word decision. Fishler's results showed no difference between the participants with explicit instructions and those who were not told about the effect, nor was there an interaction between effect and instructions. He does suggest that with more preliminary trials an additional facilitative effect might occur as processes involved in the task become more automatic.

Post-lexical processes

Briand, den Heyer, and Dannenbrig (1988) required participants to make a lexical decision about a briefly displayed prime word after they had named the target stimulus. Participants were more likely to make a correct response if the target and the prime were semantically related; Briand et al. dubbed this phenomenon *retroactive priming*. The conclusions that they drew from this finding are that processing the target influenced the ongoing processing of the prime which in turn influenced the processing of the target. Dark and Benson (1991) found additional support for retroactive priming effects. Their experiments (2 and 3) required participants to perform a prime recognition task after they had completed a LDT. During the task the primes were shown very briefly. In Experiment 2 the prime was shown for 33ms followed by an interval of 17 ms before a mask was displayed for 50 ms. The stimulus onset asynchrony (SOA) was 1000 ms. In Experiment 3 the prime was displayed for 50 ms with an interval of 150 ms before the target was displayed; the SOA was 250 ms. On completion of the task, participants were given an unexpected forced choice recognition task using the same materials. Recognition memory was low, but there was significantly better recognition of primes which had been related to targets in the LDT. Dark and Benson also reported that only those primes that were recognised produced a priming effect. There was no significant difference in the priming effect produced by the unrelated primes versus the unrecognised primes. They claim that this is further evidence that semantic priming is not an automatic process, since priming was not dissociable from awareness of the prime.

Retroactive priming should not be confused with *backward priming*, which refers to the direction of a relationship in an asymmetrical paired association. For example, the word “crew” might produce the associate “cut”, but the word “cut” does not produce the associate “crew”. In symmetrical associations each half of the word pair would produce the other in a word association task; for example, "boy" is associated with "girl" as much as "girl" is associated with "boy". Seidenberg, Waters, Sanders, and Langer (1984) produced a priming effect (Experiment 2) using asymmetrically related prime targets which, they argued, demonstrated the presence of post-lexical processing since the prime effects could not be produced by participants generating an expectancy about the target, nor could it be attributed to a spread of activation. They argue that the LDT is facilitated by the post lexical judgement: Is the target word related to context?

What is in a Word Association?

In Chapter 4 we concluded that awareness of a relationship is necessary before that relationship can be considered to be symbolic. In Experiment 5 (this chapter) we aimed to test our hypothesis that semantically related word associations are open to conscious inspection: that a semantic relationship is an explicit relationship. However, there is much debate in the literature about what comprises a semantic association between words. An additional experimental question was framed about the origins of semantic associations: are they derived from episodic/perceptual associations, or from verbal information?

The majority of lexical decision experiments investigating semantic priming have employed related prime-targets drawn from word association norms (e.g., Keppel & Postman, 1970). These normative lists are constructed by compiling the relative probabilities with which words will elicit other words in a free association task. The origins of these associations are, however, diverse and idiosyncratic: deriving from episodic experience, verbal knowledge, and patterns of verbal regularity. It has been argued that free associates are not necessarily related by semantic similarity; they may also be related by "accidents of contiguity" (Fischler, 1977 a, p.335).

Hodgson (1991) investigated which types of relationships between words might support priming in both a pronunciation task and a LDT. He compiled word pairs from a range of different types of relationship: antonyms, synonyms, conceptual associates (word pairs whose referents are associated in the world; e.g., rain-umbrella and hoe-weed), phrasal associates (word pairs associated by common phrases; e.g., mountain-range, and salad-bowl), and co-ordinate and superordinate-subordinate pairs. To measure the strength of association between the word pairs, Hodgson collected free associates for the first word of each pair (the prime). The frequency with which the target word was generated for each class of relationship was calculated: Targets that were conceptually related were the most frequently generated with a mean predictive strength of 16; for phrasal associates the mean predictive strength was 9.5. In contrast, the targets from the two classes of categorical relationship were generated significantly less frequently than for the other types of relationship (mean predictive strength of 1.9 and 4.8 for category co-ordinates and for superordinate-subordinate respectively).

This is the pattern that might be expected from the developmental sequence of linguistic symbols described by Barsalou (1991). He proposes that linguistic symbols develop from perceptual experience in the same way as perceptual symbols. As simulators for words become established, they become linked either to an entire entity or event, as in the word "car", or to a part of that entity, as in the word "tyre". Links between the simulators for the words develop so that there is a spread of lexical associations that mirror the underlying conceptual field. Eventually, if a simulator for a word is activated, this will produce activation in the corresponding conceptual simulations. The surface syntax in speech or text provides both instructions for constructing conceptual simulations and the means for constructing novel simulations.

In this way, language provides the means for developing conceptual representations that extend beyond an individual's direct experience.

Hodgson (1991) found that the predictive strength of associations did not correlate with the amount of facilitation produced between the associated words in a LDT. Hodgson used four different SOAs to determine whether different types of relationship might cause differential rates in spreading activation. Despite the differences in predictive strengths, he recorded significant priming effects for all classes of relationship at SOAs of 500 ms, 250 ms, 150 ms, and 83 ms. There were no significant differences in the amount of priming recorded for the different classes of relationship. Hodgson concluded that his results suggest that automatic priming is not restricted to a purely lexical network, nor to a specifically semantic network.

The results we obtained in Experiments 3 and 4 suggest that priming occurs between imagery and lexical representation; we propose that semantic associations are derived from both verbal and perceptual processes. Those experiments employed artifical (novel) stimuli. We concluded that semantic relationships had been established between these novel words and pictures among our "aware" subjects. Only subjects who were aware of the relationship between primes and targets were able to benefit from priming based on that relationship. This raises the question: is awareness of the relationship between prime and target necessary for semantic priming between real words? In Experiment 5 (this chapter), participants were asked to describe how word pairs drawn from different normative sources were related. It was predicted that semantic associations would not be classed as purely verbal knowledge but would also be related through imagery.

Are word associations semantic?

Paivio's dual coding model predicts that semantic representation will be spread across both the visual and the verbal systems, with abstract information represented in the verbal system and perceptual information in the visual system. The strongest associations would be between concrete words since they activate representations in both verbal and visual systems. Deacon's (1997) model of symbolic reference proposes that semantic or conceptual reference occurs as a result of understanding the relationships within a logically closed group of signs and tokens that have indexical relationships with each other. The meaning of an item is a product of its relationships with other signs and tokens within that closed group. The signs and tokens are lexical representations or representations of pictures or objects in the world. Patterns of association develop either directly from experience of objects in the world or from associations between tokens. This model suggests that semantic association is restricted neither to the lexical nor to the perceptual domain, since semantic knowledge is enclosed in patterns of relations existing among lexical and perceptual representations.

The data produced by our decision task in Experiment 4 showed that priming could be produced between novel words associated only by participants' experience of a paired association between their associated (referent) pictures, and picture priming could be derived from an association between the names for those pictures. We propose that semantic priming is an index of knowledge of relationships existing between or within both lexical and visual representations.

Automatic Priming: Semantic or Associative?

The debates about automatic versus intentional priming, and about semantic versus associative relations, have implications for different models of semantic representation.

Shelton and Martin (1992) argue that associative priming can be derived from automatic processes, whereas semantic priming reflects strategic processes such as expectancy generation or post-lexical checking. They propose that the priming effect they produced derives from a process of post-lexical checking, in which the relationship between the prime and the target is assessed after the target has been identified and this facilitates the lexical decision process (See Neely, 1991).

Shelton and Martin (1992) compared the effects of semantically related but not associated word pairs with associatively related word pairs (according to Postman & Keppel's, 1970 word association norms). When selecting semantically related word pairs, Shelton and Martin followed Smith, Rips, and Shoben (1974) and selected word pairs that they deemed to have overlapping semantic features. Target recognition would be facilitated if shared semantic features were already activated by the prime. Over half of the word pairs were category co-ordinates, but pairs in which both members were highly typical exemplars were avoided. Examples of their semantic pairs include "duck-cow", "dance–skate", "motel-tent", and "peas-grapes". Similar ratings of "semantic similarity" were obtained for both the associative list and the semantic list.

Both the associative and semantic pairs were presented to two groups of participants using different LDTs in each group. The first LDT employed a paired presentation technique, in which, following a fixation mark, the prime was displayed for 250 ms and, after an ISI of 500 ms, the target was displayed for 250 ms; participants responded only to the target word. The purpose of this task was to demonstrate that priming could be obtained between the related prime-target pairs. The second LDT employed a single presentation methodology in which stimuli were presented individually at equal time intervals so that participants were unaware that there were word pairs; this was to ensure that participants could not employ strategic processes. Shelton and Martin obtained priming for both the associative and semantic word pairs using the paired presentation task; however, they only obtained priming for the associated pairs using the single presentation technique. Shelton and Martin conclude that automatic priming occurs only between associated word pairs and not between non-associated words related through shared semantic features. They propose that this is evidence that automatic priming is due to a spread of activation through nonsemantic lexical associations. Shelton and Martin suggest that, since there is no evidence that automatic priming reflects semantic associations, it might be due to frequency of co-occurrence.

Williams (1996) examined the possible dissociation between the representations of lexical associations and semantic associations that produce facilitation in LDT's. He claims that the differences observed by Shelton and Martin (1992) could be attributed to a differential time course of activation. Williams demonstrated priming in a LDT for word pairs that were semantically similar, and also for word pairs that were rated as close collocates in addition to being strong normative associates. His data did not support the idea that associative relations are purely intra-lexical --(restricted to lexical level representations). Williams argues that automatic priming reflects semantic activation; it is the retrieval of word meanings that is primed rather than the activation of lexical level representations.

In each LDT (Experiments 2, 3, and 4), Williams (1996) employed a forward masking technique combined with a short SOA (50 ms) between the prime and the target to ensure that any priming was due to automatic rather than strategic processes.

Williams selected semantically related word pairs that included approximately 50% hyponyms (one word is a superordinate of the other, e.g., bag-suitcase), 18% meronyms (one word is a part of the other, e.g., hand-palm); the remainder were category coordinates selected because they were intuitively similar (e.g., blanket-sheet). Association strengths were obtained for these word pairs by presenting the prime word in a free association task to a group of participants who were not taking part in his priming experiment. A percentage score was calculated that represented the mean number of times the target was generated as one of the first three associates for the prime. A significant priming effect of 20 ms was obtained. As a more stringent measure, Williams excluded data from participants who were able to report the presence of the prime; he also excluded data from the four strongest associates. The mean primary association strength of the 18 pairs included in the analysis was 7.5%. The analysis of this data set showed a significant priming effect of 24 ms. Williams proposes this provides evidence that the priming effect obtained was both automatic and semantic. His results, then, contrast with the results of Shelton and Martin (1992).

In a subsequent LDT, Williams (1996, Experiment 3) compiled a list of 20 category co-ordinates that were rated as highly functionally similar but with a low associative strength (e.g., radio-television, train-bus); 14 of these pairs were also rated as highly structurally similar (e.g., dog-fox, stone-brick). The mean primary associative strength for these word pairs was 4%. A significant mean priming effect of 39 ms was produced and, in a further analysis that excluded data from participants who reported an awareness of the primes, there was a significant priming effect of 52 ms.

In his final LDT task Williams (1996, Experiment 4) used the list of word pairs from his Experiment 3 and a list of word pairs comprising the same 20 prime words as in his Experiment 3 paired with target words that were judged to be from the same semantic field but with lower semantic similarity. The mean primary association strength of the lower semantic similarity word pairs was 0.2%. Significant priming effects of 16ms were obtained for the lower similarity pairs and 18ms for the higher similarity pairs. After excluding all participants who were aware of the primes, the mean priming effects were 22 ms and 18 ms for the low and high similarity pairs respectively.

This suggests that the observed priming resulted from deeper processing mechanisms than that proposed by the intra-lexical hypothesis (Williams, 1996). The intra-lexical hypothesis suggests that associative relations between words are encoded at the level of their lexical representations and that, as such, they will support priming without involving semantic processing. Williams claims that these experiments demonstrate automatic priming produced in the absence of an associative relationship. This, he argues, is evidence that priming occurs during the retrieval of meanings rather than at a level of lexical identification and offers further support for Collins and Loftus' (1975) model of spreading activation.

The semantically related pairs employed by Williams had a low associative value as calculated by presenting a free association task to 6th form school children. It is possible that this value might have been higher if it had been calculated using free associates generated by the Cambridge undergraduate population from whom Williams drew his participant sample.

There was no interaction between the semantic and the collocates condition, and, because the priming effects were produced by the most highly associated of the collocates, no clear divide between priming as a result of strong association or of close collocation can be made.

Experimental Aims

Williams (1996) suggests that it would be hard to separate the effects of collocation and semantic relationship, since "it may be difficult to find normative associates that have a similar production frequency that are not close collocates"(p.134). This is an important discrimination because without separation there is no clear distinction between priming effects due to stored lexical patterns and effects due to stored semantic relations. In Experiment 5 (this chapter) we will attempt to examine the question of whether automatic priming is derived from collocation or semantic association.

The data collected in Experiment 4 (Chapter 4) suggest that semantic priming in a LDT requires automatic access to explicit knowledge about the relationship between prime and target. Dual coding models (Barsalou, 1999; Paivio, 1991) propose that a semantic association between words can be represented by (a) an association between logogens within the verbal system (e.g., associations between abstract concepts), or (b) an association between imagens within the visual system, mediated by the referential links between the systems. Deacon's (1997) model of symbolic referential relationships suggests that semantic relations result from the recognition of a pattern of relations within a logically closed system of token-token and token-sign relations.

A common feature of both of these models is that semantic information derives from both perceptual and verbal experience, and is stored within both verbal and perceptual memory systems. We contend that the underlying difference between associative relations and semantic relations is that semantic relations require explicit knowledge about the relationship, whereas associative relations can be derived from implicit learning. If the same automatic activation underpins priming, it might be expected to reflect patterns of association that are the products of explicit processing, rather than implicit associations arising only from exposure to random patterns of environmental contiguity. From this it would be predicted that priming effects should be recorded only for those instances where the prime and the target are explicitly associated by the participant, and there should be no effect if the participant has no conscious knowledge of an association between those two words. If this is the case, it would bring a new perspective to the associative versus semantic priming debate.

Methodological Decisions

The results of Experiment 4 suggest that priming reflects the product of explicit processing, and that patterns of association that are available to conscious inspection. However, it cannot be claimed that the relationships between the novel pictures and the novel word pairs in Experiment 4 is comparable with the long history of experience that underpins associations in the real-world, both between real words and between words and their referents in the real world. This experiment aims to examine whether priming reflects the contents of explicit memory.

There are various ways in which the relationship between two words can be measured. We selected our associated word pairs using free associates, category coordinates and collocates. As has been discussed, there has been some debate about whether free association reflects a semantic relationship. If priming were found for free associates and for category co-ordinates, it would follow that an additive effect might be predicted for word pairs that are both free associates and category co-ordinates, if the locus of priming was different. Collocates were selected because it has been suggested (Lupker 1984, Shelton & Martin, 1992) that associations within the lexical network arise from the frequency of co-occurrence of written and spoken words. If priming was obtained for collocates but not for semantically similar pairs, this would support the intra-lexical hypothesis; if any priming were obtained for the semantically similar pairs, this would undermine the lexical locus position and suggest priming effects are linked to semantic similarity.

Experiment 5 has been designed to test the individual and combined effects of collocation, category membership, and normative association and to examine the role of explicit knowledge about these relations in a LDT. We propose the following hypotheses: explicit knowledge about the relationship is necessary to produce a semantic priming effect; a stronger priming effect will be produced if words are associated as a result of perceptual experience.

The measure of interest in Experiment 5 is automatic priming, rather than priming attributable to strategic processes. To ensure that any facilitation could be attributed to automatic processes the following procedures, employed by Williams (1996), were adopted. Forward masking of the prime was employed to prevent semantic matching strategies by obscuring the relationship between the prime and the target. The SOA was kept very short to eliminate expectancy strategies (den Heyer, 1986).

There is evidence that blocked stimuli produce a facilitative effect that might influence either target expectancy strategies or post-lexical strategies. Bajo (1988) found that keeping the same class of stimulus pair, for example word-picture, picture-picture, maximised the prime effect in both naming and categorisation tasks, suggesting that strategies or expectations are being employed. Kroll (1990) found that mixed block presentations increased the response latency, which would not be expected if the processes involved were purely automatic. Priming effects produced from a very short exposure time disappeared if the trials were presented in a mixed block with trials that had a longer prime exposure time (Chapnik Smith, Besner, & Miyoshi, 1994). To increase the chances that any priming effect produced in Experiment 5 reflects automatic spread of activation rather than expectancy strategies, the different types of relationship between prime target pair were presented in mixed blocks.

The proportion of related trials has been shown to have an effect on the size of the priming effect produced when the SOA is greater than 500 ms, both when the prime is associatively related (den Heyer, Briand, & Dannenbring, 1983; Seidenberg Waters, Sanders & Langer, 1984; Tweedy, Lapinski, & Schvaneveldt, 1977) and when the prime is categorically related (Neely, Keefe, & Ross, 1989). Shelton and Martin (1992) attribute this effect to strategies rather than automatic processes, arguing that automatic processes would be constant regardless of the number of related trials. It seems probable that increasing the number of related trials increases the likelihood of participants noticing the relationship and thus increases the chance of their using expectancy strategies. The experiment was designed with a low proportion of related trials (25%) and a very short SOA (50 ms).

To amplify any priming effects, it was decided to degrade the target. Williams (1996, Experiment 1) examined the effects of target degradation and, in keeping with previous research (e.g., Sperber, McCauley, Raigen, & Weil, 1979), found that facilitative effects were increased when the target was degraded. This effect was particularly pronounced for the semantically similar and the free associates pairs. Mild degradation had little effect on the co-ordinate word pairs, but severely degraded co-ordinate targets produced a facilitative effect of 47ms. This is possibly due to a different time course for processing semantic information compared with lexical information. La Heij, Dirkx, and Kramer, (1990) reported a semantic interference effect at SOA close to zero when naming a picture after a categorically related prime word had been displayed. In contrast, the same word-picture pairs produced a facilitation effect at an SOA of 400 ms. Williams (1996) suggests that a common feature of those experiments reporting a semantic priming effect is the speed of the response time; the slower the mean RT the larger the semantic priming effect. For example, Hines et al. (1986) reported a priming effect of 5ms for the participants with the fastest overall mean response time in Experiments 1 and 2, and 36 ms for the participants with the slowest overall mean RT.

Because a large variability in RT between participants had been obtained in pilot studies, it was decided that the control and experimental measures (unrelated vs. related prime target pairs) should be presented as a repeated measure.

Experiment 5

Method

Participants

Of the 105 participants who were recruited, 88 completed the experiment. Participants recruited from the community panel were paid £7.00, and participants recruited from psychology undergraduates at Bangor University of Wales received two course credits. The age range was 18 - 50.

Stimuli

The following sets of word pairs were constructed for the LDT. Fifteen nouns were selected as target words. The mean Krucera-Francis frequency value for these target words was 89.2 (*SD* = 87.2; range = 8 - 321). For each target word, a set of seven different prime words were found that conformed with the following seven conditions of normative relationship: a prime that was a free associate (but not a collocate or a member of the same category class); a prime that was a collocate (but not a free associate or a member of the same category class); a prime that was a category co-ordinate (but not a free associate or a collocate); a prime that was both a free associate and a collocate (but not a category co-ordinate); a prime that was both a free associate and a category co-ordinate (but not a collocate); a prime that was both a collocate and a category co-ordinate (but not a free associate); and finally a prime that was related as a free associate, a collocate and also a member of the same category class. Each target word was also paired with an unrelated prime. Associated primes were selected from the Kiss (1973) *Edinburgh Associative Thesaurus* (EAT); category co-ordinates were taken from Battig and Montague's (1969) Category Norms; collocates were selected using *Cobuild Direct Collocation* values. The word pairs are shown in Appendix 5.1

Associated prime words were selected from the Edinburgh Associative Thesaurus so that the target words were produced as responses to the prime words. The EAT gives a rank ordered list of free associates to any given word according to the number of people who generated that word as the first associate; it also gives a score representing the proportion of respondents who generated each associate. The mean rank order of the targets as associates of the prime was 3.6 (*SD* = 3.8; range 1 - 20). The mean EAT proportional response value was 17 (*SD* = .17; range, 69 - .01). The EAT values for each class of relationship are shown in Table 5.1.

Battig and Montague's (1969) Category Norms were used to determine categorical relationships such that the prime and the target were both members of the same category, and wherever possible having similar rank. The mean rank order for the primes was 13.6 (*SD* = 13.6, range = 1- 52); the mean rank order for the targets was 6.6 (*SD* = 6.4, range = 1 - 24). Scores based on the proportion of Battig and Montague 's respondents who generated each category exemplar were calculated. The mean values were 40% (*SD* = 30%, range = 1- 99%) and 58% (*SD* = .28, range = 9 - 99%) for the primes and the targets respectively. The mean normative values for each condition of normative relations are shown in Table 5.1.

Table 5.1: Mean relationship measures(+ SD) for each condition of normative prime-target relations.

Prime-Target Relations	Krucera-Francis frequency	mean EAT rank	mean EAT prop	mean COB *t* score	mean COE MI score	mean B&M rank	mean B&M prop.
Ass	4.9 (4.91) *n* = 13	3.1 (2.53) *n* = 15	.19 (.2) *n* = 15				
Ass+ Col	25.7 (36.7) *n* = 14	2.1 (1.6) *n* = 15	.31 (.23) *n* = 15	3.9 (1.95) *n* = 15	7.0 (2.03)		
Cat	24.3 (28.7) *n* = 13					11.2 (8.13) *n* = 15	.36 (.28) *n* = 15
Cat + Ass	19 (15.83) *n* = 15	4.6 (4.03) *n* = 15	12 (.1) *n* = 15			25.8 (15.9) *n* = 15	.14 (.15) *n* = 15
Cat+Ass+Col	85.2 (119.78) *n* = 15	4.7 (5.55) *n* = 15	12 (.1) *n* = 15	4.2 (1.63) *n* = 15	5.5 (1.48)	5.9 (5.38) *n* = 15	.58 (.28) *n* = 15
Cat+Col	161.2 (252.1) *n* = 15			3.2 (1.35) *n* = 15	4.4 (2.46)	16.7 (16.11) *n* = 15	.36 (.3) *n* = 15
Col	67.2 (77.58) *n* = 12			2.9 (1.05) *n* = 15	6.0 (2.95)		

Note: ASS p = free associate, CAT p = category co-ordinate, COL p = collocate, EAT p = Edinburgh Associative Thesaurus, B&M p = Battig and Montague's category norms, COB p = Cobuild Direct interactive Corpus Access Tool

The *Cobuild Direct Interactive Corpus Access Tool* was used to obtain collocation values. The full corpus of 20 million words was searched for collocation values. This corpus is drawn from the Bank of English, and is compiled from spoken speech, magazines, newspapers (*Times* and *Today*), British and American books and ephemera. Collocates were selected that had both a high Mutual Information score (MI score) and a high *t* score.

The MI score is a measure of the strength of association between two words, calculated by comparing the observed frequency of collocation with the frequency with which the words might be expected to occur in any given sample. The bigger the score the greater the influence the node word has on its surrounding lexical environment. This measure is accurate for word pairs with a high joint frequency; it also highlights technical terms and fixed phrases such as "post mortem" with low frequency scores. However, the comparisons between the observed frequencies and the expected frequencies for words with a low collocation frequency will be unreliable. For this reason a *t* score is calculated to determine whether the association between two words is true and not due to the vagaries of chance. The *t* score gives a reliable measure of significant collocates which occur frequently, for example., "post office" or "post war". If a collocation has both a high *t* score and MI score it can reliably be considered to have a strong collocational relationship. For this reason both t scores and MI scores are reported in Table 5.1.

A series of nonwords was generated using the program *Nonwords to Go (Graham, 1996)*, and checked for nonword status using the ClarisWorks English dictionary. Evidence has been produced suggesting that nonwords constructed by altering a vowel or consonant activate lexical information corresponding to real word lexical neighbours. This has been attributed to a graphemic similarity effect such that there is repetition priming effect produced between the words, for instance, *stafe-STATE, bamp-CAMP* (Evett & Humphreys, 1981; Forster, Davis, Schoknecht, & Carter, 1987), This is particularly so when the start and end letters are identical (Humphreys, Evett, & Quinlan, 1990). Nonwords have also been shown to produce a psuedohomophone effect caused by phonological processes influencing lexical processing (Ferrand & Grainger, 1992; Lukatela & Turvey, 1994). The experimenter excluded all nonwords that were judged to be similar to real words; because the design of this experiment was intended to produce as large a semantic priming effect as possible, it was desirable to ensure that the nonwords in the LDT did not produce lexical or semantic interference.

Seven lists of word pairs were compiled. In each list each of the 15 target words appeared twice, once paired with a related prime and once paired with an unrelated prime. The lists are shown in Appendix 5.1. Each list comprised prime-target pairs conforming to all the different permutations of normative relations. For example, the first target word was primed by an associate on the first list, a collocate on the second list, a category co-ordinate on the third list, et cetera. The second target word was primed by a collocate on the first list, a category co-ordinate on the second list, both a free associate and a collocate on the third list, et cetera. For each list, 30 nonword targets were paired with prime words taken from the other lists.

To reduce any effects of repetition priming, each list was divided into two such that each target word appeared as a target once in each sublist, in one paired with a related prime, in the other paired with an unrelated prime. Half of the targets were paired with a related prime in each sublist. These sublists were presented in counterbalanced order across subjects, and pseudorandomised internally within subjects, so that half of the subjects saw each target paired first with an unrelated word and half saw it first paired with a related prime.

In the first sublist the prime words appeared in a lower case and the targets appeared as capital letters, and in the second the prime words appeared in capital letters and the targets in a lowercase font. Thus, each target word would appear once in capitals and once in lower case within each condition.

In addition to the seven experimental lists, a practice list of five real word pairs and five word-nonword pairs was compiled.

All the prime words were real words; there was a 50% probability that a prime would be followed by a real word target, and a 25% probability that the target word would be related to the prime. Wherever possible, word pairs that were visually and phonologically dissimilar were selected, as it has been shown that it is possible to induce priming if the unidentified prime is orthographically or phonologically similar to the target, if the design has a short SOA between the prime and the target (Evett & Humphreys,1981; Ferrand & Grainger, 1992).

A further seven lists of words for the word association task were compiled. Each list contained the prime words from its corresponding experimental list; for example, List 1 was comprised of the prime words from the related pairs in Experimental List 1.

Apparatus

The first part of the experiment was a free association task. This required only a pen and paper for each participant. The experimenter used the association task word lists and a stopwatch

The second part of the experiment, the LDT, was performed using a program generated in Psyscope (Cohen, McWhinney, Flatt, & Provost; 1993) run on a Power Macintosh 4400/160, and displayed on a 15" Apple monitor using a Psyscope button box for recording the response times.

During the post task interview the experimenter used questionnaire sheets to record participants responses.

Design

There were three tasks in this experiment: a free association task, a LDT, and a structured interview. To measure the associative strength of the word pairs for the participant sample employed in our experiment, the first task was a free association task. During this task participants were asked to generate free associates to prime words that were employed in the second task, Participants were not told that these words would be used during the second task. The second task was a LDT. The last was an interview designed to assess whether the participants were aware of any relationship between the normatively related word pairs, and if so how they considered the word pairs to be related. This experiment took place in two sessions separated by an interval of at least one week. In the first session participants were given a free association task and in the second session participants performed a LDT immediately followed by the interview.

The LDT had a mixed design. The between subjects variable was the normative relationship between the prime and the target. There were seven conditions of normative relationship (associative, collocational, categorical, associative + collocational, categorical + associative, categorical + collocational, and categorical + associative + collocational). The within subject variable was the prime-target relationship; each target was presented twice, once preceded by a related prime, and once preceded by an unrelated prime. The dependent variable was response time (RT) measured from the onset of the target.

Any difference between the length and frequency of the target words was controlled for; all of the target words were presented to each participant. Individual differences in response times were controlled by treating prime-target relationship as a within subject variable.

Free association task

This part of the experiment took place in a quiet research room. Participants were run individually or in groups of up to four. There were seven participant groups in this experiment, one group for each list of prime words. Allocation of participants to each group was pseudorandom; it was dependent on the order in which the appointments were filled and the need to balance the numbers in each group. Each participant was given some lined paper and a pen. The experimenter then read the following instructions to the participants.

> I am going to read a series of words to you. After each word you will have 30 seconds in which I would like you to write down all the word associations that come into your head that relate to the word that I have read to you. Try to give associations to the word that I have given you and avoid chains of association. For example if I said “knife” and you associated the word "sharp" with knife but then went on to give the words “needle” and the “thread” that is a chain of association, whereas “sharp”, “fork” and “dagger” might all be associates of the word “knife”. I am not going to use the information to psychoanalyse you, so please feel free to write down whatever associations come into your head.

Using the word list appropriate to that group the experimenter proceeded with the free association task. Each word on the list was pronounced twice and spellings were provided if requested. After reading each word, the experimenter started the stopwatch;, after 30 seconds the experimenter said “Stop writing. And the next word is ...." This was repeated until all the words on the list had been read out. Participants were asked to write their name and group

Lexical decision task

Participants performed this task individually, in a quiet research room. The word list presented in this task was selected to correspond with the group to which participants were allocated during the free association task. For example, participants in Group 7 were presented with List 7. The order in which the related and unrelated primes were displayed was counterbalanced, alternating participants in each group commenced with the "a" list or the "b" list. At the start of the experiment the following instructions were displayed on the screen.

> Welcome to this experiment. Your task is to decide whether the target word is a word or a nonword. At the start of each trial you will see a row of "xxxxxx" to warn you that the target word is about to be displayed.
>
> If the target word is a real word press the red button
>
> If the target is a nonword press the green button.
>
> Please make your responses as quickly and as accurately as possible. There are 10 practice trials and 60 experimental trials. When you are ready to start the practice trials please tell the experimenter.

After 10 practice trials the following message appeared on the screen

> You have now finished the practice trials. When you are ready to begin the experimental trials please tell the experimenter.

Providing the participant had understood the task, the experimenter started the 60 experimental trials. Each trial commenced with a forward mask of "XXXXXX" displayed for 500 ms (for longer words the mask was increased in length accordingly).The prime then appeared for 50 ms, and was immediately replaced by the target which remained on the screen for 400 ms. Participants responded by pressing either the red key (to the left) or the green key (to the right) on the button box. All the stimuli (mask, prime, and target) were presented in the centre of the screen, in Chicago font, point 18, in black on a white background. The target was degraded using a setting of 3 on the stimulus template setting in the Psyscope program. To counterbalance any bias caused by faster responses with the dominant hand, the response key designated "correct" was the red key for every other participant and the green key for the intervening participants. There was a minimum intertrial interval of 3000 ms. An additional counterbalance was the order in which the two lists for each group was presented. This was reversed after every second participant in each group, so for approximately half of the participants the first decision about a target word followed a related prime, and for the other half of the participants the first decision about that word was after an unrelated prime. The order in which the 2 sublists appeared was fixed, but the order in which the stimuli from each sublist were presented was pseudorandom.

Post LDT Interview

After completing the LDT the experimenter then asked each participant the following questions:

> Did you notice that there was a word displayed very briefly before the target word?
>
> If so did you notice if it was related to the target word?
>
> Can you recall any of the word pairs that you saw?

The experimenter then went on to explain that she was going to read out a series of word pairs, and she asked the participant to say if they were related, and if so how. Thus:

> Would you say it was a verbal association or do you have some image that unites the two words. A word association could be the feeling that one word just triggers the next, or the two words could go together because of something that you know about the world- something that you have been taught or told, or because they are members of the same category class. Imagery might involve a visual image, or provoke sensations and emotions, or it might be a motor memory, a memory of doing something. These images might result from a memory of a specific event or they might be a general sensation of an imagined image. It is also possible that you might feel that two words are related both verbally and through imagery. I would like you to try and say how you feel the words are related.

The experimenter then read the related prime-target pairs from the group list that had been used in the LDT for that participant. The experimenter noted the type of association for each word on the questionnaire response sheet.

When participants described a relationship as verbal, the experimenter prompted them to say whether the word association reflected a categorical relation, something they knew, or whether the one word "just triggered the other". If an imagery relationship was described, the experimenter prompted the participant to characterise it as a visual, other sensory, or a motor sensation. For word pairs that were reported as related by verbal and imagery associations, participants were asked to characterise the relationship that they felt to be dominant. Participants' further classification of the associations was noted. The experimenter asked the participants to confirm that they had accurately categorised each word association before reading out the next pair.

Results

The dependent variable was response time (RT) measured from the onset of the target stimulus in milliseconds. Only correct responses were included in the analysis; this led to an exclusion of 3.4% of the data. Response times greater than 1200 ms and less than 200 ms were excluded. Outliers, defined as RT greater than 2.5 standard deviations of each participant's mean response time to the targets (for both related and unrelated primes), were also excluded. A total of 6.5 % of the data was excluded. The alpha level for all analyses was .05.

The mean response times and standard deviations for each prime-target relationship are shown in Table 5.2. Priming effects were calculated as a within subjects measure, by comparing the response times to the related and the unrelated primes.

Table 5.2: The mean RT (+SD) for each condition of normative relations and prime-target relations in the LDT.

Normative Relations	n	Prime-Target Relations		Simple main effect (related vs. unrelated)
		Related mean	Unrelated mean	
associative	166	609 (136)	701 (165)	$F = 102.9$, $df = 1, 165$ $p < .0001$
categorical	170	639 (170)	690 (163)	$F = 28.3$, $df = 1, 169$ $p < .0001$
collocational	157	653 (155)	698 (163)	$F = 38.0$, $df = 1, 165$ $p < .0001$
associative + collocational	158	606 (137)	703 (155)	$F = 153.4$, $df = 1, 157$ $p < .0001$
categorical + associative	171	613 (140)	669 (155)	$F = 54.5$, $df = 1, 170$ $p < .0001$
categorical + collocational	168	638 (157)	680 (170)	$F = 21.4$, $df = 1, 167$ $p < .0001$
categorical + associative + collocational	168	627 (151)	714 (159)	$F = 161.9$, $df = 1, 167$ $p < .0001$

Effect of Prime-Target Condition

The effects of *Normative Relationship* and *Prime-Target Relations*[*] on RT were analysed using a mixed samples ANOVA. The between subjects variable was Normative Relationship. This had seven conditions (associative, collocational, categorical, associative + collocational, categorical + associative, categorical + collocational, and categorical + associative + collocational). The within subjects variable was Prime-Target relations with two conditions (related and unrelated). The dependent variable was the RT measured in ms.

There was a significant main effect of Prime-Target Relations ($F = 462.98$; $df = 1,1151$; $p < .0001$). Analyses of simple main effects showed that there was a significant effect of Prime-Target Relations for all conditions of Normative Relationship (see Table 5.2). There was no significant effect of Normative Relationship. The interaction of Prime-Target Relations and Normative Relationship was significant ($F = 8.33$; $df = 6, 1151$; $p < .0001$). The ANOVA tables are shown in Appendix 5.2.

Planned means comparisons were carried out on the interaction between Prime-Target Relations (related and unrelated) and the Normative Relationship to see if there was a significant difference in the priming effects produced in each condition of Normative Relationship. Because of the large number of comparisons this involved, Dunn's method of multiple comparisons (using Bonferroni t values) was also employed to reduce the chance of Type I (family wise) errors. Both the F values and the t values are presented in Table 5.3.

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[*] The variable names will appear with capital letters to aid the clarity of the text.

Table 5.3: Means comparisons showing significant differences between conditions of Normative Relationship (priming effect =r unrelated prime RT – related prime R)

Prime Target condition	Priming effect (ms)	Comparison condition	Priming effect (ms)	Means comparisons	Dunn's multiple t
associative	92	categorical	51	$F = 12.6$; $df = 1, 1151$ $p = .0004$	$t = 3.6$ $df = 1150$ $p < .05$
		collocational	45	$F = 15.8$, $df = 1, 1151$ $p < .0001$	$t = 3.8$, $df = 1150$ $p < .05$
		categorical collocational	42	$F = 18.2$, $df = 1, 1151$ $p < .0001$	$t = 4.7$, $df = 1150$ $p < .05$
		categorical + associative	56	$F = 9.5$, $df = 1, 1151$ $p = .0021$	$t = 3.0$, $df = 1150$ $p < .05$
categorical	51	associative + collocational	98	$F = 15.9$, $df = 1, 1151$ $p < .0001$	$t = 4.4$, $df = 1150$ $p < .05$
		categorical + associative + collocational	87	$F = 10.1$, $df = 1, 1151$ $p = .0015$	$t = 3.2$, $df = 1150$ $p < .05$
collocational	45	associative + collocational	98	$F = 19.3$, $df = 1, 1151$ $p < .0001$	$t = 4.5$, $df = 1150$ $p < .05$
		categorical + associative + collocational	87	$F = 13.0$, $df = 1, 1151$ $p = .0003$	$t = 3.4$, $df = 1150$ $p < .05$
categorical + associative	56	associative + collocational	97	$F = 22.0$, $df = 1, 1151$ p $< .0001$	$t = 3.7$ $df = 1150$ $p < .05$
		categorical + associative + collocational	87	$F = 7.3$, $df = 1, 1151$ $p = .0072$	$t = 2.6$, $df = 1150$ $p < .05$
categorical + collocational	42	associative + collocational	98	$F = 22.0$, $df = 1, 1151$ $p < .0001$	$t = 5.4$, $df = 1150$ $p < .05$
		categorical + associative + collocational	87	$F = 15.1$ $df = 1, 1151$ $p < .0001$	$t = 4.3$, $df = 1150$ $p < .05$

Analysis of Normative Relations for targets generated by participants

Prior to the LDT participants performed a free association task. A data set was constructed of RT for Normatively Related words that participants had generated during the free association task. Data were included only if the participant had generated the target word that appeared in the list presented in their LDT. Only 20.4% of the total data were included. We will refer to this variable as *Participant Generated Pairs.*

The RT for Participant Generated Pairs was analysed. The means and standard deviations for Normative Relationship condition for the Participant Generated Pairs are given in Table 5.4.

A mixed ANOVA was performed in which Normative Relationship was the between subject variable and Prime-Target Relations (related vs. unrelated) was the within subjects variable. The dependent variable was RT. There was a highly significant effect of Prime-Target Relations ($F = 59.89$; $df = 1{,}230$; $p < .0001$), but there was no effect of Normative Relationship, nor was there an interaction between the condition of Normative Relationship and Prime-Target Relations. The ANOVA table is shown in Appendix 5.3.a.

A χ^2 Test of independence was performed to determine whether the number of Participant Generated pairs was different between conditions of Normative relationship (see Table 5.4). The difference was significant ($\chi^2 = 126.8$ $df = 1, 6$; $p < .0001$). The tables for the observed and expected values are given in Appendix 5.3.b.

Table 5.4: *the mean RT (+SD) for each condition of Normative Relationship and Prime-Target Relations condition for the Participant Generated Pairs*

Normative Relationship	n	Prime-Target Relations		Priming
		Related	Unrelated	(unrelated – related)
associative	64	624 (135)	705 (145)	82
categorical	5	602 (130)	690 (91)	88
collocational	31	646.8 (161.67)	709.3 (171.43)	62.51
associative + collocational	71	594.4 (123.03)	694.1 (152.9)	99.61
categorical + associative	28	564 (125.5)	673.1 (165.68)	109.07
categorical + collocational	2	535 (66.47)	635 (36.7)	100
categorical + associative + collocational	36	588.6 (144.48)	693.6 (159.06)	104.97

Analysis of Word-Pairs by Participant's Classification.

Participants' responses to the post LDT interview were classed as "unrelated" and "related". The data sets from this classification will be referred to as Participant Unrelated and Participant Related. The Participant Related set was then classified as "related due to verbal association", "related due to imagery associations" or "related due to both verbal associations and imagery associations". These conditions for Participant Related word pairs will be referred to the "verbal-link", "imagery-link", and "both-links". Verbal-link word pairs were further classified as predominantly "categorical", "general knowledge", or "lexical associated". Imagery-link word pairs were classified as "visual", "sensory" (if the dominant sensory image was not visual) or "motor". The dominant characteristic was selected for both-link pairs. All participants' responses were classified before the data was analysed.

The percentage of Participant Unrelated word pairs was 10% of the total data set. Of the Participant Related word pairs, 43% were categorised as imagery-link, 44% as verbal-link, and 13% as both-links. The proportion of verbal-links attributed to categorical relations was 40%: 18% were attributed to general knowledge and 8% to lexical associations. Of the imagery links, 40% were attributed to visual associations, 8% to sensory associations, and less than 1% (0.7%) were associated due to motor imagery.

The percentages of Participant Related word pairs for each condition of Normative relationship were calculated. The percentage values are shown in Table 5.5.

Table 5.5: Percentage of Participant Related word pairs for each condition Normative relations.

Normative relations	Classification of Participant Related word pairs						
	Verbal-Link			Imagery-Link			
	Not related	Categorical	Lexical	General knowledge	Visual imagery	Sensory imagery	Motor imagery
categorical	14	52	-	6	24	4	-
associative	5	2	8	24	50	8	2
collocational	28	2	18	16	35	7	-
categrical + associative	6	30	3	22	35	3	-
associative+ collocational	1	-	9	23	51	16	-
categorical+ collocational	15	38	2	11	28	4	1
categorical+ assciative+ collocational	1	36	9	13	35	5	1

Effect of prime-target relations on RT for word pairs classed by participants as unrelated

The effect of Prime-Target Relations on the RT for the Participant Unrelated word pairs was analysed. The mean RTs were 674.63 ms (*SD* = 160.64) for the related condition and 669.53 ms (*SD* = 156.86) for the unrelated condition. A mixed samples

ANOVA was performed in which Prime-Target relations (related vs. unrelated) were treated as the within subjects variable and condition of Normative Relationship was treated as the between subject variable. The dependent variable was RT.

There was no effect of Prime-Target relations, nor was there an effect of Normative Relationship. There was no interaction between Prime-Target relations and Normative Relationship (The ANOVA table and means table for this data set are given in Appendix 5.4.a and 5.4.b).

A condition of particular interest in this analysis was collocation; it is possible that a history of exposure to written text would allow implicit learning of patterns of co-occurrence between words that were not necessarily available to conscious inspection. To test this, simple main effects analysis of the data from the condition of collocates was performed. The mean RT to the target following a collocate was 723 ms (SD = 168), and following an unrelated prime it was 707 ms (SD = 168). The difference was not significant. The ANOVA table is shown in Appendix 5.4 c.

Effect of prime-target relations on RT for word pairs classed by participants as related

The data set for Participant Related word-pairs excluding Participant Generated word pairs were analysed. A mixed ANOVA was performed in which Prime-Target Relations (related vs. unrelated) were treated as the within subjects variable and condition of Normative Relationship was treated as the between subject variable. The dependent variable was RT.

There was a significant effect of Prime-Target Relations (F = 332.01; df = 1, 800, p < .0001). There was no main effect of Normative Relationship, but the interaction between Prime-Target Relations and Normative Relationship was significant (F =

4.96; $df = 6, 800$; $p < .0001$). A table of means and the ANOVA table are given in Appendices 5.4.d-e. Dunn's post hoc comparisons showed no significant differences between the amounts of priming produced by each prime-target condition (see Appendix 5.4.f).

The ANOVA was repeated, this time including the Participant Generated word pairs. There was a significant effect of Prime-Target Relations ($F = 493$; $df = 1, 1037$; $p < .0001$), but no main effect of Normative Relationship. The interaction between Prime-Target Relations and Normative Relationship was significant ($F = 5.51$; $df = 6, 1037$; $p < .0001$). The ANOVA table and a means table for this analysis are given in Appendices 5.4 g-h. A Dunn's post-hoc analysis showed no significant differences between the amount of priming produced for each prime condition (see Appendix 5.4.i)

Analysis of participants' classification of the word-pairs.

The effect of participants' classification of the word –pairs was examined. The effect of Prime-Target Relations on RT for Participant Generated, Participant Related and Participant Unrelated word-pairs was compared using a mixed ANOVA (see Figure 5.1). Participants' classification of the word pairs (Participant Generated, Participant Related and Participant Unrelated) was treated as the between subjects variable; the within subject variable was Prime-target Relations (related or unrelated); the dependent variable was RT. The ANOVA table and means tables are given in Appendices 5.5.a-b.

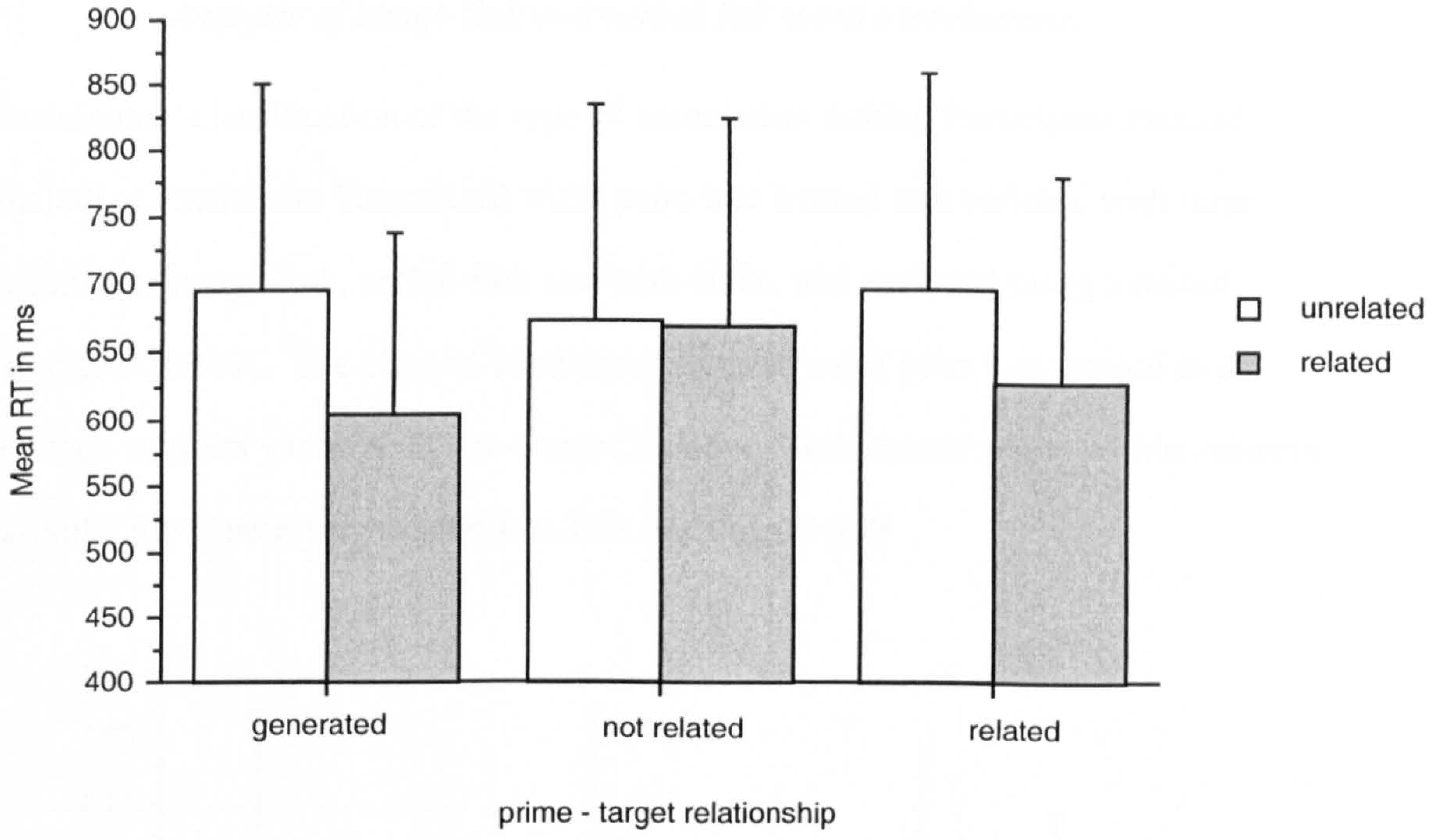

Figure 5.1: mean RT (+ SD) for the effect of participants' classification of word pairs on Prime-Target Relations

There was no main effect of Participants' Classification of the word pairs, but there was a significant effect of Prime-Target Relations ($F = 170.98$; $df = 1{,}1155$; $p < .0001$) and a significant interaction between Participants' Classification and Prime-Target Relations ($F = 25.92$; $df = 2, 1155$; $p < .0001$). Simple main effects showed no effect of Prime-Target Relations for Participant Unrelated word pairs ($F = .26$; $df = 1{,}113$; $p = .61$), but there was a significant effect of Prime-Target Relations for Participant Generated word pairs ($F = 235.7$; $df = 1{,}236$; $p < .0001$) and Participant related word-pairs ($F = 315.7$; $df = 1{,}806$; $p < .0001$) (see Appendix 5.5.c-e). Planned means comparisons showed a significantly greater effect of Prime-Target Relations for Participant Generated word-pairs compared with Participant Related word pairs ($F = 8.63$; $df = 1{,}1155$; $p = .003$) (see Appendix 5.5.f).

Analysis of image-link and verbal link word associations.

Participants' classification of the type of association linking Participant Related (including Participant Generated) word pairs was treated as a variable with three conditions: image-link, verbal-link and both-links, and analysed using a mixed samples ANOVA. The class of Participant Related word pairs was treated as a between subjects variable; Prime-Target Relations was treated as the within subjects variable; the dependent variable was RT. (see Figure 5.2)

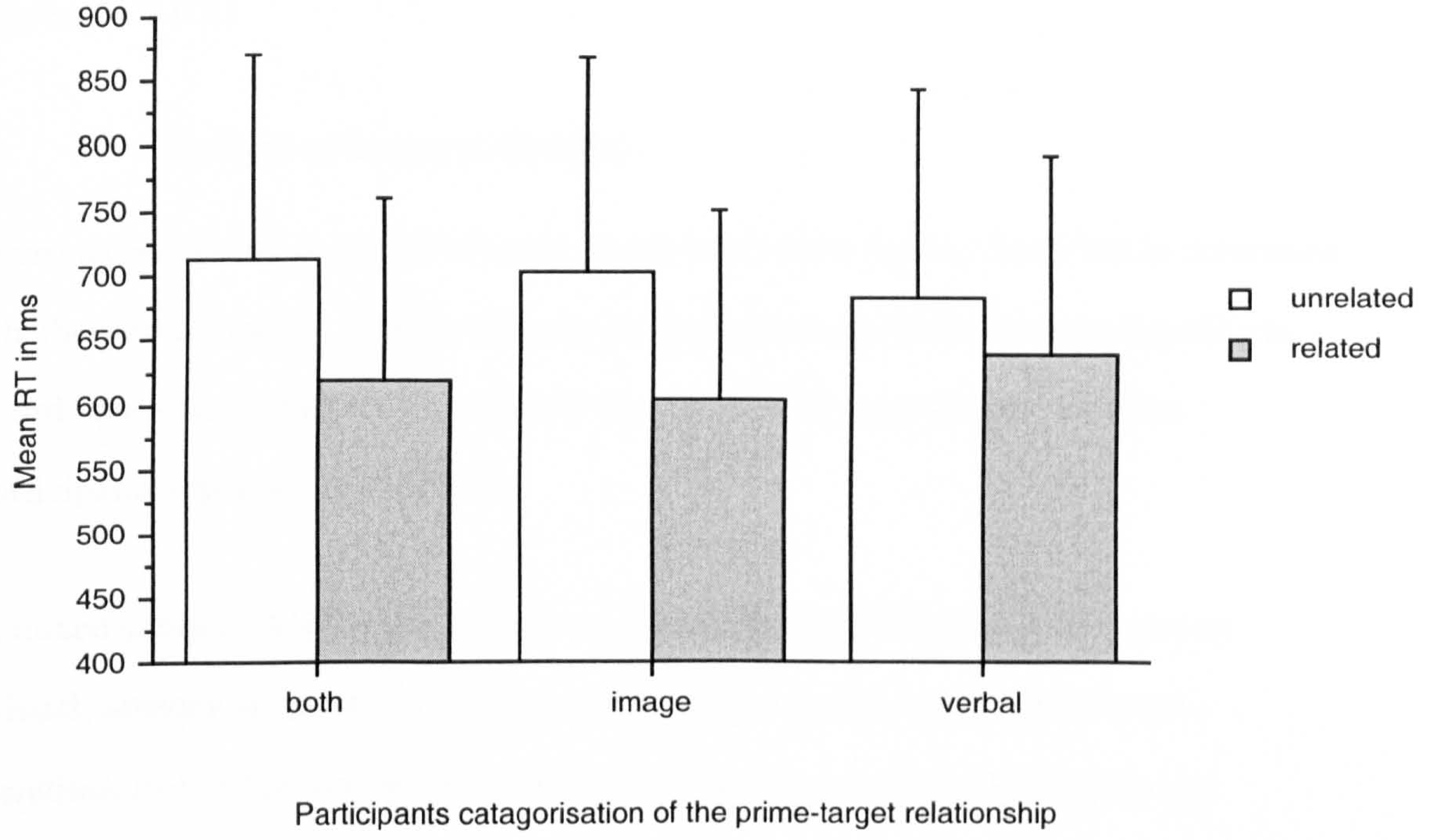

Figure 5.2: Mean RT (+ SD) for the effect of Prime Target relations on the class of Participant Related word pairs.

There was a significant main effect of Prime-Target Relations ($F = 447.3$; $df = 1, 1041$; $p < .0001$) but no main effect for class of Participant Related word pair (see Appendix 5.6.a). Simple main effects showed a significant effect of priming for all classes of Participant Related word pair: verbal-link ($F = 97.24$; $df = 1, 462$; $p < .0001$) image-link ($F = 377.85$; $df = 1, 448$; $p < .0001$) both-links ($F = 91.12$; $df = 1,$

132; $p < .0001$) (See Appendix 5.6.d-e). There was a highly significant interaction between Prime-Target Relations and class of Participant Related word pairs ($F = 38$; $df = 2, 1041$; $p < .0001$). Planned means comparisons showed that there was no significant difference in the effect of Prime-Target Relations between image-link and both -link conditions. There was a significantly greater effect of Prime-Target Relations for image-link associations than for verbal-link associations ($F = 70.3$; $df = 1, 1041$; $p < .0001$). There was also a highly significant difference between the both-link condition and the verbal-link condition ($F = 26.7$; $df = 1, 1041$; $p < .0001$). (See Appendix 5.6.f.)

Analysis of imagery relations

Word pairs classed as related through image-links were further classified to determine whether visual, motor, or other sensory imagery produced different priming effects. Word –pairs in the both-link condition were classified according to the class participants reported as dominant.

A mixed samples ANOVA was performed with the type of imagery association (visual, sensory or motor) as the between subjects variable and Prime-Target Relations (related or unrelated) as the within subjects variable. The dependent variable was RT. The response times are shown in Figure 5.3. (See Appendix 5.7.b for a table of means and standard deviations) There was no main effect of type of imagery. There was a highly significant effect of priming ($F = 37.3$; $df = 1, 503$; $p < .0001$). There was no interaction between priming and type of imagery (see Appendix 5.7.a).

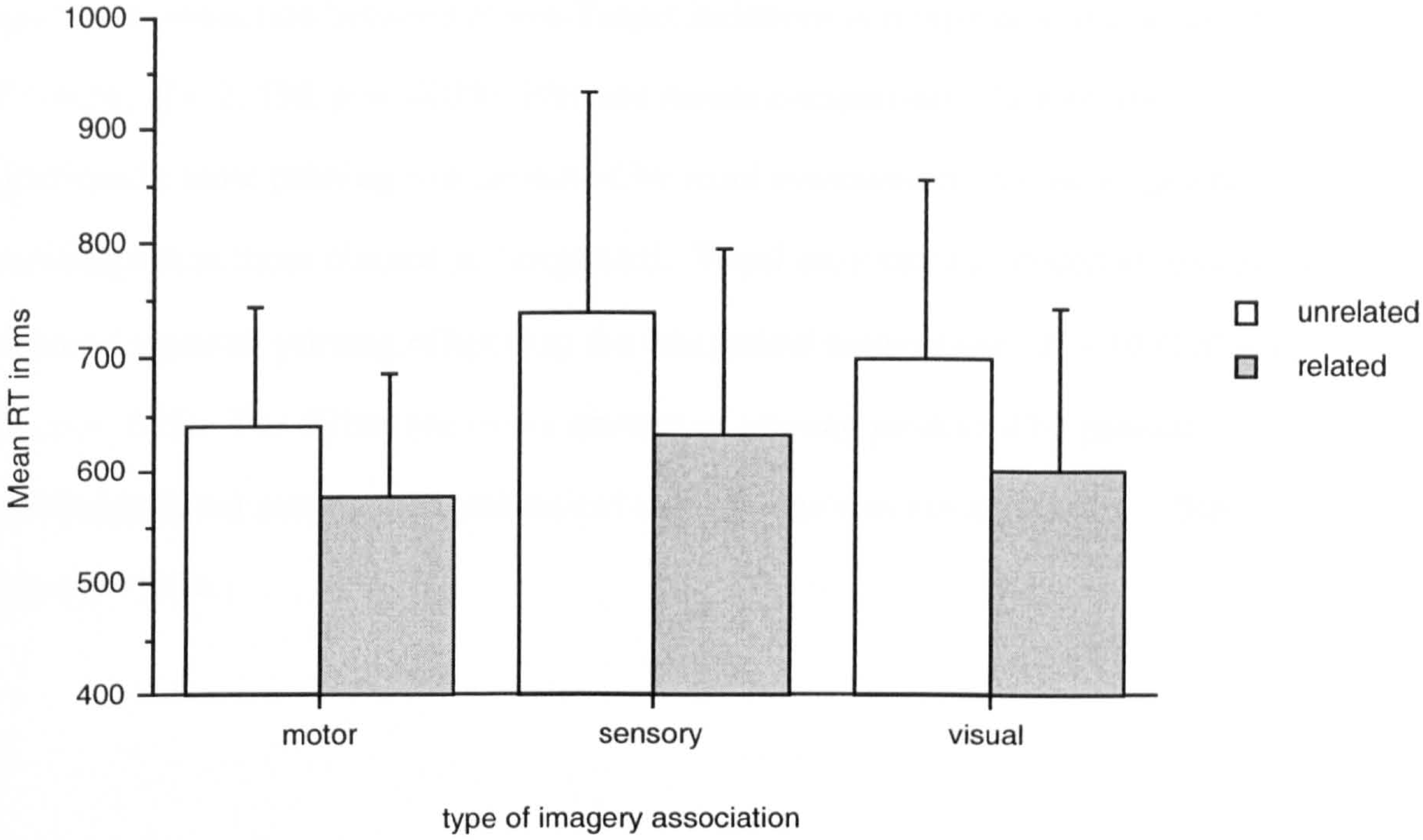

Figure 5.3 The mean RT (+ SD) for the effects of type of imagery on prime-target relations

Analysis of verbal relations

The word pairs related through verbal links were further classified as associated through category membership, general knowledge, or lexical association. The RT for each condition of verbal link and Prime-target relations is shown in Figure 5.4

The RTs were analysed using a mixed samples ANOVA (Appendix 5.8.a). The condition of verbal association (categorical, general knowledge or lexical) was treated as the between subjects variable, and Prime-Target Relations (related or unrelated) was treated as the between subjects variable. The dependent variable was RT. (See Appendix 5.8.b for table of means and standard deviations.)

There was a significant effect of Prime-Target Relations (F = 135.08; df = 1, 536; p < .0001). There was no main effect of the type of verbal association. There was a significant interaction between Prime-Target Relations and type of verbal association ($F = 6.36$; $df = 2, 536$; $p = .0019$). Planned means comparisons showed that significantly more priming was produced by word associations classed as general knowledge than those classed as categorical. Word associations classed as lexical also produced a greater priming effect than the categorical associations ($F = 10.6$; $df = 1, 536$, $p = .001$). The difference in the amount of priming produced by general knowledge based associations and lexical associations was not significant. (See Appendix 5.8.c.)

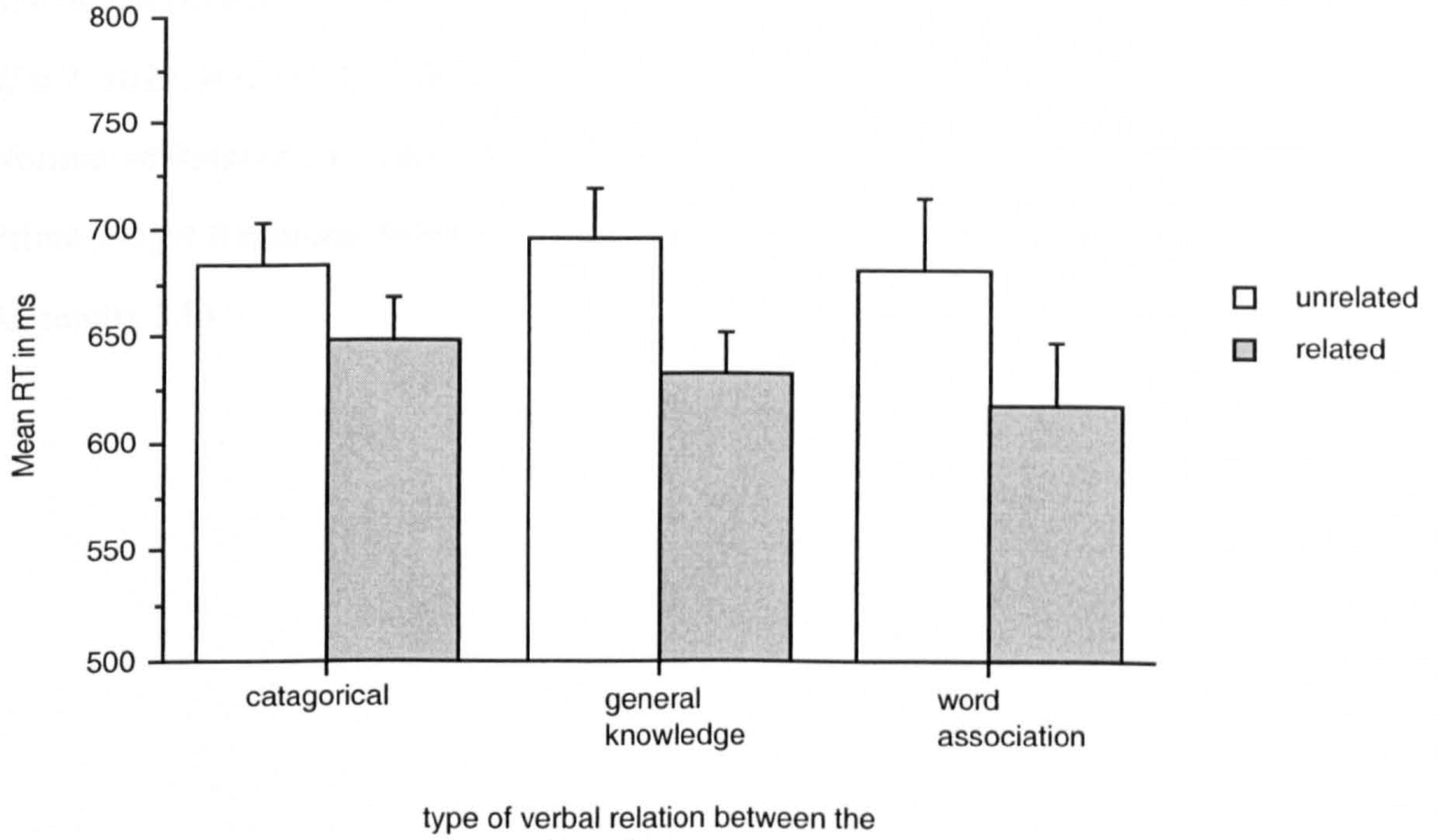

Figure 5.4 The mean RT (+ SD) for the effect of class of verbal association (categorical, lexical or general knowledge) on Prime-Target relations.

Analysis of effects of normative relationship, participants classification of word pairs and prime-target relations on RT

The effects of Normative Relations and of Participant Classification of word pairs (image-link, verbal-link, both links) on RT for each Prime Target Relations condition (related and unrelated) were analysed using a mixed sample ANOVA. Normative Relations was treated as a between subjects variable, as was Participant's Classification of word pairs. Prime-Target Relations were treated as the within subjects variable. The dependent variable was RT. The means (and SD) are presented in Table 5.6. As in the previous analysis, there was a significant effect of Prime-Target Relations ($F = 332.05$; $df = 1, 1023$; $p < .0001$), and a significant interaction between Prime-Target Relations and Participant Classification ($F = 27.78$; $df = 2, 1023$; $p < .0001$). The interaction between Prime-Target Relations and Normative Relations was not significant, nor was the three-way interaction between Prime-Target Relations, Normative relations and Participants Classification (see Appendix 5.9)

Table 5.6: Mean RT in ms (+ SD) for Prime-Target Relations each condition of Normative Relations classified as related through imagery, verbally or both verbal and imagery for each condition of prime classified as related through imagery, verbally or both verbal and imagery for each condition of prime

Normative	Prime	Image -Link		Verbal -Link		Both-Links	
		mean RT	priming effect	mean RT	priming effect	mean RT	priming effect
Associative	related	589 (130)	115	635 (132)	60.	648 (210)	110
	unrelated	703 (160)	(*n* = 98)	695 (173)	(*n* = 52)	758(216)	(*n* = 7)
Categorical	related	614 (130)	103	671 (174)	28	547 (123)	80
	unrelated	717 (164)	(*n* = 44)	699 (173)	(*n* = 93)	627 (129)	(*n* = 9)
Collocate	related	630(166)	68	633 (125)	43	658 (128)	35
	unrelated	698 (167)	(*n* = 59)	676 (159)	(*n* = 48)	693 (129)	(*n* = 9)
Ass-Col	related	594 (130)	106	635 (132)	83	715 (157)	80
	unrelated	700 (165)	(*n* = 95)	702 (153)	(*n* = 47)	636 (175)	(*n* = 15)
Cat-Ass	related	591 (139)	88	622 (145)	32	597 (118)	93
	unrelated	679 (150)	(*n* = 52)	655 (158)	(*n* = 80)	690 (156)	(*n* = 28)
Cat-Col	related	605 (156)	95	647 (160)	13	634 (141)	118
	unrelated	670 (175)	(*n* = 47)	660 (158)	(*n* = 71)	752 (165)	(*n* = 24)
Cat-Ass-Col	related	620 (167)	109	636 (148)	63	620 (141)	102
	unrelated	730(179)	(*n* = 54)	699 (147)	(*n* = 72)	722 (155)	(*n* = 41)

Note the abbreviations for the condition of prime-target relations are as follows: Ass - associative; Cat - categorical; Col - colocational; AssCol - associative + colocational; CatAss - categorical + associative; CatCol - categorical + colocational; CatAssCol - Categorical + associative + colocational

Effect of Awareness of the Prime

After completing the priming task, participants were asked if they had noticed the brief presentation of the prime prior to the onset of the target word. Participants who reported seeing it were asked if they had noticed any relationships between the prime and the target words. The effects of being unaware of the prime, of noticing that there was a prime, and of noticing that some of the prime-target pairs were related was analysed using a mixed ANOVA. Reported prime experience was treated as the between subjects variable (unaware of prime, noticing or aware of the prime-target relationship) and Prime-Target Relations (related or unrelated) was treated as the between subjects variable. The dependent variable was RT. There was no effect of reported prime experience, nor was there an interaction between reported effect and the amount of priming recorded. The mean response times are shown in Figure 5.5, and the ANOVA table is shown in Appendix 5.10.

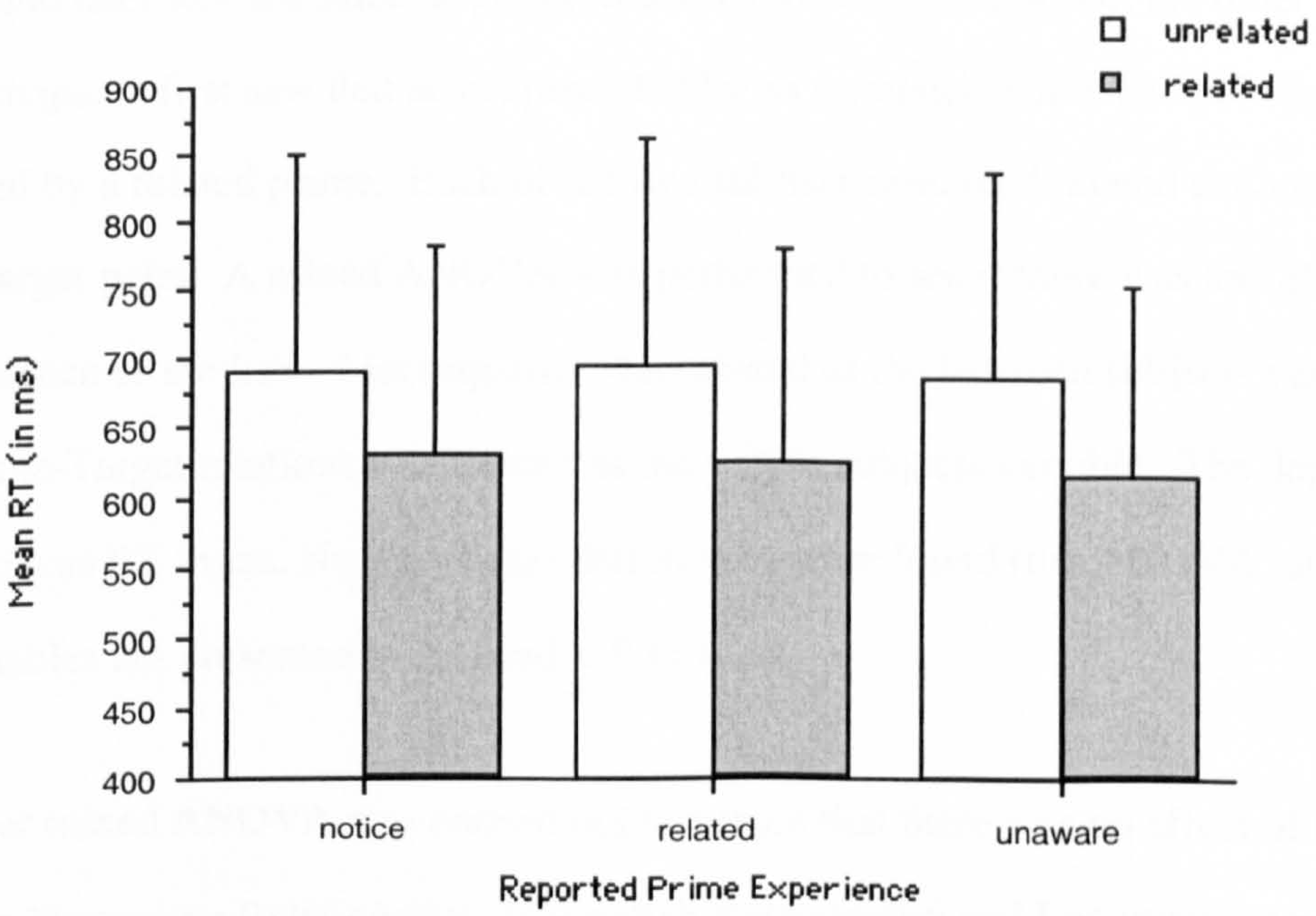

Figure 5.5: The mean RT (+ SD) for the effect of Prime-Target Relations on reported experience of the prime (participants who reported no knowledge of the prime, participants who noticed the prime and participants who noticed that some of the prime-target pairs were related)

Analysis of Target Stimuli

An analysis was carried out to determine whether there was any difference between the different target word stimuli for each type of prime target relationship. The dependent variable was the priming effect measured in ms. A mixed ANOVA showed that there was no significant difference in the mean response times between the different words ($F = .79$; $df = 14{,}1053$; $p = .68$), nor was there any difference in response times between the different types of related primes ($F = .92$; $df = 6{,}1053$; $p = .48$), nor was there an interaction between prime type and different target words ($F = 1.1$; $df = 84{,}1053$; $p = .25$). The ANOVA table is presented in Appendix 5.11.

Analysis of Counterbalances

Each of the different conditions of prime target relationship was presented in two lists. Approximately half the participants first saw any given target preceded by a related prime, and later saw the same target preceded by an unrelated prime; the other half of the participants first saw that target preceded by an unrelated prime and subsequently preceded by a related prime. Each of the two sublists contained related and unrelated prime target pairs. A mixed ANOVA was performed to see if there was any effect of the sequence of the lists. List sequence was treated as the between subjects variable and Prime-Target relations was treated as the within subjects variable. The dependent variable was RT in ms. No significant differences were found (the ANOVA table and means tables are presented in Appendix 5.11.a, b).

A further mixed ANOVA was carried out to ensure that there was no effect of list order on Normative Relationship. Normative Relationship and List order were treated as between subject variables and Prime-Target relations were treated as within subject variables. The dependent variable was RT. There was no significant interaction between list sequence and Normative Relations (see Appendix 5.11.c).

The response buttons designated "yes it is a word" and "no it is not a word" were switched to control for a dominant hand bias, so approximately half the participants used the right hand green button and half used the left hand red button to record a "yes" response. A mixed ANOVA was carried out to determine whether there was a difference in RT attributable to this. The response button selected was treated as the between subjects variable and Prime-Target Relations as the within subject variable. The dependent variable was RT. Although the mean response time to the left hand button was slower than that to the right hand button; 667.1 ms (SD = 170) and 652.1 ms (SD =148.3) respectively this difference was not significant. There was no interaction between response button and Prime-Target Relations (see Appendix 5.11.d),

Discussion

Similar semantic priming effects were shown in Experiment 5 for word-pairs derived from different normative sources, but only when participants were aware of a relationship. Greater priming effects were produced for word pairs associated through imagery than for word pairs with a purely verbal association.

The data are consistent with predictions of dual coding and symbol grounding theories. Further interpretation of these results provides an alternative explanatory framework that might reconcile some of the apparently contradictory findings reported in the semantic priming literature. We do this by suggesting that semantic priming requires explicit knowledge about the relationship between the prime and target.

Semantic Priming: A Measure of Explicit Associations

Our results showed a significant priming effect for those word pairs that participants had classed as related, but there was no difference in the amount of priming produced by different conditions of prime-target pairs (relationships with different normative values). No priming was produced by word pairs classed as unrelated. This result supports our hypothesis that semantic priming requires explicit knowledge of the relationship between the prime and the target.

Williams (1996), in a LDT, reported an automatic priming effect in a LDT for word pairs that were related by semantic similarity and for category co-ordinates (with very low free association values). Williams attributed these priming effects to a facilitation in the retrieval of word meaning rather than a facilitation of lexical associations. Following Deacon's (1997) definition that word meanings are the product of a set of symbolic associations, we propose that priming attributed to a facilitation in word meaning retrieval can be attributed to a spreading activation between symbolic associations.

According to Deacon (1997) a word's meanings are defined by its symbolic relationships with other words and concepts (see Chapter 4). A symbolic relationship comes about when patterns of relationship between associated items within a logically closed group of tokens and signs are *re-cognised.* The transition between indexical and symbolic reference is a process that recodes existing representations so that they become accessible both from bottom up processing (through indexical relations) and through top down processes (through symbolic relations). Once a symbolic relationship has been recognised, symbolically derived relationships are as easily and readily accessible as indexical relations derived from contiguity in time or space.

Given the explicit nature of a symbolic relationship, we argue that the priming effect we observed in Experiment 5 is an index of the symbolic relationships between the prime and the target. It is not necessarily a measure of associations underpinning a symbolic relationship, nor does it preclude the possibility that spreading activation at a lexical level might also contribute to a priming effect. However, our data showed no evidence of priming between collocates that had been classed as unrelated by the participants; this suggests that the primary source of priming in our experiment was from explicit symbolic associations.

Semantic Priming is Automatic

Like Hodgson (1991), we attribute the facilitation in LDT to an automatic process. In Experiment 5 we adopted the procedure employed by Williams (1996) to obtain automatic rather than strategic priming in a LDT. Williams found no difference in the amount of priming when data from participants who could report the presence of a prime word were excluded from the analysis. Williams argues that this is evidence that the facilitation is derived from automatic rather than strategic processes, since participants who were unaware of the presence of the prime would not be in a position to generate possible targets. Fischler (1977b) cites an unpublished experiment carried out by Fischler and Goodman in which they obtained significant priming effects when the prime was displayed for only 40 ms followed by a mask for 50 ms. Priming was not dependent on the participants' ability to report the prime word at the end of the trial. Our data show that there was no difference in the priming effect produced by participants who were unaware of the presence of a prime compared with participants who had noticed "something", or with participants who noticed that some of the prime-target pairs were related. This suggests that our procedure had resulted in automatic rather than strategic priming.

Like Shelton and Martin (1992, Experiment 3), we obtained similar priming effects following associated primes and semantically related primes in a paired presentation LDT. There was no significant difference in the amount of facilitation produced by the different types of prime relationship for word pairs participants classed as related. However, Shelton and Martin did not obtain a significant priming effect for their semantically related primes when a single presentation LDT was employed. Shelton and Martin argue that this difference indicates that the priming effect produced in the paired presentation task reflects strategic processes rather than automatic processing. The data Shelton and Martin obtained from their paired presentation LDTs presents a problem for their argument. They manipulated the proportion of related pairs between two paired presentation LDTs and found no difference in the amount of priming produced when there was a low proportion of related pairs (26%) compared with when there was a high proportion of related pairs (74%). If the priming reflected strategic processes, a greater priming effect would be expected in the condition with a high proportion of related pairs (Neely, 1991). Given our findings, it is possible that some of Shelton and Martin's participants might have considered the prime–target pairs to be unrelated.

Our results appear to contradict the findings of Dark and Benson (1991), who claimed that semantic priming occurs only when the prime is recognised. They employed a recognition task in which participants had to decide whether a word had appeared as a prime during the preceding LDT. Participants were asked to select one of four categorical responses to describe how confident they felt about recognising the prime from the LDT. A possible problem with their conclusions lies with their criterion of recall. Only correct responses classed as "somewhat confident old word" (from the LDT) were treated as correct, and responses to old words classed as "somewhat confident new word" (control word) were counted as false alarms. Considering that their data show similar numbers of false alarms and correct hits for each prime, confidence does not appear to be a good measure of recall. The other response options "guessing – old word" and "guessing – new word" were treated as misses or correct rejections. Data from participants who were "guessing" did not effect the amount of priming. During the LDT, primes were presented below the recognition threshold for many of the participants, so it seems unlikely participants who were unaware of the presentation of a prime would confidently report having seen the word before. Dark and Benson's conclusion that awareness of the prime is necessary for semantic priming does not address whether participants were aware of the relationship between the prime and the target. Their evidence does not eliminate the possibility that retroactive priming requires recognition of the prime, and that this process could account for the effect they observed, independent of any semantic priming effects.

Williams (1996) suggests that the top-down effects of semantic activation are most apparent when lexical recognition responses are slow, because lexical recognition is also influenced by bottom-up stimulus driven information. In Experiment 5, we used a degraded target, to slow the response time; this might have provided a sufficient window in which to observe the effects of top-down processing on word recognition. Our mean RTs of 693 ms for unrelated pairs and 629 ms for related pairs (across all conditions of prime-target relationship) are similar to the overall mean RTs of 682 ms for unrelated primes and 647 ms for related primes obtained by Shelton and Martin in their paired presentation LDTs (means calculated across high and low proportion conditions and for associated and semantically related word pairs). The mean RT for their single presentation LDT, in which they failed to obtain semantic priming, was 523 ms for related primes and 530 ms for unrelated primes. Williams posits that this might be due to faster responses masking the effects of semantic priming. Our mean response times are considerably slower than those reported by Williams, but in keeping with his predictions, the slower response times produced in our experiment have produced greater priming than Williams recorded.

The patterns we observed in our data are consistent with the results obtained by Fischler (1977b), Hodgson (1991), Shelton and Martin (1992, Experiment 3), and Williams (1996). Following Williams, we interpret the data as evidence that the priming effect we obtained is the result of automatic processing rather than strategic processing.

Priming Derives from Semantic Activation

Analysis of our data for word-pairs which participants classed as related showed that the different conditions of prime-target relationship (according to normative lists) did not show significantly different priming effects, nor was there evidence that the different conditions of relationships recognised by participants were additive. For example, there was no significant difference in the priming effects produced by categorically related primes compared with associatively related primes or with primes that were both free associates and category co-ordinates.

These results are similar to the findings of Lupker (1984), who found similar priming effects for free associates, category co-ordinates and free associates that were also category co-ordinates. Since Lupker suggests that only category co-ordinates have a "purely semantic relationship" (p. 718), he interprets his results as evidence of two processes in priming. The first, a facilitation of pre-lexical access resulting from spreading activation along the links in an associative network; the second, a facilitation of post lexical processes such as lexical decision mediated by semantic links between infrequently associated concepts. This explanation accommodates different priming effects produced in a LDT compared with a naming task when the same stimulus pairs are presented. No priming effects were produced between non-associated category co-ordinates when the task demanded participants to pronounce the target word. Lupker argues that only lexical access is facilitated by associative relationships, whereas both associative and semantic relations can result in post-lexical priming in a LDT. Because semantic facilitation does not augment the post-lexical facilitation produced by associated relationships, Lupker proposes that semantic associations are processed by a secondary retrieval mechanism that activates much of the information that would be activated by spreading activation, so the effects of semantic association are essentially redundant.

Our interpretation of these patterns of facilitation is diametrically opposed to that of Lupker (1984). We suggest that facilitation observed in a LDT is mediated by semantic associations. Semantic activation occurs between symbolic associations that derive from both perceptual and verbal associative information. Following the assumptions of Deacon's symbolic reference model, associations derived from temporal or spatial contiguity precede the development of symbolic associations. Since Deacon suggests that symbolic associations, once established, are activated as readily as associations derived from contiguity, no additional facilitation would be predicted from the presence of associative and semantic relations. Because associative and categorical associations are both incorporated by higher symbolic associations, it is improbable that semantic processing is secondary and largely redundant.

There is no evidence from our results to suggest that "secondary" processing occurs during the LDT. If purely associative information could support priming in a LDT, we would expect to have observed a priming effect when participants were unaware of the prime-target relationship, particularly between the collocates. We propose that priming in a LDT results from top down activation of lexical representations; it reflects semantic activation, because a word's meaning must be accessed to determine its lexical status.

Williams (1996) suggests that the greater the amount of semantic information that is associated with a word, the more readily that word will be retrieved, and the faster it will be recognised. A prime word inducing a spread of associations at a semantic level will make those semantic associations more accessible; a target word that maps onto those activated associations will benefit from this interaction and will be retrieved more easily and recognised more quickly. However, the presence of a semantic level activation does not preclude any effect of lexical level associations on the activation of semantic representations.

We do not dispute Lupker's (1984) suggestion that different processes are demanded in a pronunciation task versus a LDT. However, we suggest that it is priming in a pronunciation task, rather than a LDT, which might derive priming from "secondary processing". Pronunciation might be facilitated by both symbolic associations and by word associations based purely on contiguity. However, Hodgson (1991) failed to produce priming in a pronunciation task using the same semantically related pairs that produced priming in a LDT. Our experiment had no bearing on this question; future experiments are required to determine whether priming can be produced in a pronunciation task if participants are unaware of any prime-target relationship.

We suggest that our results support the argument that facilitation obtained in a LDT can be attributed to automatic semantic priming of pre-lexical processes.

Redefining Semantic Association

In Experiment 5 we recorded similar automatic priming effects for word pairs related according to free association norms, according to categorical norms, according to collocation norms, and according to different combinations of these norms. These effects were observed only between word-pairs that our participants classified as related.

The similarities in priming effect that we observed between the different prime-target relations suggest that the norms produced for free associates, collocates, and category membership do provide an index of semantic relationship, but they are not definitive of semantic associations as opposed to associations based in contiguity.

Paired association is not semantic association

An experiment performed by den Heyer (1986) provides a clear illustration of differences between semantic and paired associations. Den Heyer manipulated automatic and strategic priming using a LDT in which participants were exposed to repeated presentations of both semantically related and unrelated word pairs. At an SOA of 550 ms an increased facilitation was observed after six repetitions for both the related and the unrelated word pairs, compared with a neutral prime condition (in which the prime was the word "BLANK"). At an SOA of 100 ms the mean response times decreased after six repetitions, but the amount of semantic priming did not increase. Semantic priming was evident, but no priming was observed between the unrelated word pairs compared with the neutral prime condition. Den Heyer demonstrated that the repetition priming effect reflected the specific relationship between a prime and a target, rather than between a prime and the lexical status of the target (word or nonword), by switching the pairings between prime and target words for the sixth repetition, of the task. A prime that was succeeded by a related word in the first five trials was followed by an unrelated word in the final repetition, and primes that had preceded unrelated words were paired with related words in the final repetition; the lexical status of the targets remained unchanged. After the first five trials, repetition priming was observed; response times following the unrelated primes were facilitated relative to the neutral prime. A semantic priming effect was demonstrated when the related and the unrelated prime condition were compared. In the sixth trial, the same degree of semantic priming was recorded, but there was no evidence of a repetition priming effect. It is clear that the associations established by repeated presentation of the unrelated word pairs were specific; participants had an expectation of a specific target word, not an expectation of selecting a generalised "word" response.

Den Heyer's (1986) results demonstrate that two different priming effects influence a LDT: semantic priming and paired associate priming induced by repetition. Automatic priming produced at both long and short SOAs is an index of semantic association. Associative priming reflects specific expectations about the target based on experientially derived paired associations. This is an example of strategic processing, and as such requires a greater SOA before it can be observed.

Den Heyer postulates two different types of associative links, one for semantic priming and one for paired associate priming. His distinctions between associative and semantic links map closely with the distinctions which Deacon (1997) draws between symbolic and indexical associations, Deacon suggests that indexical associations between representations are derived from spatial or temporal contiguity. Symbolic associations are the product of further processing which allows patterns between existing indexical associations to be recognised. Den Heyer suggests that paired associations are based in episodic memory, but associations that are accessible at short SOAs must have direct access to semantic memory. This does not necessarily imply that two different memory systems are involved. Tulving (1984) suggests that episodic memories form a part, albeit a distinct part, of semantic memory.

Different types of associative link have long been acknowledged and discussed in different frameworks. As we have already discussed in Chapter 4, there are similarities between the classification of associations in Deacon's (1997) model of symbolic reference and the ways that researchers in the behaviourist tradition distinguish associative learning, such as classical and operant conditioning, from verbal learning which embraces rule governed and symbolic behaviours.

We propose that the focus of the debate about whether automatic priming results from semantic or associative relationships has been obscured by the issue of which normative list is an appropriate index of semantic relatedness. We suggest that a semantic relationship requires explicit knowledge of the relationship between two items, but an associative relationship can be produced by accidental contiguity. Semantic relationships develop from associative relationships when related patterns of association are recognised (for example, associations between objects and their related names). To determine whether there is a semantic relationship between two items, the nature of the associative link needs to be investigated, as opposed to trying to establish whether the two items have overlapping semantic features, or whether they are related due to accidental or meaning related contiguity.

Are word associations semantic?

Analysis of the effects of normative relations showed that free associates produced significantly more priming than category co-ordinates or collocates. However, when the word pairs classed by participants as unrelated are excluded from the analysis, there is no difference between the priming effect produced by the different normative relations. This suggests that the effects of normative relations can be explained by awareness of the relationship between the prime and the target.

Participants' awareness of a relationship between the prime and the target did not always mean that their own descriptions of the class of relationship showed a correspondence with the normative sources of the word pairs. Analysis of each participant's responses to each word pair drawn from category norms showed that 14% of the pairs were classed as unrelated. Of the category word pairs that were classed as related, only 52% were thought to be associated through a categorical relationship. Of the normatively associated word-pairs, only 5% were classed as unrelated, but only 8% were classed as related because one word just triggered another. Our data suggest that free associations reflect conceptual relations because 60% of participants' responses classed the relationship between the normative associates as related through imagery, and 24% due to general knowledge.

Like Hodgson (1991) we found significantly fewer categorically related targets compared with associatively related targets were generated by participants when the prime words were presented in a free association task.

We found no significant difference in the amount of priming produced by word pairs drawn from three different normative sources: category co-ordinates, collocates, and free associates. There was no evidence that the priming effects produced by the different prime-target conditions were additive, since there were no significant differences between any of the conditions in which the prime-target pairs were related according to two or all three of the normative sources. It appears that the normative source of the relationship is not an appropriate means of classifying a relationship as semantic.

Our data is similar to that collected by Hodgson (1991). He found that, although category co-ordinates were produced as free associates less frequently than word pairs derived from associative norms, synonyms, or antonyms, there was no correlation between the predictive strength of their association value and the amount of priming produced in a LDT.

Spence and Owens (1990) reported a correlation between associative value and the frequency with which word pairs co-occur in printed text. For example, the free associates "ocean and water" appear significantly more frequently within 50 characters of each other than do the words "ocean and hand" which have similar individual frequency values. The correlation was maintained at an interval of 1000 characters (about 200 words). An inverse relationship was found between association strength and collocation value: the more highly associated the word pairs the more likely they were to co-occur in text. Like Ratcliff and McKoon (1978), Spence and Owens found that lexical distance within a sentence was unrelated to associative strength. This suggests that both associative and collocational relationships provide an index of semantic association. Our data suggest that, although there is a high degree of agreement between individuals when the task is to determine whether word pairs are related, there is less consensus about how or why they are related. It seems that relationships derived from a variety of sources are capable of attaining the same degree of semantic relationship, and that this relationship is widely accepted as semantic within a linguistic community.

Spreading Activation or Compound Cue theory?

A consequence of concluding that semantic relations emerge from patterns of association between related items is that the strength of a semantic relationship is the product of the strength of the associations between all of the tokens comprising a symbolic concept. This does not necessarily correlate with an associative value derived from free association values. Compound cue theory could account for priming between semantically related but unassociated word pairs, since the familiarity of a compound cue is a product of the associative strength between a prime and a target.

The priming we observed can also be accounted for by models of spreading activation, which suggest that processing the prime word causes a spread of activation between semantic nodes that facilitates the recognition of corresponding lexical representations.

Imagery and Semantics

The second hypothesis tested in Experiment 5 was that semantic associations would be derived from both verbal and perceptual associations. We found semantic priming both for word associations classed as related through imagery and for associations related verbally. Our data showed significantly more priming for word pairs that participants reported as associated through imagery than for purely verbal associations. This result is compatible with both dual coding (Paivio, 1991) and symbol grounding theory (Barsalou, 1999). It is harder to account for this result in the framework of Deacon's symbolic reference, in which it seems to be expected that symbolic associations have equal strength. There was no difference between words that were classed as related both through image and word associations compared with those classed as related through imagery alone. This is not surprising considering the verbal nature of the task. It is likely that all of the image-based associations have a corresponding verbal association.

Our results are in keeping with the predictions of dual coding. Paivio (1991) reported that words with a high imagery rating are more easily recalled than words with a high rating of meaningfulness (calculated by the number of verbal associations generated from a word). Paivio concludes "imagery is a preferred and an effective mode of symbolic mediation given high image-evoking value in stimulus items."(p.42) Paivio suggests that words that are highly imageable form better conceptual pegs as items can be associated through stimulus evoked images. It follows from this that a prime word associated through imagery would act as a more effective retrieval cue than a prime word with only verbal associations.

Barsalou (1999) proposes that the mechanisms underlying semantic knowledge are enmeshed with, and to a considerable extend shared with, the mechanisms underlying perception. Conceptual knowledge is grounded in our perceptual experiences. Our data shows the largest priming effects for words that are related through imagery. If priming is a measure of the strength of an association between two words, our data shows that there is a stronger association between words with an association grounded in perceptual representations. According to Barsalou, attention is central to symbol formation; it provides the means through which perceptual experiences enter long-term memory. During a perceptual experience, attention is focused on meaningful and coherent sensory patterns. For example, the shape of an object might be attended to rather than the shape or colour of the background. Aspects of the perceptual array that are selectively attended to are more likely to enter long-term memory, and it is from these schematic representations that basic symbolic functions develop. According to Barsalou, a perceptual symbol is a pattern of neural activation that can be established for any sensory modality. Perceptual simulators do not exist independently: they are organised into simulators that allow perceptual information (including perceptual symbols for speech) to be integrated into an organised conceptual system. Barsalou suggests that conscious experience may be necessary for the process of symbol formation, and that conscious perceptual effort falls away as automaticity develops. Our priming data can be accommodated by this framework. Word associations that have been established with conscious awareness are both automatically activated in the LDT and available for conscious inspection when participants are asked to categorise the relationship.

Deacon's (1997) model of symbolic reference incorporates many of the assumptions of dual coding (Paivio, 1991, see Chapter 1 and 2) and perceptual symbol grounding (Barsalou, 1999). Deacon proposes that associations are formed between representations of the original sensory states and that word meaning is derived from these associations. Deacon's model posits that word meaning is not conveyed by a one-to-one mapping of word onto objects; a word meaning is the complex product of many–to-one and one-to-many associations between lexical and other representations. Within Deacon's model it is possible for relations between items that comprise a closed symbolic relationship to have different association strengths. If the strength of symbolic associations can reflect the number of related indexical associations between items, one might expect greater priming to be produced for items that are associated both through imaginal and lexical representations.

Our data do not provide a means of discriminating between Deacon's model of symbolic reference and Barsalou's perceptual symbol system, because hey do not directly challenge the assumptions of either model.

Conclusion

The results of Experiment 5 show evidence of automatic semantic priming between word pairs with a relationship that participants are aware of. There was no priming produced by word pairs with a normative relationship that was not recognised by the participants. We interpret these results as evidence that semantic associations reflect explicit knowledge, but can be automatically activated. In keeping with Barsalou (1999) and Deacon 1997), we propose that semantic associations are the product of explicit processing; the associations underpinning symbolic associations are not necessarily explicitly acquired, however. We propose that the priming effect we obtained is an index of the strength of explicit symbolic associations between the prime and the target.

Summary

- The aim of Experiment 5 was to determine whether semantic associations between real words are explicitly mediated.
- Priming measured in a LDT was taken as an index of semantic relations.
- Evidence of automatic semantic priming was obtained between word pairs that participants deemed to be related.
- No evidence of automatic semantic priming was obtained between word pairs that participants did not deem to be related, despite their normative relationships.
- Analysis of the word-pairs participants classed as related showed no significant difference in the amount of priming produced by word-pairs related by associative, categorical or collocational norms.
- It was concluded that semantic associations are the product of explicit processes.
- There is no evidence that semantic relations are best defined by any one of the three normative sources employed. Collocates, category co-ordinates and free associates can all be related semantically.
- The data were interpreted as support for the notion that semantic relations can derive from episodic memories.
- Greater priming effects were observed for word pairs related through imagery compared with word pairs that were verbally related

- The data lend support to perceptual grounding theories.

- The data do not allow us to discriminate between Barsalou's perceptual symbol theory and Deacon's symbolic reference model.

Chapter 6

General Discussion

This thesis set out to examine the interaction of verbal and imagery representations. We focused on the transfer of associative information between stimulus modalities by training paired associations between novel pictures and novel words. Our results showed that the transfer of associations is a symbolic process, occurring only when participants are aware of the correspondence between the visual and the verbal items afforded by the name relations.

We also obtained evidence to suggest that symbolic associations develop more readily from picture associations than from word associations. We argue that this is evidence that semantic knowledge is grounded in perceptual experience.

Development of Methodology

Considerable methodological challenges had to be faced in order to get clear results about the development of new semantic associations. There was considerable evolution, improvement and refocusing of our methodology over the course of this exploration. We believe that the methodology arrived at in Experiment 4 can be quite powerful and adaptable to related questions. In the course of dealing with problems encountered in our earlier experiments (the pilots reported in Chapter 2; Experiment 2, Chapter 3), there was also a development of the questions we addressed. Intriguing patterns of results suggested that transfer-of-association tasks, combined with measures of semantic or explicit processing and awareness of relations, could provide a useful tool for "looking inside" the acquisition of semantic associations.

Our methodology demanded that we employed stimuli that were not embedded in semantic knowledge and had no existing associations. In Chapter 2, we demonstrated that recently trained contiguous associations between novel stimuli could produce a priming effect in decision tasks. In Experiment 1 we demonstrated cross modal priming for word associations derived from corresponding picture associations, but not for picture associations derived from word associations. This result needed to be solidified, however, before we could draw conclusions about associative or semantic processing.

To generate robust results, we designed a variation of the stimulus equivalence paradigm which provided a measure of the transfer of associations across stimulus modalities. The pattern of results remained consistent. This led us to question whether this was an experimental artefact due to the complexity of the novel visual stimuli and the simplicity of the novel word stimuli. The stimuli were changed, and we were able to show that picture associations could be derived from words. By manipulating the order of training tasks we were able to establish that picture associations are not necessarily verbally mediated.

The matching to sample task provides evidence of a relationship but little indication of the nature of that relationship in the terms of cognitive models. By harnessing the associative equivalence task to a decision task, we were able to demonstrate that transitive associations could behave like semantic associations between real words. To be certain that neither acquisition nor forgetting of the trained associations was a factor in the pattern of results, we added additional tests of participants' recall of the trained association. Participants' self reports provided us with insights into the nature of the relations they were actually engaged in, and a surprising 'awareness effect' suggesting that it is knowledge of the association, rather than its source modality, that is of importance in the emergence of transferred associations. To test this, we carried out lexical decision tasks in which the normative relations between words were manipulated and the effects of participants' knowledge about the associations were investigated.

Synopsis of Results

We found some consistent patterns in the data obtained from our experiments, which are outlined below. The conclusions drawn from these patterns will then be discussed.

Naming and the transfer of associative information

The results of Experiments 3 and 4 showed that performance on the association test tasks was related to participants' awareness of the mediating role of the name relation (picture-word association) in the transfer of associative information between the trained picture pairs (or word pairs) and the test task pairs (word or picture pairs). We will refer to this as the participants' being *aware*. Participants who were aware produced significantly more correct responses in the test association task for the experimental stimuli than the control stimuli, whereas the unaware participants performed at chance (see Experiment 4). Participants who were aware showed semantic priming in the decision tasks, but no priming was produced by unaware participants in these tasks. Awareness cannot be explained by superior recall; unaware participants recalled as many of the trained associations as the aware participants. For the same reason, we can see that the locus of the awareness effect is at the stage of transferring associations across modalities, not at the stage of acquiring the trained associations themselves. Participants who became aware only after the relationships had been explained to them were then able to perform correctly on the association test task, but they showed no semantic priming in the decision tasks.

Our results suggest that naming is more than a bidirectional association between a word and its referent; we suggest that awareness of a name relationship is required before it can mediate the transfer of associative information between the visual and the verbal processing systems. Our data indicate that there are qualitative differences between bidirectional associations and symbolic associations. We propose that name relations are symbolic associations. Once symbolic name relations have been established, picture associations are automatically transferable to the verbal system, and word associations are automatically transferable to the visual system. We argue that establishing a name relation is not an automatic process; it is an effortful, explicit process. Symbolic associations are available to conscious inspection. Contiguous associations on the other hand can be implicitly represented and are not necessarily automatically available to conscious inspection. Further evidence for our argument was obtained in Experiment 5, where we found semantic priming was produced only between word pairs for which participants were aware of a relationship, despite all the word pairs being taken from lists of normative relations.

Visual-semantic superiority effect

We found a consistent pattern across Experiments 2, 3, and 4 in which the order of acquisition of paired associations are acquired affected the ease with which associations could be transferred between stimulus modalities. We found that word associations emerged more readily from picture associations than picture associations emerge from word associations. Participants were most likely to be aware in the condition in which novel picture associations were trained prior to presenting the names for those pictures. Participants were least likely to be aware in the condition in which novel word associations were trained prior to learning the association between those words and their referent pictures. Picture associations transferred to word associations more readily if the association between the pictures was trained before the names for the pictures were trained. If the relationships between words and pictures were trained first, word associations transferred to picture associations as readily as picture associations transferred to word associations. We will refer to this pattern of data as the *visual-semantic superiority effect.*

We interpret this as evidence that the order in which paired associations are acquired affects the ease with which a symbolic relationship can develop between items linked by chained associations. We suggest that because semantic representations are grounded in perceptual representations, novel pictures are inherently more meaningful than novel words, because they convey perceptual information. The results of Experiment 5 lend further support for this proposal; larger priming effects were produced by word pairs participants related through imagery compared with word pairs that were related verbally. We further argue that another cause of the visual-semantic superiority effect is that visual stimuli are more grounded in implicit processing than verbal stimuli.

Semantic Associations Can Arise From Perceptual Associations

We began the research reported here with three general hypotheses to guide our exploration: (1) Verbal experience and visual experience are unrelated, with word collocations underpinning the semantic system. (2) Semantic association can arise from associated perceptual experience. (3) Semantic associations between words arise if items are automatically named when they are contiguously presented.

Our data support the second hypothesis: semantic associations can arise from perceptual associations; words that are infrequently associated might still have strong semantic associations if their perceptual referents are closely associated. If a visual association exists between two items, and names for those items are learned, the existing perceptual association would create a corresponding verbal association.

The data do not support the first hypothesis. We found no evidence to suggest that associations within each modality are established only by modality specific associative experiences.

The third hypothesis is rejected. We demonstrated that a transfer of associative information between the verbal and the visual system (and vice versa) can occur. The transfer of associations between stimulus modalities does not require a name relation to be established before the words or pictures are associated. Although cross modal associations could result from the automatic activation of corresponding lexical representations when the pictures are associated (or from the automatic activation of corresponding visual representations when the word associations are learned), this is not the only means through which a transfer of associations can be effected.

The Transfer of Associative Information between Stimulus Modalities Is A Symbolic Process

We argue that the automatic transfer of associative information between stimulus modalities requires symbolic processing. We will examine our data in the light of cognitivist and behaviourist models of symbolic processing.

Dual coding versus single semantic stores: The effect of the order of learning paired associations and name relations

Initially we examined the transfer of associations within a framework of the relative predictions of dual coding and single semantic store models. The results of Experiments 2, 3, and 4 show that the order in which the paired associations are acquired affects the transfer of associations across stimulus modalities. This pattern is accommodated by dual coding but runs counter to the predictions of single store models. Single semantic store models propose that semantic information from verbal and perceptual sources are represented as amodal propositions in the same semantic store. It follows from this that the order in which associations are encoded should not affect the transfer of associations.

Paivio's (1991) dual coding model proposes that verbal information is stored in a lexical store and picture information in a visual store. This model suggests that abstract words are represented only in the verbal system, whereas concrete words are represented in both the verbal and the visual system. This predicts that concrete words will have richer and more easily associable representations than abstract words. Novel word associations encoded before picture referents for those words have been learned are effectively abstract, and so weaker associations might be predicted compared with word pairs that have picture referents. Because visual and verbal information are encoded separately, an asymmetry in the strength of associations between the visual and the verbal stores for the same conceptual pairs is expected in dual coding models.

An assumption of dual coding theory is that visual materials act as superior retrieval cues compared with verbal materials. If the transfer of associative information between the visual and the verbal systems is mediated by chained associations, then the enhanced transfer of associations observed when novel picture associations were learned prior to name relations between those pictures and novel words would be predicted by dual coding models (see Chapter 3, Discussion). Our evidence indicates that automatic transfer is not mediated by chained associations. Though dual coding can accommodate patterns in our results, it is not an appropriate framework in which to explore the effect of awareness and the role of explicit processing in specifying name relations.

Our results fit the predictions of the dual coding model better than the predictions of single semantic store models. However, Paivio's dual coding model does not specify the nature of the referential links between the visual and the verbal stores. Although his model can accommodate differences in associative strength derived from contiguous experiences or from name relations via chained associations, there is no suggestion of a difference between the role of symbolic relations and associative relations. Our data suggest that these are two different forms of referential link.

In Experiment 4, participants who were aware showed semantic priming in the cross modal decision task. Participants who were only aware after instruction did not show semantic priming in the cross modal decision task. We suggest that this difference can be explained by examining the status of the picture<->word associations. The picture<->word relationship is functionally symbolic for the aware participants; it can automatically mediate the transfer of associative information between the visual and the verbal systems. For the participants who were aware only after instruction, the picture<->word relationship is a bidirectional association that allows them to respond correctly in the test association task through a process of chained associations, but this process does not support semantic priming.

We argue that name relations require more than a bidirectional association between a word and its referent; an awareness of that relationship is also required. We suggest that higher level cognitive processing than is demanded by associative learning are required before the bidirectional relations between a word and its referent can be said to have the symbolic functions demanded by a name.

A recent model of semantic representation that acknowledges the role of awareness in symbolic function is Barsalou's (1999) perceptual symbol system. The basic level of representation in Barsalou's theory is the perceptual symbol. Perceptual symbols are partial reactivations of the patterns of activation produced by an original experience. These symbols can function unconsciously during preconscious or during automatic processing, but they can produce conscious counterparts. Barsalou proposes that conscious and unconscious processes are the products of different neural mechanisms.

Barsalou stresses that activation of perceptual symbols is not necessarily accompanied by conscious imagery, (and many individuals report never having conscious imagery). Barsalou suggests that conscious experience might be necessary for the formation of perceptual symbols but that attentional effort of perception falls away as the processing of a particular symbol becomes automatised. However, he is not specific about the role of awareness in the acquisition of symbolic function, nor about the architecture that supports different neural mechanisms for conscious and unconscious processes.

According to Barsalou (1999), concepts are represented by the integration of individual perceptual symbols into simulators. Because perceptual symbols are selectively encoded by the focus of attention, a simulation does not provide an holistic representation of an event or an individual but represents knowledge about the perceptual components of a type or category. This suggests that a simulation represents explicit knowledge, open to conscious inspection.

A name is represented, in Barsalou's (1999) model, when the perceptual symbols for words (acoustic and/or visual) become integrated in a simulator with perceptual symbols for associated experiential states, which can be physical (sensory or motor) or introspective (emotional or a reactivation of previously encoded states). A word has conceptual meaning only when it is integrated into a simulator; it appears that naming is an explicit process in Barsalou's model.

Our data showed that recall of the trained associations was not sufficient to demonstrate a transfer of associations on the test association task or to produce semantic priming in the decision task. We suggest that awareness is required for the selection of the perceptual symbols comprising a simulator, but not necessarily for encoding a perceptual symbol.

Deacon's (1997) model of symbolic reference specifically accommodates not only the distinction between associations derived from contiguity and associations afforded by symbolic relations, but also the role of awareness in the transition between associative and symbolic relations. Deacon suggests that sign and indexical relations are simple associations; these are defined by relationships of temporal or spatial contiguity and can be learned as a conditioned response. A symbolic relationship between a sign and its referent is a function of the relationship between that sign and other signs and not the product of contiguity. Symbolic relations require a different learning strategy; they emerge from *re-cognising* corresponding patterns between previously learned indexical and iconic relationships. Once a symbolic relationship has been recognised, associations created by virtue of that symbolic relationship are accessed as readily as associations derived from contiguity.

There are clear parallels between Deacon's assertion that the transition between simple associations and symbolic associations is the product of an effortful restructuring of existing relationships and Barsalou's suggestion that the unconscious neural mechanisms that representing perceptual symbols can produce conscious counterparts. However, Deacon's model specifies the role of explicit processing in the transition between simple associations and higher level symbolic associations. Our data lend support to Deacon's model.

Our results lead us to conclude that a name is more than a bidirectional relationship. Deacon's model discriminates between an indexical bidirectional relationship and a symbolic representation. Deacon asserts that word meaning is represented by symbolic reference, not indexical reference and that the two forms of representation are qualitatively distinct. A bidirectional association between a word and a referent object is not a symbolic representation; it is an indexical representation. The indexical representation is an association between the iconic representation of the word sound (which would be iconically related to past utterances of that word) and the iconic representation of the object (which would have iconic associations with similar objects that have been previously seen). Deacon stresses that none of these relationships are symbolic; they could all be established by simple conditioning. An animal in a Skinner box would be capable of learning these associations.

Identifying a symbolic relationship

Deacon gives a comprehensive account of what symbolic reference is and is not; he also shows how a complex indexical representation can, at first glance, appear to be symbolic. If someone has learned a new word and uses it appropriately in a novel context, this could be taken as evidence that the individual understands the meaning of that word and uses it as a symbolic referent. A merely indexical relationship could underlie the same behaviour, however, with appropriate use produced by a process of set transference in which similar elements from the first context are mapped onto elements of the second context. Such a transfer of learning between similar contexts can take place by a process of stimulus generalisation. Stimulus generalisation occurs when a conditioned response to a given stimulus is also produced by a similar stimulus; for example, Pavlov's dogs were conditioned to salivate when they heard a bell of a certain pitch, but the response was generalised to a range of different pitches. Pavlov used stimulus generalisation to investigate animals' powers of sensory discrimination (Ridley, 1987). Deacon points out that it is easy to assume that transfer of learning between similar contexts works by creating a feature list of the salient details of the first context and mapping the second context onto this, but this is not necessarily the case. Stimulus generalisation and set transference do not require symbolic representation; they are mediated by indexical representation.

Testing a symbolic relationship

Deacon (1997) proposes that, in a symbolic representation, the predictive nature of the indexical relations are subsumed by the richer relationships between words.

Once a word has acquired symbolic reference, it will evoke other words forming a systematic higher order relationship: word meanings are *about* indexical relationships, but are not themselves indexical. Indexical relations serve word meaning only as cues for determining the relationships between words. Deacon proposes that indexical relations can be discriminated from symbolic relations, because an indexical relationship will be extinguished if the spatial or temporal contiguity between a word and its referent breaks down. Symbolic relations are not dependent on contiguity (and many words appear rarely or ever with their referent). Although extinction might provide a means of discriminating between symbolic and indexical relations, it is not a practicable test of symbolic representation.

In Chapter 4, we discussed similarities between Deacon's model and the framework of the stimulus equivalence research traditions. In both models, symbolic relations emerge from simpler associations, producing associations that have not been learned through direct experience. In the stimulus equivalence paradigm, equivalence relations parallel Deacon's symbolic relations. Both models suggest that acquiring symbolic representation requires higher level cognitive processes. Behaviourists describe these higher level processes as rule-governed or verbal behaviours. Much evidence has been put forward to suggest that stimulus equivalence is essentially related to the ability to use language. Sidman (1992a) describes word meaning as an equivalence relationship between a word and its referent. Equivalence relations have to be inferred since they cannot be directly observed, and as Deacon has pointed out, inferring the presence of a symbolic relationship is not easy because simpler associations can result in similar behaviours. A test of stimulus equivalence provides a tool for determining whether a relationship is an equivalence relationship - in other words, a symbolic referent (Sidman, 1992a).

In Experiments 3 and 4 we used an adaptation of the stimulus equivalence procedure to test for equivalence relations between corresponding associations. We demonstrated that the associations that were automatically transferred between the visual and the verbal systems showed equivalence. For ease of discussion we will call this *associative equivalence.* Sidman (1992a) notes that instructions can produce a positive performance in an equivalence test, and we found that many participants who failed the first association test performed correctly after explicit instructions, but we argue that this was not necessarily due to associative equivalence. Participants who performed correctly on the first association test also demonstrated semantic priming in the decision task, but participants who required explicit instructions before succeeding in the association test task did not show semantic priming.

This methodology may be useful in further investigation of symbolic representation by harnessing an equivalence task with a priming task we have obtained a means of discriminating between equivalence relations that are symbolically mediated and those that are mediated through chained associations. Our results show that name relations refer to more than an association between a word and a referent; they also refer to other related associations. This is in keeping with Deacon's account of symbolic reference.

The pattern of our results also sheds some light on the question of which comes first: stimulus equivalence relations or verbal rules. This is an important question. If it can be shown that equivalence relations are not derived from other behavioural processes it can be concluded that equivalence, like reinforcement and discrimination, is a primitive stimulus function (Sidman, 1992). The difference in priming task performance -- between Aware 1 and Aware 2 participants suggests that there is a difference in the type of stimulus relationships they had acquired. If we accept that our Aware 2 participants failed to benefit from semantic priming because they acquired no functionally symbolic relationships between the stimuli, we are to suspect that functional equivalence relations are not established by verbal rules.

Participants' self reports from Experiment 4 also suggest that the transfer of associations could be mediated by two different processes. Participants who performed correctly on the first association test task (and showed semantic priming on the decision task) did not describe a chain of associations; the majority of these participants did not refer to the name relation, but focused on maintaining the relationship they had learned in the training trial. Typical responses from this group of participants were: "I remembered the pairings from first time around"; "I used the old pair associations and kept them the same"; "... the ones [words] with pictures I matched to according to the pictures"; and "...[I] tried to use the relationship from the previous ones". In contrast, participants who only performed correctly after instruction tended to mention the chain of relations and needed to recall each link in the chain; for example, "I was able to make the connection between the names of the pictures and then the pairs between the pictures"; "I remembered the seed and the bag so S&M and that ruled the others out"; and "I remembered the R with the hook; R went with L which was the squiggle one."

Verbal rules or symbolic processes?

The use of the phrases "verbal rules" or "verbal learning" is loaded, suggesting language mediated processes rather than cognitive processes that mediate language. An example of this occurs in Mandell and Sheen's (1994) attempt to determine the direction of causality in the relationship between stimulus equivalence and naming. They manipulated the pronounceability of their stimulus sets by using pronounceable letter strings (e.g., CHIRT), unpronounceable letter strings (e.g. NSJBM), and strings of punctuation marks (e.g. +] *^!). They claim,

> ... the use of non-pronounceable stimuli inhibited acquisition of the discriminations and consequently the formation of conditional relations(p. 39).

They appear to equate pronunciation of a letter string with naming, and suggest that the most parsimonious account of their findings is that equivalence relations are mediated by verbal behaviour, specifically by naming. We suggest that a more parsimonious account of their findings is that paired associations are established more readily between pronounceable words because of the additional mnemonic cues provided by acoustic representation in addition to the visual representation. Another simple alternative explanation is that the unpronounceable words constitute more chunks in short term memory (Miller 1956) than the pronounceable materials. Alternatively, the instruction - to pronounce the words might override a default strategy preventing participants from trying to recall the un-pronounceable word pairs as two strings of letter sequences. We encountered similar difficulties with the abstract stimuli employed in Experiment 1, where several participants tried to recall the sequence of black and white squares in the matrix rather than trying to see an overall shape or pattern. In all of our experiments, our novel words were pronounceable, but this was not sufficient to produce the equivalence associations that are conveyed by a name relationship. We propose that higher level or symbolic processes are involved in the acquisition of language and of equivalence relations, and that equivalence relations are required before a name is functionally symbolic.

A limitation in the behaviourist approach is reluctance to investigate relationships between those covert behaviours that cognitivists refer to as processes, or systems, for example, phonological processing or working memory. However, the rigour of their experimental procedures is exemplary, and we will return to this later when evaluating Deacon's symbolic reference model. The traditions of behaviourism and cognitivism have such different vocabularies and paradigms that they often appear to be researching entirely different problems, and to fail to recognise how the findings of one tradition might compliment or advance the findings of the other.

Symbolic processing of transitive associations

We suggest that symbolic representations or equivalence relations are produced by an additional learning process: the restructuring of previously learned contiguous associations. This restructuring is an effortful mental process that brings the patterns of associations relating different items (or representations of those items) into the explicit domain, rendering them open to conscious inspection. This is the processing required for the transition between indexical representation and symbolic representation in Deacon's (1997) model, the construction of perceptual simulators in Barsalou's (1999) model, and the formation of equivalence relations in Sidman and Tailby's (1982) model of stimulus equivalence. All of these models suggest that symbolic associations are established on a foundation of simpler associations.

We propose that the automatic transfer of associative information between stimulus modalities is a symbolic process mediated by the name relationship between a word and its referent. A name is more than a bidirectional association between a word and its referent; it requires an awareness of the correspondences afforded by that relationship. Our argument is in keeping with accounts of symbolic processes from both the behaviourist and the cognitivist traditions of psychology.

Advantage of picture associations over word associations

A consistent pattern in our results showed an advantage in learning novel picture associations prior to learning associations between those pictures and novel words. We called this the visual-semantic superiority effect: participants who learned the picture associations first were more likely to be aware of relations between the training and the test tasks, were more likely to perform correctly on the test association task, and were more likely to show semantic priming. This was true when their performance was compared with participants who learned the word-picture associations before the picture associations and also when it was compared with participants who learned novel word associations and were tested for emergent associations between the novel pictures. This difference cannot be accounted for by better recall of the trained associations. We also observed a greater semantic priming effect in Experiment 5 for word pairs that participants related through imagery rather than through purely verbal associations. This finding is taken as support for perceptual grounding theories such as Barsalou, (1991, 1999).

We have suggested that the visual-semantic superiority effect might be due to pictures being inherently more meaningful than words, because they convey more information about possible uses, or because they show likenesses with other objects. Ellis (1994a) argues that the rich associations afforded by visual imagery support the advantage demonstrated for visually imagable words in free recall, paired associate learning, and the Stroop Task (Ellis, 1991, Paivio, 1971).

In Chapter 4, we discussed a range of evidence which suggests that pictures have an inherent symbolic status. If it is believed that a picture was intentionally created as a representation, it will be treated as a symbol even if it has only a very approximate similarity with its referent (Gelman & Ebeling, 1998). We discussed Paivio and Csapo's (1973) experiment demonstrating that picture recall is as good after incidental learning as it is after intentional learning, whereas word recall is improved by intentional learning. It appears that pictures are processed more easily than words, and yet novel pictures convey more meaningful information than novel words. This poses some interesting questions about the mechanisms involved in these two tasks. Schacter and Cooper (1993) propose that the structural details of a visually presented object can be encoded in a presemantic representational system. If this is the case, it might be predicted that learning novel pictures requires less encoding effort than learning novel words.

Schacter and Cooper (1993) carried out a series of experiments in which participants studied line drawings of objects that were either structurally possible or impossible. The impossible objects had surface and edge violations that would prohibit them from existing in three dimensions. The test task required participants to decide whether briefly presented (50 ms) objects were possible or impossible. Schacter and Cooper demonstrated priming effects that were independent of the study task and of participants' ability to recall the stimuli. For example, they manipulated the depth of processing occurring during the study phase across conditions by giving participants different tasks. Participants were told that they would see a series of pictures and that they would be asked to make a particular judgement about them. Participants in the structural encoding condition were asked to decide whether the object faced primarily to the left or to the right. Participants in the functional encoding condition were asked to decide whether the object would be better suited to function as a tool (e.g., for cutting, scooping, or pounding) or whether it would serve better for support (e.g., for sitting on, stepping on, or leaning against). After a break, participants were given an object decision task in which they had to determine whether the pictures displayed were possible or impossible objects. Priming effects were observed: decisions were made more quickly for pictures that had been studied previously. Participants were also given a recall test. Schacter and Cooper argue that, if the decision task relied on explicit processing during the study phase, then there would be an effect of study task on test performance. The functional encoding task requires a greater depth of processing than the structural encoding task. This would lead one to predict a greater facilitation for explicit tasks. This was the case for the object recognition task: participants in the functional encoding condition recognised more pictures correctly than participants from the structural encoding condition. However, there was no effect of encoding condition on performance in the object decision task.

Implicit visual processes

We argue that the above is evidence that learning perceptual details can occur implicitly. Implicit learning of perceptual details should result in greater availability of attentional resources for associations between novel pictures, for mapping the novel names onto the paired pictures, and for the consequent development of symbolic relations.

Further evidence of implicit encoding of perceptual details comes from Musen and Treisman (1990). Participants were presented with a list of briefly exposed novel dot patterns. The test task required participants to copy dot patterns that had either appeared during the original study phase or that were previously unseen. Participants showed a priming effect for the studied dot patterns that was independent of their ability to recognise the patterns from the study phase. Gabrieli, Milberg, Keane, and Corkin (1990) showed that the profoundly amnesic patient, HM, showed the same priming effects for the previously exposed dot patterns. Musen and Squire (1992) found no significant difference between the perceptual priming effect produced by amnesic patients and that of controls. They used a perceptual priming task in which studied patterns and new patterns were presented at threshold; the task was to reproduce each pattern after it was presented. Significantly more of the studied patterns than the new patterns were reproduced correctly by both groups. In a forced choice memory task, the amnesics recognised significantly fewer of the studied patterns than the controls.

Experiments performed with anterograde amnesics are often regarded as a means of distinguishing between implicit and explicit learning; since these patients have no explicit memory for events after the cerebral insult has occurred, any learning must be implicit.

It appears that encoding novel words requires a greater depth of processing than is required for encoding perceptual details. Cermak, Talbot, Chandler and Woolbarst (1985) presented evidence that amnesics show perceptual priming for words but not for nonwords. A group of Korsakoff patients were presented with a study list of 10 words; each word was presented individually and the patients were instructed to read the word aloud and try to remember it. The patients performed very badly on a subsequent recognition test, but when they were given a perceptual identification task in which they had to name words that were briefly presented on a screen they named the words from the study list faster than new words. The procedure was repeated with a study list that included pronounceable nonwords. No facilitation was produced by the nonwords from the study list.

Diamond and Rozin (1984) suggest that amnesics are impaired in their ability to learn novel word form. They compared the free recall and cued recall ability of amnesic patients following training with three types of trained stimulus sets: (a) unrelated paired associates (e.g., great-path), (b) disyllabic familiar words (e.g., window), and (c) disyllabic psuedowords (e.g., comda). The amnesics performed very badly on the free recall task for all stimulus sets. In the cued recall task, they were presented with the first syllable of the words, the first syllable of the pseudo-words, or the first word of the word pairs. The amnesics were able to complete the familiar words, but they were unable to complete the pseudo-words, nor were they able to produce the paired associates for cue words. There was no evidence that the amnesics had learned the novel word form. Diamond and Rozin posited that the amnesics' ability to recall familiar words is due to activations of engrams in long term memory.

These studies lend some support to our suggestion that encoding a picture representation is an easier process than encoding a word representation. However none of these studies were designed to test the differences between encoding picture forms and surface word forms

Novel words require more processing than novel pictures

Amnesics' ability to demonstrate perceptual learning of novel objects and random dots but not of the form of a novel word, is incongruous. Both types of stimuli are visually processed. What is the difference in learning a novel written word and a novel picture? Some clues might be gleaned from Musen and Squire's (1991) finding that amnesic patients show normal practice effects for reading both words and nonwords. Both amnesics and control participants read lists in which five words, or five nonwords, were repeated 20 times. They read these lists faster than lists of 100 words or 100 nonwords, though the amnesics showed a significantly impaired performance on the forced choice recognition task. Facilitation appeared to be specific to the entire word form; when the repeated nonwords were presented with the same letters in a different sequence, neither the amnesics nor the controls showed any facilitation. This adds to Musen, Shimamura, and Squire's (1991) finding that amnesics (and controls) showed an improved reading speed with repeated reading of the same text, but that the facilitation did not generalise to new material; it remained specific to that text.

It is possible that, when a novel word is encountered, more automatic processing resources are employed than those required for processing a novel picture. Processing a word involves automatic phonological processing as well as visual processing. Not only is there a visual representation to be encoded but also an acoustic representation and a motor pattern for vocalising that word. Deacon suggests that iconic representations have to be established before indexical relations are acquired. We suggest that iconic representations of a picture are learned more easily than iconic representations for a word because word forms trigger additional processing mechanisms.

Further indications that pictures require less processing than words are the findings that amnesics, although unable to learn novel associations between words, can use imagery as a means of producing paired associate learning, providing the image is interactive. Parkin (1987) cites studies by Lewinsohn, Danaher and Kikel (1977) and Wilson (1982) where imagery has been successfully employed by amnesic patients. Wilson's patient, Mr. B, learned the names of 12 people over a period of 12 days by using interactive images. For example, for Barbara he imagined a barber holding a large letter "A" up to her face. In contrast, Gabrieli, Cohen, and Corkin (1983) performed a study with the amnesic patient HM, who was poor at defining commonly occurring words that he had encountered since his amnesia. After 10 days of intensive training in the meaning of the unfamiliar words, HM was unable to reliably match the definitions with the words.

It appears that visual representations convey some meaningful relations more easily or at a lower level of processing than verbal representations. This pattern of results parallels the visual-semantic superiority effect we observed in our experiments. We suggest that learning perceptual representations of visual information is an implicit process. As we have already noted, simple associations are formed before complex or symbolic associations can develop. Supporting evidence for this idea can be seen in the following models. In Deacon's (1997) model, iconic representations are the first level of representation in a hierarchical structure. In Barsalou's (1999) model, perceptual symbols must be encoded before conceptual simulators can be constructed. In Paivio's (1991) dual coding model, items are recognised by means of representational connections before associative links can be activated. If simple associations necessarily precede the acquisition of symbolic representations, it follows that semantic learning is underpinned by implicit processing; explicit processing is supported by implicit processing. This implication, although not unsupported by previous related research, raises empirical questions worthy of further investigation.

Symbolic associations: Explicitly acquired, implicitly activated.

On first inspection, it might appear that we are making contradictory claims about the nature of a symbolic association. This is because we are claiming that a name relation is acquired through explicit processing and that the association is available to conscious inspection, and, in apparent contrast, we claim that a symbolic association can be automatically activated. Only participants aware of the relationship between word pairs or picture pairs showed semantic priming in a decision task. We also suggest that explicit processes might be supported by implicit processes.

Are implicit and explicit processes dissociable?

If implicit learning supports explicit learning it follows that explicit tasks might not be a pure measure of explicit processes. This is not a novel idea. Jacoby and Kelley (1991) propose that subjective or conscious experiences are constructed from, and reflect unconscious attribution processes. For example Jacoby, Allan, Collins and Larwill (1988) used a noise judgement task in which participants had to judge the background noise level. Participants listened to sentences that they had heard previously and to new sentences against a background of white noise. The previously heard sentences were more readily perceived causing participants to report that the background noise was lower. The memory of the previous experience of the sentences had altered the subjective experience of the volume of the white noise. This is an example of underlying implicit processes affecting a task that is reliant on explicit experience.

Jacoby and Kelley (1991) propose that feelings of familiarity contribute to a recognition decision. Feelings of familiarity can be induced by perceptual fluency without conscious knowledge that this is derived from past experiences of those items. Jacoby and Whitehouse (1989) gave participants a word recognition task in which they had to decide whether words were new or had previously appeared in the study list. If a new word was flashed below the participant's perceptual threshold prior to being displayed as a new word, it increased the probability of that word being falsely recognised. It appears that both implicit and explicit (or, to use Jacoby & Kelley's preferred terminology, strategic and automatic) processes can contribute to the conscious sensation of recall. Jacoby and Kelley report an experiment designed to demonstrate the influences of implicit and explicit memory on recognition. Participants were given a list of non-famous names to study. In the test task, they were asked to judge which were the famous names in a list that contained famous names, names from the study list, and new non-famous names. Participants were informed that all the names on the study list were of non-famous people. If participants could recall the name from the study list they would know that it was not famous; therefore above-chance fame decisions for these names could be attributed to familiarity caused by unconscious memories of the study list. When the study task was performed under conditions of divided attention, requiring participants to monitor an auditory digit list, there were significantly more false famous responses for names from the old list than for new nonfamous names. The opposite pattern was produced for participants who had been able to give their full attention to the study list. Further tests showed that participants in the divided attention condition recognised significantly fewer names from the study list, but that they still showed a familiarity effect, indicating unconscious effects of their previous experience (Jacoby, Woloshyn, & Kelley (1989).

Further evidence that implicit learning can support explicit learning comes from studies with amnesics. Glisky, Schacter, and Tulving (1986) successfully managed to teach a group of amnesic patients items of new computer vocabulary by means of intensive training employing a technique of vanishing cues. Patients were presented with a definition of a computer term such as "to store a program" and the name of the command (in this example "save"). On subsequent trials, the definition was presented with a fragment of its associated command (e.g. "sav"). When patients were able to successfully complete the command word, subsequent presentations were reduced by a further letter (e.g. "sa" then "s"). Eventually, the patients were able to recall 15 different computer commands without the presence of a cue. It must be noted though that all of the commands were already part of the patients' vocabularies.

A similar study successfully taught amnesic patients a new colour name. Although patients were able to map the word to the colour, they were unable to integrate it with their conceptual knowledge of other colours (Dopkins Kovner & Goldmeyer, 1990). It appears that these patients had used implicit processing to learn a paired association between a word and its referent or its definition.

Haist, Shimamura, and Squire (1992) demonstrated that performance on recall and on recognition tasks are related, and that performance on the recognition task corresponds closely with participants' feelings of confidence about their responses. Although there were significant differences in the performance of amnesics and controls on these tasks, there was no evidence that the recall ability of the amnesic participants was disproportionately impaired compared with their recognition ability. The tests were repeated over increasing time intervals, and both the controls and the amnesics performance deteriorated over time. The amnesics performed at above chance levels on the recognition task for over 24 hours. Haist et al. mapped the forgetting curves for the amnesics and the controls together, so that the recognition performance of the amnesics 15 seconds after the study task was shifted to the point on the graph where controls produced a similar performance. The shifted recall and confidence levels produced by the amnesics also matched those produced by the controls. Although Haist et al. argue that this is evidence that both recall and recognition are supported by declarative memory, this does not account for the amnesics performance on the recognition task. We suggest that their results indicate that recognition is supported by implicit memory and that recognition processes contribute both to a feeling of knowing and to recall processes. We are not denying that there is a role for explicit processes in these operations; we are emphasising the role of implicit memory.

Implicit processes underpin explicit processes

We propose that explicit learning is supported by implicit learning and that explicit processes are supported by implicit processes. Once learned, explicit associations can be automatically activated. The visual-semantic superiority effect occurs in part because learning novel words involves additional phonetic processing. Because novel pictures require less attentional processing than learning novel words, there are more resources available for learning the paired associations and for identifying the symbolic relationships between the pictures and the words.

Jacoby, Woloshyn, and Kelley's (1989) experiment, outlined above, shows implicit processing can influence explicit processes; recognition is more likely if there is a feeling of familiarity or perceptual fluency. Their results also suggest that more attention is required to acquire explicit memories, available to conscious inspection than to acquire implicit memories that support perceptual fluency and familiarity.

Barsalou's (1999) model accommodates Jacoby et al.'s data. Barsalou suggests that perceptual symbols are not available to conscious inspection, they function unconsciously; as in preconscious processing and automatised skills. Implicit memories are encoded as perceptual symbols for specific items. He proposes that attention is required for selecting which components of the sensory array are encoded as perceptual symbols. We suggest that attention is required for the process of integrating perceptual symbols.

Attention and awareness

Nissen and Bullemer (1990) demonstrated that implicit processes require attention. Participants in a sequence tracking task showed the same amount of interference when an "out-of-sequence" item was presented whether they were aware of the sequence or not. Awareness of the sequence was determined by whether participants were able to predict the next response key. Interference was demonstrated by comparing response times in this task with response times in a random sequence task. They propose that interference effects are produced because participants were attending to the anticipated response key.

Posner and Rothbart (1991) propose that awareness is the focal output of an integrated network of attentional processes, in the same way that our visual experience is the integrated product of the visual system. A process that requires attention is not necessarily a conscious process. Consciousness is the integrated product of the attentional system, so we might become aware of a change in a visual array, but we are not necessarily aware of monitoring the array up to the point of change, nor are we necessarily aware of the movement of our eyes towards that change. Posner and Rothbart suggest that it is to be expected that lexical items can activate semantic representations without conscious attention whereas abstracting meaning from a sentence does require conscious attention. Our results are in keeping with Posner and

Rothbart's assertion that whereas simple linear sequences may be leaned without conscious attention, hierarchical associative structures cannot be learned without conscious attention. They also observe that there can be no fixed boundary between what can and cannot be learned with or without conscious attention, because of individual differences based on prior learning experiences and constitutional abilities. This observation is especially pertinent to our results.

Attention is related to awareness; the more attentional resources available during the original experiences, the more likely it is that episodes or experiences will be consciously recalled. It is also likely that implicit processes such as pre-semantic processing or unintentional reading responses require some attentional capacity; they are sensitive to divided attention manipulations (Perry, Watson & Hodges, 2000). It is interesting to note that the second most prevalent cognitive impairment for patients in the early stages of Alzheimer's disease is attentional deficit. The most common is an episodic memory deficit, but this is true by definition since impaired episodic memory is a diagnostic criterion for Alzheimer's. Perry et al. (2000) tested 27 Alzheimer's patients with a battery of psychological tasks. All of the patients were amnesic with poor recall of recent events and were assessed as having mild or minimal difficulties; over 85% were impaired at split attention tasks such as the elevator task and the Stroop task. In the elevator task, participants are presented with a number representing floors in a lift; participants have to count upwards and downwards to keep track of the lift. This is considered a measure of attentional set shifting and a test of cognitive flexibility. Sixty-five percent of the patients performed badly on tests of sustained attention (Perry et al. 2000).

Young (1996) asserts that consciousness is not an all or nothing phenomenon; there are different levels of consciousness. He also suggests that consciousness is not simply a change from neural inactivity to neural activity: it is a change in neural systems function. He supports his assertions with neuropsychological evidence from studies of patients with different forms of neglect, and evidence from experiments performed with participants in different states of consciousness. For example, he found that participants demonstrated priming after auditory exposure to paired associations while anaesthetised.

In our experiment, we observed differences in performance from participants who were spontaneously aware compared with those who were aware after instruction and with those who remained unaware. Those who were unaware had conscious recall of the trained associations, but this was not sufficient to establish semantic associations between the related sets of paired associations. Our results are more in keeping with the idea of graded processes (Weiskranz, 1991) or a depth of processing account (Craik & Lockhart, 1971) than of a dissociable processes account, which would suggest two discrete states.

Are semantic processes automatic?

Tasks are often characterised by the types of responses they demand. Automatic processes are defined as occurring without intention or awareness; they are driven by the environment. By contrast, intentional or controlled processes are conscious (Jacoby & Kelley, 1991). Priming tasks have been considered a measure of implicit knowledge because they do not demand explicit knowledge of the study episode. In the case of a LDT, this means that awareness of the prime is not necessary for the response to a related target to be facilitated. However, LDTs do not discriminate between facilitation derived from words associated by habit or contiguity, and facilitation derived from semantic or meaningful associations. Simply because a task demands automatic responses, this does not imply that it is a measure of implicit or unconscious associations.

The term "automatic response" can refer to innate responses, or explicitly learned skills such as driving and reading, that have become automatised with practice and can then be executed without awareness, or intention. A frog's response to a passing fly is a tongue flick resulting in the capture of a morsel of food. The frog does not analyse the situation and determine an appropriate response; the same response is evoked by any similar pattern of movement across the frog's retina. This is an automatic response, produced by an innate behaviour (Lettvin, Maturana, McCulloch & Pitts, 1959). The interference effect manifest in the Stroop task, in which the time taken to name the ink colour in which a word appears is slower for incongruent colour words than letter or symbol strings (Glaser & Glaser, 1989) is explained by automatic processes. The colour word provokes an automatic response -- reading the colour word -- which interferes with the colour-naming task. It might be concluded from this that reading interferes with naming, but to understand the processes revealed by the task, the automatic responses to the stimuli must be examined. In the Stroop task the interference is not caused by the act of reading; it is caused by the association between the colour word that has been automatically accessed through reading and the colour word that is required to name the ink colour.

The comparison of these two tasks highlights some important differences. Both the frog's response to the fly and the participant's response to the colour word are automatic responses, but they are very different processes; one is innate and one is learned. Innate responses cannot be brought under intentional control; in other words the component skills cannot be transferred to other tasks. Learned responses can be brought under conscious control. For example, degraded words can be read by applying knowledge of legal letter combinations and letter forms to the task, and different grapheme to phoneme translation rules can be applied to the task. Although the fly catching response and the reading response were both elicited as automatic responses to environment stimuli, they are fundamentally very different processes;

one is an innate implicit response and the other is a highly skilled response requiring explicit learning.

It is potentially misleading to classify both these responses as automatic. Similarly, it is potentially misleading to suggest that a facilitated response in a LDT always reflects the same type of association between the prime and the target; important distinctions can be obscured by the generalisation. Our experiments demonstrate that priming in a LDT task can be produced by association resulting from contiguous exposure (Pilot Study 1) or from symbolic associations (Experiment 4). It appears that awareness of the association is necessary for a priming effect to be produced, but the origins of the association do not effect the facilitation (Experiment 5). In Experiment 5, we recorded a priming effect for word associations derived from different sources, but only when participants were aware of the associations. As we discussed in Chapter 5, this result throws new light on the debate about whether facilitation in a LDT measures associations derived from contiguity or semantic relations. This is of relevance because contiguous associations are derived from direct experience and as such they might be considered to reside in the domain of episodic memory, whereas symbolic associations reside in the domain of semantic memory. We suggest that the distinction between episodic and semantic is more usefully conceived as a continuum rather than as two discrete processing or storage systems.

Awareness of an association appears to be necessary before it can be used in intentional cognitive processes. We argue that explicit learning underpins the automatic responses produced in a LDT, but that this explicit learning can be facilitated by implicit processing.

Theoretical Implications

Our results did not fit the predictions of single semantic store models. The results of Experiments 2 and 3 offer support to Paivio's (1971, 1986, 19991) dual coding model. However, although Paivio's model predicts an equivalent transfer of associations between the visual and the verbal systems when referential links between the novel pictures and the novel words have been established prior to the paired association training, it does not predict the visual-semantic superiority effect. Nor does dual coding readily adapt to our finding that automatic transfer of associations between the visual and the verbal system is mediated by symbolic relations rather than chained associations.

Our results are more easily accommodated by the models of symbolic representation proposed by Barsalou (1999) and Deacon (1997). These models have some similarities with Paivio's dual coding model. Neither of them propose a core of amodal representations, and both models allow for the specialist representation of verbal and sensory information. Like Paivio, they propose systems of representational, associative, and referential links. Unlike Paivio, they do not propose functionally discrete processing systems but propose distributed processes instead. Our experiments were not designed as a means of discriminating between these two models; however, our data allow some comparison of their relative merits.

Are episodic memories semantic?

Our results confirm that symbolic associations can be derived from perceptual experiences. We demonstrated that functionally symbolic word associations could emerge from novel picture associations. This result supports the central tenet of Barsalou's (1999) perceptual symbol system, which proposes that cognition is inherently perceptual.

The basic unit of Barsalou's model is the perceptual symbol. Perceptual symbols are partial records of the neural states produced by the original perceptual experience. Information about perceived events in the external or internal environment is selectively encoded. Perceptual symbols do not comprise a holistic record of the experience, rather a schematic multi-modal components of the experience. Related perceptual symbols are integrated into simulators, and simulators provide the means of conceptual representation. Barsalou proposes that perceptual simulators function as concepts that represent types, produce categorical inferences, and combine to form complex simulations of situations that have never been experienced. Perceptual simulators provide the framework for the representation of concrete objects and abstract concepts. Barsalou argues that it is possible to provide an entirely perceptual theory of knowledge.

Barsalou (1999) proposes that perceptual representations can represent abstract knowledge by framing, by selective attention, and by combining and recombining sensory-motor, introspective, and proprioceptive perceptual symbols. Frames provide the means of systematically integrating perceptual symbols to construct specific simulations for a category, allowing for simulations to be represented within simulations in a hierarchical fashion. For example, basic perceptual symbols might represent the approximate size and shape of a car and some of its components; these are embedded in an object-centred reference frame. Framing allows hierarchical organisation of perceptual symbols, so the simulation for a car might have simulators for car doors and wheels embedded in it. Each subsequent perceptual experience of a car will result in additional perceptual symbols being integrated into the frame. By focusing attention on a sub-region of a frame, for example the car door, either perceptual symbols for specific doors can be reactivated or an average superimposition state could be activated. Selective attention can highlight the core content of a series of perceptual simulations of event sequences, abstracting the underlying patterns. Barsalou's account provides the outline of an architecture for a perceptually based semantic knowledge system.

Deacon (1997) has a different perspective. He puts more emphasis on the role of words as mnemonic devices. In his system, words can activate a complex matrix of systematically arranged hierarchies of symbolic associations between words and shared indexical relations between words, signs, and iconic representations. It is the ability to represent these patterns of associations in a top-down way that gives words their mnemonic power; individual indexical and iconic relations do not have to be accessed once the hierarchical structure has been recognised. Symbolic associations develop from overlapping sets of associative relationships at the indexical level, so the pattern of symbolic representations will map the relationships between objects and events in the perceptual world. Word meanings are not derived directly from correlations with, or representations of, perceptual experiences; they are distributed across the associated network. A word is defined as a function of its relationships with other words. Complex symbolic relationships are constructed on a foundation of overlapping patterns of perceptual representations. Individual indexical associations might be quite weak, but it is their combined value that gives a symbolic association its strength.

The results of Experiments 3 and 4 could be accommodated by either model. Both of these models are compatible with our conclusion that symbolic associations are constructed from simpler associations acquired from episodic experience. Our visual-semantic superiority effect, and the facilitation observed for words associated by imagery (Experiment 5) suggest that perceptual associations are more influential in shaping the patterns of symbolic association than Deacon's account proposes.

Our conclusions provide a problem for Tulving's (1984, 1995) account of the relationship between episodic and semantic memory. Tulving maintains that episodic memory is a subsection of semantic memory, and that the function of episodic memory is dependent on the integrity of semantic knowledge. Tulving argues that the development of semantic memory precedes the development of episodic memory. Retrieval from semantic memory is relatively stable, but retrieval from episodic memory requires the reconstruction of an event using contextual cues. Information is stored in episodic memory and interpreted by the semantic system, often resulting in a change in its content.

In support of his claims, Tulving suggests that amnesia demonstrates a dissociation between semantic and episodic memory. Tulving claims that amnesics' ability to perform categorisation tasks, sentence verification tasks, word completion tasks and so forth demonstrates a preservation of semantic memory, whereas their failure in recall and recognition tasks demonstrates an impairment of episodic memory.

Because Tulving proposes that recall from episodic memory requires semantic processes, a double dissociation would not be possible. Recent research has reported a dissociation in which episodic memories remain intact but semantic memory is impaired. Graham, Simon , Pratt, Patterson, and Hodges (2000) report that patients with semantic dementia present with a progressive (and sometimes relatively selective) deterioration of semantic memory, though their memories for recent events remain intact. They found that these patients had preserved recognition of previously studied pictures only if a perceptually identical picture was represented. If another exemplar was shown, there was no recognition. Graham et al. proposed that this suggests that recognition was supported by episodic memory. They propose a revision of Tulving's model that permits top-down and bottom-up processing between perceptual representations and both semantic and episodic memories (see Figure 6.1).

This revised model is better suited to Diamond and Rozin's (1984) prediction that new semantic memories would be severely compromised in amnesic patients due to a deficit in the formation of new episodic memories. They suggest that cued recall in amnesics is supported by semantic memory. For example, Winocur (1982) demonstrated that amnesics could learn paired associations between words that had a pre-existing relationship with each other (e.g., battle and army) but not paired associations between previously unrelated words. Parkin (1987) supports the view that amnesia causes problems encoding semantic information; he noted that the amnesiac professor, PZ, was unable to remember technical words introduced in the later part of his academic career, that is, after he had become ill.

Our data suggest that symbolic relationships can be abstracted from episodic experiences. Our participants learned arbitrary paired associations between novel stimuli. Tulving's (1984) model emphasises both the similarities and the differences between episodic and semantic memory, but gives no clear definition of either.

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Figure 6.1: Graham et al.'s (2000) revised model of semantic and episodic memory

However, we assume that the training tasks provided episodic memories. As Tulving states "Organisation of knowledge in the episodic memory is temporal: One event precedes, co-occurs, or succeeds another in time"; and "The episodic system registers immediate experiences, the semantic system registers knowledge conveyed by referential events and language" (p.225). We propose that episodic memories must then be transferred to the semantic system; since this is the system that has rich inferential capabilities compared with the limited inferential capabilities of the episodic system. Tulving proposes that the semantic system tends to be automatic; this is at odds with our conclusion that effortful processes are required.

Continuing the continuum: Implicit influences on semantic memory

Many of the commentaries provoked by Tulving's (1984) account of episodic memory challenge the usefulness or parsimony of the episodic/semantic distinction. Hintzman (1984) observed that dissociations provide insufficient reasons to assume that different "systems" are involved. Word frequency has opposite effects on recall and recognition, but this is not taken as evidence of two entirely different systems. While the distinction might prove to be a useful heuristic when contemplating the roles of various underlying processes in tasks purported to dissociate the two systems, it is equally possible that episodic and semantic memories are processed by the same system.

Lachman and Naus (1984) argue that all memories can be located on the continuum between highly episodic (an experience containing many autobiographical markers) and highly semantic (an experience devoid of spatial and temporal information). They argue that the ability to preserve the details of episodic memory is adaptive, but that intellectual processing demands the abstraction of semantic information from episodic experience for problem solving. Divorced from the contextual constraints of an episodic memory, salient features of previous experiences can be used for decision making and problem solving. In an elaborate example, Lachman, and Naus suggest that there is an evolutionary advantage for a system that can distill a concrete experience into its salient features while maintaining an intact representation of the episode for future analysis. For example a memory that, at a particular waterfall, on a particular moonlit night, a large black and yellow striped animal killed a brother, is adaptive if the knowledge that black and yellow striped animals should be avoided can be abstracted. There is no immediate advantage if another independent memory of a large black and yellow striped animal and a father screaming on a hot day in the meadow when the blue flowers were out is recalled. However, abstracting the salient details from these two memories allows the inference that large black and yellow striped animals should be avoided wherever and whenever they are encountered. Later experience might allow other salient features to emerge, for example about the location, or the season. A one-off experience does not provide enough data for salient patterns to be identified.

An interesting juxtaposition to Lachman and Naus' (1984) argument can be found in Reber's (1989, 1993) experimental demonstrations of people's abilities to implicitly apprehend underlying patterns of regularities from complex sequences of stimuli. Winter and Reber (1994) do not assume these relations are abstracted as a result of incidental exposure to the stimuli, but as "a by-product of the application of attention to relevant rule-governed structures in the environment" (p. 117). When explicit attention is given to salient elements within a stimulus array, information about the underlying structural regularities can be implicitly abstracted and tacitly represented. Implicit knowledge of rules can detect, for example, that a specific sequence of stimuli predict the subsequent presentation of a certain stimulus, or that certain sequences are "illegal". Implicit knowledge of the probabilities with which stimuli co-occur can then influence explicit judgement tasks and decision making. Winter and Reber suggest that we subjectively experience the process of guiding explicit processes as "intuitions" or "hunches". Winter and Reber claim that implicit and explict systems operate in parallel and that the outcome of these complementary processes is a cohesive synthesis.

Not only might it be adaptive to retain perceptual details of an episodic event for future analysis (Lachman & Naus, 1984), but also it appears that humans are adapted to analyse patterns of regularity from such records. Implicit knowledge abstracted from episodic memory might then influence the focus of attention during future perceptual experiences and produce explicit knowledge of their salient details. Barsalou's (1999) model proposes that the selection of perceptual details to be encoded as perceptual symbols is a function of attention, and that attention is the mechanism for selecting which of the encoded features are salient. His model does not specify why some features might attract more attention than others. We suggest that implicit learning might underpin the acquisition of explict knowledge by bringing the regularities between a current experience and previous episodic memories into the focus of attention, thus guiding the selection of perceptual experience for encoding as perceptual symbols.

Graham et al.'s (2000) revised model suggests that both semantic and episodic representations stemming from events are maintained, and both representations can provide top-down information during perceptual analysis. If this model were implemented by means of distributed representations it seems likely that the resulting architecture would be very similar to Deacon's (1997) model (see Chapter 4 for details).

We showed (Experiment 4) that aware participants were able to abstract symbolic relationship from the paired associations they had learned. These paired associations would be represented as episodic memories in Graham's (2000) revised model or indexical relations in Deacon's (1997) model. The relationship between the two sets of associations abstracted from these memories would be represented as semantic knowledge in Graham's model and as symbolic relations in Deacon's model. Deacon's model provides an architecture with the potential to support spreading activation through symbolic associations and a means of grounding symbolic representation in perceptual experience.

Symbolic or Perceptual Reference?

Deacon's (1997) symbolic reference model focuses on the symbolic processing underlying language; he then extends his argument to the role of language in cognition. Like Barsalou (1999), Deacon's starting point is the problem of reference. Barsalou uses the perceptual grounding problem as his starting point, whereas Deacon takes an ontological approach. He argues that reference is not unique to language, and that what distinguishes language from other animal communication is the way that words refer to things. It is apparent that animals are able to communicate by means of calls and gestures and that these have referential status. Vervet monkeys have specific cries for different predators that require very different evasive actions (Cheney & Seyfarth, 1990, in Deacon, 1997). Deacon proposes that language has evolved from non-linguistic communication such as smiling or sobbing; these innate forms of communication do not require language to learn or interpret them. The acquisition of language is dependent on non-linguistic communication, and the use of language is supported by nonverbal communication such as facial expressions, gestures, and interactions with objects that disambiguate a speaker's meaning. Deacon stresses that language has evolved in parallel with non-linguistic communication; language has neither replaced nor superseded it. Deacon assumes that the types of reference supporting nonverbal communication (iconic and indexical) are used by humans and other species alike, but symbolic reference is peculiar to humans.

There are parallels between Deacon's assumptions about the relative roles of language and nonverbal communication and our conclusions about the relative roles of explicit and implicit learning. We have presented arguments suggesting that implicit learning supports explicit learning. In Chapter 4, we compared implicit learning with classical and operant conditioning demonstrated by animals and explicit learning with verbal or rule-governed learning that is peculiar to the human species. The distinctions between language and nonverbal communication and between explicit and implict learning demarcate the threshold between human and non-human capabilities, with language and explicit learning being uniquely human abilities.

To understand symbolic reference, it is necessary to determine how animal behaviours, or calls that produce specific behavioural responses from members of the same species, are qualitatively different from words that we employ in linguistic communication. Deacon (1997) asserts that there is a fundamental difference in the way a word refers to a thing and the way a monkey call refers to a predator, or a picture refers to an object. Calls are unintentional responses. If a vervet monkey sees a leopard it will produce a specific call and will climb a tree; other monkeys hearing the call will echo it and take the same evasive action- regardless of whether or not they have seen the leopard and whether or not any monkeys remain on the ground. There is a complex indexical relationship between the presence of a leopard and the call, and between hearing the call and the behaviours this evokes climbing a tree and echoing the call (Cheney & Seyfarth, 1990, in Deacon 1997). A dog's understanding of a word is dependent on a stable correspondence between the word and the event to which it refers. Our understanding of a word, by contrast, is *not* dependent on a stable correspondence between the word and its referent: very few words frequently appear contemporaneously with their referents, yet their meaning remains stable. Then again, words that are synonyms rarely appear together, but the association between them is strong.

Deacon is theoretically very clear about this distinction. To develop his argument, and to clarify the different stages in acquiring symbolic reference, he refers to language studies carried out with chimpanzees (see Savage-Rumbaugh,1986; Savage-Rumbaugh, Rumbaugh, Smith & Lawson, 1980). These chimpanzees have been trained to associate specific arbitrary lexigrams on a large keyboard with different stimuli, for example foods and tools for opening different food dispensers. They have been taught lexigram -> food item relations and food ->lexigram relations. These relationships have been maintained by daily training sessions. The experiment that fired Deacon's imagination showed that the chimps appeared to use symbolic inference to form new associations in a categorisation task. The chimps were trained to associate a set of food items with a lexigram glossed as "food" and to associate a set of individual tools with a "tool" lexigram. When new food items were introduced into the set the chimps were able to select the appropriate "food" category lexigram, and when new tools were introduced the chimps selected the appropriate "tool" lexigram. Deacon attributes their performance to an awareness of the systematic relationship between food and that particular lexigram. The chimps had knowledge of the information that they had already learned, and they were able to employ this knowledge to solve new problems. Deacon claims that this demonstrates symbolic behaviour, that the chimp's performance is crossing the threshold of symbolic behaviour.

"Defining the symbolic threshold"

It is of particular interest to look at a behaviourist analysis of the chimp's performance. After a careful review of the training procedures, Dugdale and Lowe (2000) suggest that, at best, Savage-Rumbaugh's language trained chimps have demonstrated unidirectional transitive relations between the stimuli, (A -> B and A -> C yielding B -> C). There is no evidence of symmetry in any of these relationships. A symbolic relationship requires equivalence between the related items. The stimulus equivalence paradigm (discussed in Chapter 3) demands that reflexivity, symmetry, and transitivity are established before a relationship can be considered to be equivalent. Dugdale and Lowe (1990) ran an experiment with these same language trained chimpanzees designed to test them for symmetry (training A -> B; testing B -> A). The chimps were trained with new stimuli that had not been employed in their previous language training. Despite extensive training, there was no evidence of any emergent untrained symmetrical relations between the stimuli. When the same training regime was employed with two year old children, they were able to pass the symmetry test (Horne and Lowe, 1996).

Deacon's model implies that indexical relations are symmetrical. He states that the transition between iconic reference and indexical reference demands a recognition of the co-occurance between the two iconic referents. Deacon defines indexical reference as dependent on a unique relationship between individual contexts, items or places. An example of an indexical relationship is a proper name, which is a word associated with an individual. Deacon also claims that iconic and indexical representations are supported by the design logic of all vertebrate brains. Following Deacon's definition of indexical reference it would be predicted that the language trained chimps could perform a symmetry task. However, the language trained chimps were able to learn A -> B and to learn B -> A as two independent relations (Dugdale & Lowe, 1990, 2000). They did not abstract the rule "if A -> B, then B -> A". Dugdale and Lowe (2000), report that, to date, there have been no convincing demonstrations of non-human species passing a symmetry test. Deacon's claims for symbolic or even indexical reference in non-human animals conflict with well established results from the stimulus equivalence tradition. It appears that awareness of the regularities is required to pass the symmetry test, or to transfer associations across modalities in our test association tasks. ; Learning the rule is a symbolic function. We concluded that participants in Experiment 4 (Chapter 4) who could perform the paired association task correctly only after explicit instructions had not abstracted knowledge of the underlying relationship; they were using chained associations to perform the task. These participants did not show a semantic priming effect in the decision test task, which lends further support to our argument that they had not acquired a symbolic relationship. We assumed that this was because they had not recognised the transitive relationships entailed by the name relations. An alternative possibility is that these participants had not recognised the symmetrical relationship presented during the vocabulary training task.

It is possible that there are two stages demanding higher level processes to explicitly abstract these underlying regularities 1) awareness of symmetry between the word and its referent (e.g. if A -> B, then B -> A); 2) equivalence relations or symbolic reference where awareness of the associative relationships that are entailed in the name relation is required (for example if A -> B is the name relation and A -> C and B -> D are existing paired associations then C-> D is entailed in this relationship). Our data suggest that this is the case, but we did not clearly demonstrate this. We assumed that participants were treating the name relationship as symmetrical but we did not explicitly test them for symmetry, so we have no empirical data to support our assumption that there are differences between the performance of our undergraduate participants and the capabilities of the language trained chimpanzees. We note that a large body of research exists in which similar populations of subjects do pass symmetry tests without difficulty. To eliminate the possibility that we had failed to establish symmetrical name relations between the pictures and words the experiment would have to be repeated presenting only unidirectional relationships in the paired associate training and testing for symmetry as well as for the transfer of associations.

The chimpanzees' language training and performance serve to highlight the distinction between the processes required to establish a functionally symbolic word compared with the processes required to support chained associate learning. If there are two levels of symbolic representation, and symmetry is demanded for the first of these levels, then Horne and Lowe (1996) are correct to assume that a bidirectionality between a word and its referent might be produced by a history of naming behaviour. Bidirectionality is not sufficient to account for the symbolic functions endowed by a name, however. For example the word "cup" might be bidirectionaly associated with the word "saucer", but we do not define the relationship between a picture of a cup and a picture of a saucer as a name relationship. It is evident that the apparently simple task of learning a new indexical relationship demands effortful high level processing. Learning a new name might appear to be an automatic skill, but it is not an innate skill. This evidence does not undermine Deacon's suggestion that there are different types of reference; but serves to clarify the argument by defining the "symbolic threshold".

We suggest that knowledge of the underlying regularity between associations is semantic knowledge. Chimps do not show symmetry because they are not capable of crossing the symbolic threshold. Humans have crossed the threshold because of their additional cognitive capabilities. Our results show that having the capacity to recognise symbolic associations does not imply that symbolic associations are automatically recognised. The "associative equivalence" test developed for these experiments might prove to be a useful tool for evaluating the role of awareness in other cognitive tasks.

Summary

- This thesis set out to examine the interaction of verbal and imagery representations by focusing on the transfer of associative information between stimulus modalities.

- Transfer of associative information across stimulus modalities can occur.

- We found some consistent patterns of results across our experiments: 1) transfer occurs most readily in the condition where picture associations are trained before the names for the pictures are learned; 2) transfer can be mediated by name relations; 3) name relations are more than a bidirectional association, they require awareness of the associations which they entail.

- We have suggested that: 1) semantic associations can arise from perceptual associations; 2) the transfer of associations between stimulus modalities is a symbolic process.

- Our results favour dual coding compared with single semantic stores; however, the dual coding model was found to be insufficient because it does not distinguish between symbolic associations and chained associations.

- Our results suggest that semantic knowledge can be derived from perceptual experience. This is contrary to Tulving's distinction between episodic and semantic memory.

- Implicit and explicit processes are not easily dissociable because implicit learning and implicit perceptual processing underpin explicit learning.

- Our results lend support to Barsalou's perceptual symbol theory. Deacon's symbolic reference model provides a framework to accommodate the pattern of our results.

Conclusions

At the outset of this research we reviewed evidence suggesting that there are differences in the symbolic properties of pictures and words. The objective of this thesis was to examine the interaction of lexical-semantic and imagery representations. Our experiments focused on the transfer of associative information between these two forms of symbolic representation.

We have demonstrated that picture associations can produce corresponding word associations, and that word associations can produce corresponding picture associations but only if name relations between the pictures and the words have been established. We argue that name relations are more than bidirectional associations between a picture and a word; name relationships are symbolic associations according to the criteria of equivalence relations and semantic priming. We have also shown that symbolic associations are produced more easily when words are mapped onto picture associations than when pictures are mapped onto word associations. Our results support the idea that conceptual or semantic knowledge is grounded in perceptual experience.

Initially we discussed these differences in the framework of models that posit two different processing systems: a visual system and a verbal system. Our first results showing transfer of associations from visual to verbal modalities led us to give less consideration to single semantic store models, in which the verbal representational system has privileged access to semantic relations. Dual coding models have no problem accommodating visual-to-verbal transfer of association. However, although dual-coding provides a means of grounding lexical representations in perceptual experience, it does not accommodate our conclusion that there are two means by which a transfer of associations can be achieved: chained associations or symbolic associations. We suggest that symbolic representation is an integrated process incorporating both lexical-semantic and imagery representations. We do not claim that visual and verbal symbols share all the same processing mechanisms, rather that semantic processing embraces both forms of representation in a manner analagous to the way that the processing systems that support colour perception and movement perception are components of the visual system. We posit that the acquisition of symbolic representation demands higher level cognitive processes than can be supported by classical or operant conditioning.

Our conclusions are more suited to models that propose distributed representations rather than discrete processing systems. We discussed our results in terms of Barsalou's (1999) perceptual symbols model and Deacon's (1997) model of symbolic reference. Our experiments were not designed to discriminate between these two models. We suggest that these models are complementary in several ways. They both consider word meaning to be more than a one-to-one association with its referent objects, both assume distributed representations, and are both perception-based. Both suggest means by which concepts derived from sensory-motor experiences can be explicitly represented. A systematic examination of the similarities between the processing demanded by picture versus word representation might assist in the identification of specialised processing involved in either form of representation. This could provide a fruitful means of evaluating the models and understanding the organisation and processing of semantic representations.

Vygotsky (1986, 1934) proposed that *a word is the smallest unit of conscious thought*; If it is broken down it loses the properties of the whole. An analogy given by Vygotsky is trying to determine how water extinguishes fire by breaking down water molecules and examining their constituent elements, where the examination of the individual properties of hydrogen and oxygen might lead one to predict that water is a highly flammable liquid. It is important, when considering word meaning, to maintain a holistic view of the union between the representation of a word and the representation(s) of its meaning. We suggest that the interaction of lexical-semantic and imagery representations is a function of an integrated semantic system and thus it does not demand an interlingua of propositional representations. The transfer of associative information between stimulus modalities is mediated by symbolic associations. Symbolic associations are explicit associations derived from contiguous associations through explicit, effortful processes. Implicit associations underpin symbolic associations, but semantic knowledge is conscious knowledge about the patterns of association which link representations.

Appendices

Appendix 2

Appendix 2.1

Novel word prime-target pairs for ten verbal priming task

Stimulus Block 1	Stimulus Block 2	Stimulus Block 3	Practice Block
Nas Gub	Nas Gub	Nas Gub	Nas Gub
Gub Nas	Gub Nas	Gub Nas	Lof Jiz
Lof Jiz	Lof Jiz	Lof Jiz	Nid Gub
Jiz Lof	Jiz Lof	Jiz Lof	Hoj Jiz
Bif Gub	Rar Gub	Jak Gub	Gub Jeb
Mib Nas	Jul Nas	Tef Nas	Nas Yog
Ret Jiz	Dom Jiz	Kan Jiz	Cuk Koz
Pum Lof	Vuj Lof	Cal Lof	Fex Maj
Gub Pej	Gub Cib	Gub Nem	
Jiz Vap	Jiz Haj	Jiz Tur	
Nas Bav	Nas Lud	Nas Kig	
Lof Fut	Lof Mur	Lof Dis	
Yup Det	Yan Pid	Dup Beb	
Gic Hep	Wul Rif	Hif Suv	
Kum Roj	Tib Ver	Noj Yit	
Lar Cov	Mev Wij	Sez Gac	

Appendix 2.2

Example of visual stimuli used as foils in the decision task

Appendix 2.3.

A one-way repeated measures ANOVA for the mean RTs in each condition (novel-novel, associated-novel, novel-associated and trained-associated) of the verbal decision task in Pilot 1.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	10	282062.93	28206.29		
All Conditions	3	25266.16	8422.05	3.02	.0449
All Conditions * Subject	30	83538.06	2784.60		

Dependent: RT

Planned means comparisons were carried out to compare the mean response times to the primed and the unprimed novel stimuli (nov-ass vs ass-ass) and to the novel stimuli compared with the previously associated stimuli.

Comparison 1
Effect: All Conditions
Dependent: RT

	Cell Weight
nov-ass	1.00
ass-ass	-1.00

df	1
Sum of Squares	15351.05
Mean Square	15351.05
F-Value	5.51
P-Value	.0257
G-G	.0407
H-F	.0325

Comparison 2
Effect: All Conditions
Dependent: RT

	Cell Weight
nov-nov	.50
ass-nov	.50
nov-ass	-.50
ass-ass	-.50

df	1
Sum of Squares	2805.10
Mean Square	2805.10
F-Value	1.01
P-Value	.3236
G-G	.2902
H-F	.3088

Appendix 2.4

ANOVA table for Pilot 1, picture stimulus pairs. (DV = RT in ms)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	10	635496.200	63549.620		
All Conditions	3	77926.764	25975.588	3.261	.0351
All Conditions *...	30	238945.513	7964.850		

Appendix 2.5

Repeated measures ANOVA table for Pilot 1, stimulus form pictures versus words (DV = RT in ms)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	9	520168.22	57796.47		
prime-target-form	1	606273.03	606273.03	74.49	.0001
prime-target-form *Subject	9	73251.01	8139.00		
All conditions	3	155332.86	5110.95	1.18	.3353
All conditions * Subject	27	116803.64	4326.06		
prime target form * All conditions	3	66840.84	22280.28	5.693	.0037
prime target form * All conditions * Subject	27	105668.35	3913.64		

Appendix 2.6a Repeated measures ANOVA table for Pilot 2 Condition 1, unrelated versus associated primes (RT in ms). All data sets

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	147866.552	29573.310		
priming effect	1	519.286	519.286	.031	.8679
priming effect *subject	5	84769.920	16953.984		

Appendix 2.6b Repeated measures ANOVA table for Pilot 2 Condition 1, unrelated versus associated primes (RT in ms). Excluding data sets where participants Vocabulary test score < 95%

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	4	147602.270	36900.568		
priming effect	1	8.444	8.444	4.077E-4	.9849
priming effect * subject	4	82848.230	20712.058		

Dependent: Priming Effect

Appendix 2.6c Two factor repeated measures ANOVA table for Pilot 2 Condition 1. Analysis of target type (novel or previously presented) for unrelated versus associated primes (RT in ms)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	298966.980	59793.396		
target type	1	10619.666	10619.666	9.260	.0286
target type * Subject	5	5733.955	1146.791		
prime type	1	4529.587	4529.587	.532	.4983
prime type * Subject	5	42536.927	8507.385		
target type * prime type	1	1230.279	1230.279	.143	.7208
target type * prime type * Subject	5	43007.973	8601.595		

Appendix 2.7a Repeated measures ANOVA table for Pilot 2 Condition 2, unrelated versus associated primes (RT in ms). All data sets

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	1134609.577	226921.915		
priming effect	1	82536.007	82536.007	3.061	.1406
priming effect x subject	5	134828.660	26965.732		

Dependent: Priming Effect

Appendix 2.7b Repeated measures ANOVA table for Pilot 2 Condition 2, unrelated versus associated primes (RT in ms). Excluding data sets where participants Vocabulary test score < 95%

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	3	315670.633	105223.544		
priming effect	1	832.289	832.289	.389	.5772
priming effect x subject	3	6425.121	2141.707		

Dependent: Priming Effect

Appendix 2.7c Two factor repeated measures ANOVA table for Pilot 2 Condition 2. Analysis of target type (novel or previously presented) for unrelated versus associated primes (RT in ms)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	1245680.737	249136.147		
stimulus type	1	88871.610	88871.610	1.355	.2970
stimulus type * Subject	5	328049.607	65609.921		
prime	1	87077.687	87077.687	3.439	.1228
prime * Subject	5	126608.855	25321.771		
stimulus type * prime	1	12365.722	12365.722	1.646	.2557
stimulus type * prime * Subject	5	37557.132	7511.426		

Dependent: stimulus type

Appendix 2.8a Repeated measures ANOVA table for Pilot 2 Condition 3, unrelated versus associated primes (RT in ms). All data sets

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	48803.320	9760.664		
Prime type	1	237.990	237.990	.276	.6216
Prime type * Subject	5	4306.513	861.303		

Appendix 2.8b Repeated measures ANOVA table for Pilot 2 Condition 3, unrelated versus associated primes (RT in ms). Excluding data sets where participants Vocabulary test score < 95%

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	2	18406.817	9203.408		
Prime type	1	677.698	677.698	1.053	.4128
Prime type * Subject	2	1287.603	643.801		

Means Table
Effect: Prime type
Dependent: Priming Effect

	Count	Mean	Std. Dev.	Std. Error
novel prime	3	568.083	85.621	49.433
associated prime	3	546.828	50.163	28.961

Appendix 2.8c Two factor repeated measures ANOVA table for Pilot 2 Condition 3. Analysis of target type (novel or previously presented) for unrelated versus associated primes (RT in ms)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	159269.110	31853.822		
target type	1	6851.994	6851.994	3.379	.1254
target type * Subject	5	10138.427	2027.685		
Prime type	1	1453.369	1453.369	.722	.4341
Prime type * Subject	5	10058.647	2011.729		
target type * Prime type	1	3592.807	3592.807	1.056	.3513
target type * Prime type * Subj.	5	17015.048	3403.010		

Appendix 2.9a Repeated measures ANOVA table for Pilot 2 Condition 4, unrelated versus associated primes (RT in ms). All data sets

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	274069.474	54813.895		
prime type	1	1701.344	1701.344	.156	.7091
prime type * Subject	5	54507.146	10901.429		

Appendix 2.9b Repeated measures ANOVA table for Pilot 2 Condition 4, unrelated versus associated primes (RT in ms). Excluding data sets where participants Vocabulary test score <95%

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	2	155438.608	77719.304		
prime type	1	4620.597	4620.597	.227	.6804
prime type * Subject	2	40620.707	20310.353		

Dependent: priming effect

Appendix 2.9c Two factor repeated measures ANOVA table for Pilot 2 Condition 4. Analysis of target type (novel or previously presented) for unrelated versus associated primes (RT in ms)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	5	390428.185	78085.637		
target type	1	2628.913	2628.913	.385	.5622
target type * Subject	5	34160.593	6832.119		
prime type	1	2332.186	2332.186	.369	.5699
prime type * Subject	5	31568.547	6313.709		
target type * prime type	1	100.799	100.799	.014	.9102
target type * prime type * sub	5	35844.784	7168.957		

Appendix 2.10

Experiment 1, Priming Task 1 Condition 1: One factor repeated measures ANOVA for response time to primed and unprimed target pictures

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	525933.199	35062.213		
prime type	1	37302.525	37302.525	8.673	.0100
prime type * Su...	15	64514.430	4300.962		

Dependent: associated target Priming 1

Appendix 2.11

Experiment 1, Priming Task 1 Condition 2: One factor repeated measures ANOVA for response time to primed and unprimed target words

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	329566.875	21971.125		
prime type	1	325.125	325.125	.198	.6625
prime type * Su...	15	24594.875	1639.658		

Dependent: associated target Priming 1

Appendix 2.12

Experiment 1, Priming Task 2 Condition 1: One factor repeated measures ANOVA for response time to primed and unprimed target pictures

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	345076.560	23005.104		
prime type	1	21417.928	21417.928	4.834	.0440
prime type * Su...	15	66461.108	4430.741		

Dependent: Priming 2

Appendix 2.13

Experiment 1, Priming Task 2 Condition 2: One factor repeated measures ANOVA for response time to primed and unprimed target words

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	125602.500	8373.500		
prime type	1	861.125	861.125	.408	.5324
prime type * Subject	15	31621.875	2108.125		

Dependent: Priming 2

Appendix 2.14

Experiment 1, Cross Stimulus Form Priming Task 3 Condition 1: One factor repeated measures ANOVA for response time to primed and unprimed target word

s

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	344852.440	22990.163		
prime type	1	28999.243	28999.243	8.280	.0115
prime type * Subject	15	52531.959	3502.131		

Dependent: Priming 3

Appendix 2.15

Experiment 1, Cross Form Priming Task 3, Condition 2: One factor repeated measures ANOVA for response time to primed and unprimed target pictures

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	501152.875	33410.192		
prime type	1	364.500	364.500	.144	.7100
prime type * Subject	15	38066.500	2537.767		

Dependent: Priming 3

Appendix 2.16

Experiment 1, Condition 1. 2 way repeated measures ANOVA the difference in priming effects across tasks (associative priming tasks 1and 2 and cross stimulus Task 3)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	1089422.183	72628.146		
Task	2	287196.469	143598.234	34.071	.0001
Task * Subject	30	126440.017	4214.667		
prime type	1	86624.846	86624.846	9.167	.0085
prime type * Subject	15	141742.526	9449.502		
Task * prime type	2	1094.851	547.425	.393	.6783
Task * prime type * Subject	30	41764.971	1392.166		

Dependent: Task

Appendix 2.17

Experiment 1, Condition 2: 2 way repeated measures ANOVA the difference in priming effects across tasks (associative priming tasks 1and 2 and cross stimulus Task 3)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	15	643783.000	42918.867		
Task	2	1083239.083	541619.542	51.989	.0001
Task * Subject	30	312539.250	10417.975		
prime type	1	308.167	308.167	.091	.7675
prime type * Subject	15	50986.833	3399.122		
Task * prime type	2	1242.583	621.292	.430	.6541
Task * prime type * Subject	30	43296.417	1443.214		

Dependent: Task

Appendix 2.18

Experiment 1, Data sheet showing subjects mean RT (in ms) for all prime target conditions in Priming Tasks 1,2 and 3; the percentage of errors in each priming task and the percentage of correct responses in the vocabulary task (Note: "C" is Condition; "S" is Subject; V is Vocabulary Test Score; "n-n" is novel prime-novel target, "a-n" is associated prime-novel target, "n-a" is novel prime-associated target and "a-a" is associated prime-associated target, "%e" is the percentage of errors.)

C	S	V	Associative Priming Task 1					Associative Priming Task 2					Cross Stimulus Form Priming 3				
			n-n	a-n	n-a	a-a	% e	n-n	a-n	n-a	a-a	% e	n-n	a-n	n-a	a-a	% e
1	1	100	735	699	774	756	8	672	606	625	692	4	608	590	576	585	0
1	2	100	821	807	992	712	0	799	740	919	706	0	707	717	771	593	0
1	3	100	782	747	809	860	4	635	597	591	675	4	597	588	565	535	0
1	4	100	926	908	1009	765	29	878	790	884	722	8	788	708	893	715	0
1	5	100	928	897	968	1000	4	972	880	957	809	0	885	847	832	664	4
1	6	98	733	817	935	833	29	1054	893	989	767	0	720	701	900	694	4
1	7	100	703	727	628	607	25	762	707	675	710	0	630	579	564	554	0
1	8	98	1167	1038	1039	906	0	937	928	924	958	0	763	714	799	835	0

C	S	V	Associative Priming Task 1					Associative Priming Task 2					Cross Stimulus Form Priming 3				
			n-n	a-n	n-a	a-a	% e	n-n	a-n	n-a	a-a	% e	n-n	a-n	n-a	a-a	% e
1	9	100	738	732	706	739	25	733	661	719	711	0	703	681	575	647	4
1	10	100	670	627	637	574	4	613	554	603	549	4	621	579	574	533	0
1	11	98	732	675	682	567	4	632	603	636	595	0	508	547	507	501	0
1	12	96	669	628	670	628	4	608	618	676	626	4	595	600	538	525	0
1	13	100	723	672	760	716	0	635	600	687	668	4	614	582	565	517	4
1	14	100	733	656	694	592	4	654	625	696	591	8	630	575	626	513	8
1	15	98	721	700	639	613	12	704	742	697	697	0	668	642	571	544	0
1	16	100	695	615	650	630	12	788	686	754	729	0	701	622	639	575	0
2	1	98	712	773	724	658	2	786	656	686	579	4	835	809	941	784	2
2	2	100	549	464	446	458	25	621	589	556	586	6	798	765	701	715	17
2	3	98	857	849	859	854	0	723	767	807	632	0	1096	1004	1122	1067	6
2	4	100	749	703	684	706	10	778	723	719	733	7	1031	929	1025	1073	0

C	S	V	Associative Priming Task 1					Associative Priming Task 2					Cross Stimulus Form Priming 3				
			n-n	a-n	n-a	a-a	% e	n-n	a-n	n-a	a-a	% e	n-n	a-n	n-a	a-a	% e
2	5	94	625	716	646	668	0	583	569	562	538	0	765	740	709	753	17
2	6	100	878	740	680	809	4	818	782	675	703	0	938	916	887	863	0
2	7	94	639	627	590	580	6	739	710	627	657	4	948	936	959	902	0
2	8	100	590	601	613	596	10	584	559	515	584	2	670	694	618	740	13
2	9	98	688	709	568	608	8	636	646	601	569	10	864	836	773	783	2
2	10	98	766	775	790	730	2	795	796	744	688	2	969	959	883	971	0
2	11	98	734	729	778	712	0	607	595	584	559	0	783	808	808	740	0
2	12	100	616	547	494	516	0	600	627	544	540	2	1018	991	1024	1030	0
2	13	96	651	598	616	561	4	704	646	594	565	4	763	855	762	733	0
2	14	100	768	766	652	670	0	680	590	609	597	0	926	885	954	962	15
2	15	96	725	640	761	759	4	724	672	633	718	2	825	834	958	855	5
2	16	100	657	594	541	659	0	588	562	585	627	2	899	978	731	776	2

Appendix 3

Appendix 3.1

Analysis of stimuli for Experiment 2

Appendix 3.1a: Table to show the mean RT (+ *SD*) for all responses to each stimulus in each stimulus set (experimental or control) for each stimulus type (picture and word)

Type	Stimuli							
	Control				Experimental			
	1	2	3	4	5	6	7	8
picture	2149.6 (632)	2264.9 (570)	2354.3 (584)	2472.9 (765)	2364.3 (625)	2295.1 (795)	2318.4 (643)	2345.4 (638)
word	1775.7 (519)	1728.9 (490)	1831.4 (467)	1784.3 (427)	1590.5 (505)	1614.3 (439)	1632.1 (561)	1646.5 (486)

Appendix 3.1b. Mixed ANOVA table for RT for stimuli in Experiment 2. Repeated measures were stimulus set (experimental and control) were treated as repeated measures and the type of stimuli used (picture or word) was treated as the between subjects factor

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
stimulus type	1	84564093.2	84564093.2	59.2	.0001
Subject(Group)	108	154385195.4	1429492.6		
Stimulus-set	1	1062490.4	1062490.4	4.0	.0467
Stimulus-set * stimulus type	1	1775632.2	1775632.2	6.8	.0106
Stimulus-set * Subject(Group)	108	28354542.4	262542.1		
stimulus	3	1337172.3	445724.1	3.3	.0210
stimulus * stimulus type	3	436789.4	145596.5	1.1	.3604
stimulus * Subject(Group)	324	43942715.8	135625.7		
Stimulus-set * stimulus	3	778714.7	259571.6	1.3	.2655
Stimulus-set * stimulus * stimu...	3	1081044.4	360348.1	1.8	.1393
Stimulus-set * stimulus * Subje...	324	63376719.6	195607.2		

Dependent: RT

Appendix 3.1c. Mixed ANOVA table for RT for picture stimuli in Experiment 2. Repeated measures were stimulus set (experimental and control) were treated as repeated measures and the type of stimuli used (picture or word) was treated as the between subjects factor

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
stimulus type	0	•	•	•	•
Subject(Group)	53	91160740.0	1720014.0		
Stimulus-set	1	44715.6	44715.6	.2	.6900
Stimulus-set * stimulus type	0	•	•	•	•
Stimulus-set * Subject(Group)	53	14730184.0	277928.0		
stimulus	3	1488654.9	496218.3	2.3	.0805
stimulus * stimulus type	0	•	•	•	•
stimulus * Subject(Group)	159	34470851.9	216797.8		
Stimulus-set * stimulus	3	1697887.0	565962.3	2.0	.1147
Stimulus-set * stimulus * stimu...	0	•	•	•	•
Stimulus-set * stimulus * Subje...	159	44769661.1	281570.2		

Dependent: RT

Appendix 3.1 d. Mixed ANOVA table for RT for word stimuli in Experiment 2. Repeated measures were stimulus set (experimental and control) were treated as repeated measures and the type of stimuli used (picture or word) was treated as the between subjects factor

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
stimulus type	0	•	•	•	•
Subject(Group)	55	63224455.5	1149535.6		
Stimulus-set	1	2844308.8	2844308.8	11.5	.0013
Stimulus-set * stimulus type	0	•	•	•	•
Stimulus-set * Subject(Group)	55	13624358.5	247715.6		
stimulus	3	263022.6	87674.2	1.5	.2094
stimulus * stimulus type	0	•	•	•	•
stimulus * Subject(Group)	165	9471863.9	57405.2		
Stimulus-set * stimulus	3	133427.4	44475.8	.4	.7572
Stimulus-set * stimulus * stimu...	0	•	•	•	•
Stimulus-set * stimulus * Subje...	165	18607058.5	112770.1		

Dependent: RT

Appendix 3.2

Analysis of stimuli set (control vs. experimental) by condition for Experiment 2 (DV =Mean RT (ms) for correct trials only).

Appendix 3.2a: Mixed ANOVA for mean RT of correct responses. Condition was treated as the between subjects measure and stimulus set (experimental vs. control) as the repeated measure.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	5	34224395.1	6844879.0	16.4	.0001
Subject(Group)	104	43278641.9	416140.8		
stimulus set	1	573504.4	573504.4	5.3	.0230
stimulus set * Co...	5	934328.4	186865.7	1.7	.1328
stimulus set * Su...	104	11193053.9	107625.5		

Dependent: mean RT

Appendix 3.2b: Simple main Effects: Stimulus set (experimental vs. control) in Condition 1. DV = mean RT for correct responses.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	18	3581869.7	198992.8		
stimulus-set	1	252782.1	252782.1	2.2	.1530
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	18	2043412.5	113522.9		

Dependent: mean RT

Appendix 3.2c Simple main effects: Stimulus set (experimental vs. control) in Condition 2. DV = mean RT for correct responses

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	5798729.7	341101.7		
stimulus-set	1	67587.2	67587.2	1.0	.3216
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	1102531.6	64854.8		

Dependent: mean RT

Appendix 3.2d: Simple main Effects: Stimulus set (experimental vs. control) in Condition 3.
DV = mean RT for correct responses

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	18	2564991.1	142499.5		
stimulus-set	1	263397.6	263397.6	6.3	.0217
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	18	750753.2	41708.5		

Dependent: mean RT

Appendix 3.2e: Simple main Effects: Stimulus set (experimental vs. control) in Condition 4.
DV = mean RT for correct responses

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	12719745.5	748220.3		
stimulus-set	1	61075.3	61075.3	.5	.4996
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	2182013.6	128353.7		

Dependent: mean RT

Appendix 3.2 f: Simple main Effects: Stimulus set (experimental vs. control) in Condition 5.
DV = mean RT for correct responses

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	8944532.9	526149.0		
stimulus-set	1	867328.5	867328.5	20.7	.0003
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	711348.4	41844.0		

Dependent: mean RT

Appendix 3.2 g: Simple main Effects: Stimulus set (experimental vs. control) in Condition 6. DV = mean RT for correct responses

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	9668773.0	568751.4		
stimulus-set	1	8909.2	8909.2	3.4E-2	.8551
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	4402994.6	258999.7		

Dependent: mean RT

Appendix 3.2h: Planned Means comparisons. DV = mean RT for correct responses

Planned means comparison:
Condition (pictures vs words)

	Cell Weight
condition 1	.3
condition 2	-.3
condition 3	.3
condition 4	-.3
condition 5	.3
condition 6	-.3

df	1
Sum of Squares	29905564.3
Mean Square	29905564.3
F-Value	71.9
P-Value	.0001

Planned Means Comparison:
interaction condition * stimulus set

	Cell Weight
condition 1	.3
condition 2	-.3
condition 3	.3
condition 4	-.3
condition 5	.3
condition 6	-.3

df	1
Sum of Squares	679760.1
Mean Square	679760.1
F-Value	6.3
P-Value	.0135

Effect: word conditions
Dependent: mean RT

	Cell Weight
condition 1	.5
condition 3	.5
condition 5	-1.0

df	1
Sum of Squares	443135.3
Mean Square	443135.3
F-Value	1.1
P-Value	.3045

	Cell Weight
condition 1	1.0
condition 5	-1.0

df	1
Sum of Squares	20213.1
Mean Square	20213.1
F-Value	4.9E-2
P-Value	.8260

	Cell Weight
condition 3	1.0
condition 5	-1.0

df	1
Sum of Squares	1032271.8
Mean Square	1032271.8
F-Value	2.5
P-Value	.1183

Interaction of stimulus set
Effect: condition
Dependent: mean RT

	Cell Weight
condition 1	.5
condition 3	.5
condition 5	-1.0

df	1
Sum of Squares	129500.2
Mean Square	129500.2
F-Value	1.2
P-Value	.2752

	Cell Weight
condition 1	1.0
condition 5	-1.0

df	1
Sum of Squares	100294.8
Mean Square	100294.8
F-Value	.9
P-Value	.3366

	Cell Weight
condition 3	1.0
condition 5	-1.0

df	1
Sum of Squares	95732.1
Mean Square	95732.1
F-Value	.9
P-Value	.3478

Effect: word conditions
Dependent: mean RT

	Cell Weight
condition 1	1.0
condition 3	-1.0

df	1
Sum of Squares	784798.2
Mean Square	784798.2
F-Value	1.9
P-Value	.1726

Interaction of stimulus set
Effect: of condition
Dependent: mean RT

	Cell Weight
condition 1	1.0
condition 3	-1.0

df	1
Sum of Squares	54.6
Mean Square	54.6
F-Value	5.1E-4
P-Value	.9821

Effect: picture conditions
Dependent: mean RT

	Cell Weight
condition 2	.5
condition 4	.5
condition 6	-1.0

df	1
Sum of Squares	915400.9
Mean Square	915400.9
F-Value	2.2
P-Value	.1411

	Cell Weight
condition 2	1.0
condition 6	-1.0

df	1
Sum of Squares	2377715.0
Mean Square	2377715.0
F-Value	5.7
P-Value	.0186

	Cell Weight
condition 4	1.0
condition 6	-1.0

df	1
Sum of Squares	13267.1
Mean Square	13267.1
F-Value	3.2E-2
P-Value	.8586

Interaction of stimulus set
Effect: condition
Dependent: mean RT

	Cell Weight
condition 2	.5
condition 4	.5
condition 6	-1.0

df	1
Sum of Squares	6775.0
Mean Square	6775.0
F-Value	.1
P-Value	.8024

	Cell Weight
condition 2	1.0
condition 6	-1.0

df	1
Sum of Squares	62786.8
Mean Square	62786.8
F-Value	.6
P-Value	.4467

	Cell Weight
condition 4	1.0
condition 6	-1.0

df	1
Sum of Squares	11665.6
Mean Square	11665.6
F-Value	.1
P-Value	.7426

Effect: picture conditions
Dependent: mean RT

	Cell Weight
condition 2	1.0
condition 4	-1.0

df	1
Sum of Squares	2035761.6
Mean Square	2035761.6
F-Value	4.9
P-Value	.0292

Interaction of stimulus set
Effect: condition
Dependent: mean RT

	Cell Weight
condition 2	1.0
condition 4	-1.0

df	1
Sum of Squares	128580.0
Mean Square	128580.0
F-Value	1.2
P-Value	.2769

Appendix 3.3

Analysis of the correct number of responses for each stimulus in each stimulus set (experimental and control) and stimulus type (picture and word) in (Experiment 2)

A mixed ANOVA in which stimuli and stimulus set (experimental or control) are treated as repeated measures, and stimulus type (picture or word) as an independent measure. The DV was the proportion of correct responses.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
stimulus type	1	1.9	1.9	16.0	.0001
Subject(Group)	108	12.9	.1		
stimulus set	1	.2	.2	5.3	.0228
stimulus set * stimulus type	1	.3	.3	7.7	.0065
stimulus set * Subject(Group)	108	4.5	4.1E-2		
stimuli	3	.1	1.8E-2	1.0	.3923
stimuli * stimulus type	3	.1	4.1E-2	2.3	.0807
stimuli * Subject(Group)	324	5.9	1.8E-2		
stimulus set * stimuli	3	.1	2.8E-2	1.6	.1793
stimulus set * stimuli * stim...	3	.1	2.6E-2	1.5	.2019
stimulus set * stimuli * Subj...	324	5.4	1.7E-2		

Dependent: stimulus set

% mean correct for each stimulus in each stimulus set (+ *SD*)

Type	STIMULI							
	Control				Experimental			
	Stimulus							
	1	2	3	4	1	2	3	4
Picture	82	83	75	79	77	81	78	81
n =54	(22)	(15)	(24)	(17)	(22)	(18)	(18)	(20)
Word	88	83	87	84	92	94	92	91
n = 56	(18)	(21)	(19)	(19)	(.14)	(12)	(14)	(14)

Appendix 3.4

Analysis of the mean number of correct responses < 2000 ms for the test task in each condition of Experiment 2

Appendix 3.4a A mixed ANOVA for the mean number of correct responses < 2000 ms. The repeated measure was stimulus set (control vs. experimental) and the between subjects variable was condition (order of exposure to information)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	5	290.23	58.05	11.40	.0001
Subject(Group)	103	524.57	5.09		
stimulus-set	1	19.37	19.37	11.64	.0009
stimulus-set * Condition	5	20.26	4.05	2.43	.0396
stimulus-set * Subject(Gro...	103	171.43	1.66		

Dependent: #correct

Appendix 3.4 b

Simple main effect of stimulus set (control vs. experimental) on Condition 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	18	70.57	3.92		
stimulus-set	1	6.95	6.95	2.55	.1280
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	18	49.14	2.73		

Dependent: #correct

Appendix 3.4c

Simple main effect of stimulus set control vs. experimental) on Condition 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	105.08	6.18		
stimulus-set	1	2.64	2.64	2.55	.1285
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	17.58	1.03		

Dependent: #correct

Appendix 3.4d

Simple main effect of stimulus set (control vs. experimental) on Condition 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	86.56	5.09		
stimulus-set	1	3.36	3.36	2.44	.1370
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	23.45	1.38		

Dependent: #correct

Appendix 3.4e

Simple main effect of stimulus set (control vs. experimental) on Condition 4

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	96.20	5.66		
stimulus-set	1	.14	.14	.15	.7013
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	15.70	.92		

Dependent: #correct

Appendix 3.4f

Simple main effect of stimulus set (control vs. experimental) on Condition 5

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Condition	0	•	•	•	•
Subject(Group)	17	115.44	6.79		
stimulus-set	1	26.69	26.69	18.96	.0004
stimulus-set * Condition	0	•	•	•	•
stimulus-set * Subject(Gro...	17	23.93	1.41		

Dependent: #correct

Appendix 3.4g

Simple main effect of stimulus set (control vs. experimental) on Condition 6

A series of planned means comparisons were carried out between conditions and the interaction with stimulus set (experimental or control). These are shown on the following two pages.

Comparison 1
Effect: Condition
Dependent: #correct

	Cell Weight
condition 1	.33
condition 2	-.33
condition 3	.33
condition 4	-.33
condition 5	.33
condition 6	-.33

df	1
Sum of Squares	270.33
Mean Square	270.33
F-Value	53.08
P-Value	.0001

Interaction of stimulus-set with Comparison 1
Effect: Condition
Dependent: #correct

	Cell Weight
condition 1	.33
condition 2	-.33
condition 3	.33
condition 4	-.33
condition 5	.33
condition 6	-.33

df	1
Sum of Squares	11.86
Mean Square	11.86
F-Value	7.13
P-Value	.0088

Comparison 9
Effect: Condition
Dependent: #correct

	Cell Weight
condition 1	.50
condition 3	.50
condition 5	-1.00

df	1
Sum of Squares	.68
Mean Square	.68
F-Value	.13
P-Value	.7153

Interaction of stimulus-set with Comparison 9
Effect: Condition
Dependent: #correct

	Cell Weight
condition 1	.50
condition 3	.50
condition 5	-1.00

df	1
Sum of Squares	5.92
Mean Square	5.92
F-Value	3.56
P-Value	.0621

Comparison 3
Effect: Condition
Dependent: #correct

	Cell Weight
condition 2	.50
condition 4	.50
condition 6	-1.00

df	1
Sum of Squares	2.89
Mean Square	2.89
F-Value	.57
P-Value	.4527

Interaction of stimulus-set with Comparison 3
Effect: Condition
Dependent: #correct

	Cell Weight
condition 2	.50
condition 4	.50
condition 6	-1.00

df	1
Sum of Squares	.33
Mean Square	.33
F-Value	.20
P-Value	.6549

Comparison 7
Effect: Condition
Dependent: #correct

	Cell Weight
condition 2	1.00
condition 6	-1.00

df	1
Sum of Squares	11.08
Mean Square	11.08
F-Value	2.18
P-Value	.1432

Interaction of stimulus-set with Comparison 7
Effect: Condition
Dependent: #correct

	Cell Weight
condition 2	1.00
condition 6	-1.00

df	1
Sum of Squares	1.46
Mean Square	1.46
F-Value	.88
P-Value	.3513

Comparison 8
Effect: Condition
Dependent: #correct

	Cell Weight
condition 4	1.00
condition 6	-1.00

df	1
Sum of Squares	.15
Mean Square	.15
F-Value	.03
P-Value	.8656

Interaction of stimulus-set with Comparison 8
Effect: Condition
Dependent: #correct

	Cell Weight
condition 4	1.00
condition 6	-1.00

df	1
Sum of Squares	.04
Mean Square	.04
F-Value	.03
P-Value	.8733

Comparison 6
Effect: Condition
Dependent: #correct

	Cell Weight
condition 2	1.00
condition 4	-1.00

df	1
Sum of Squares	13.78
Mean Square	13.78
F-Value	2.71
P-Value	.1030

Interaction of stimulus-set with Comparison 6
Effect: Condition
Dependent: #correct

	Cell Weight
condition 2	1.00
condition 4	-1.00

df	1
Sum of Squares	2.00
Mean Square	2.00
F-Value	1.20
P-Value	.2755

Appendix 3.5

Analysis of the numerical order of the first correct response in the test tasks of Experiment 2
Mixed ANOVA for the numerical order of the first correct response (RT < 2000 ms) for the conditions in which word stimuli were presented in the final test task (conditions 1, 3, & 5). The repeated measures were stimuli and stimulus set (control vs. experimental), and the between subjects variable was condition order of exposure to information).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	2	26.15	13.08	.98	.3836
Subject(Group)	52	696.72	13.40		
stimulus set	1	11.89	11.89	3.12	.0834
stimulus set * condition	2	2.28	1.14	.30	.7427
stimulus set * Subject(Group)	52	198.48	3.82		
stimulus	3	4.24	1.41	.96	.4150
stimulus * condition	6	4.64	.77	.52	.7904
stimulus * Subject(Group)	156	230.67	1.48		
stimulus set * stimulus	3	2.61	.87	.58	.6315
stimulus set * stimulus * condi...	6	1.63	.27	.18	.9819
stimulus set * stimulus * Subje...	156	235.31	1.51		

Dependent: number order of first correct response

Mixed ANOVA for the numerical order of the first correct response (RT < 2000 ms) for the conditions in which picture stimuli were presented in the final test task (Conditions 2, 4, & 6). The repeated measures were stimuli and stimulus set (control vs. experimental), and the between subjects variable was condition (order of exposure to information)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	2	36.37	18.19	.80	.4558
Subject(Group)	51	1162.54	22.79		
stimulus set	1	4.48	4.48	.73	.3954
stimulus set * condition	2	11.34	5.67	.93	.4015
stimulus set * Subject(Group)	51	311.18	6.10		
stimulus	3	28.47	9.49	1.99	.1171
stimulus * condition	6	40.57	6.76	1.42	.2099
stimulus * Subject(Group)	153	727.96	4.76		
stimulus set * stimulus	3	36.07	12.02	2.48	.0633
stimulus set * stimulus * condi...	6	19.05	3.18	.65	.6862
stimulus set * stimulus * Subje...	153	741.88	4.85		

Dependent: order of first correct response

Appendix 3.6

Analysis of the number of correct responses produced < 2000 ms in each training task of Experiment 2.

Appendix 3.6a- one factor ANOVA effect of condition on the number of correct responses in the Vocabulary training task.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	5	296.07	59.21	2.75	.0226
Residual	102	2196.18	21.53		

Dependent: VOCAB

Appendix 3.6.b Planned means comparisons between conditions in the vocabulary task.

Comparison 1
Effect: CONDITION
Dependent: VOCAB

	Cell Weight
condition 1	1.00
condition 2	-1.00

df	1
Sum of Squares	1.80
Mean Square	1.80
F-Value	.08
P-Value	.7729

Comparison 2
Effect: CONDITION
Dependent: VOCAB

	Cell Weight
condition 1	1.00
condition 3	-1.00

df	1
Sum of Squares	175.12
Mean Square	175.12
F-Value	8.13
P-Value	.0053

Comparison 3
Effect: CONDITION
Dependent: VOCAB

	Cell Weight
condition 5	1.00
condition 6	-1.00

df	1
Sum of Squares	2.25
Mean Square	2.25
F-Value	.10
P-Value	.7472

Comparison 4
Effect: CONDITION
Dependent: VOCAB

	Cell Weight
condition 2	1.00
condition 4	-1.00

df	1
Sum of Squares	84.03
Mean Square	84.03
F-Value	3.90
P-Value	.0509

Comparison 5
Effect: CONDITION
Dependent: VOCAB

	Cell Weight
condition 1	.50
condition 2	.50
condition 3	-.50
condition 4	-.50

df	1
Sum of Squares	250.95
Mean Square	250.95
F-Value	11.66
P-Value	.0009

Comparison 6
Effect: CONDITION
Dependent: VOCAB

	Cell Weight
condition 1	.50
condition 2	.50
condition 5	-.50
condition 6	-.50

df	1
Sum of Squares	127.16
Mean Square	127.16
F-Value	5.91
P-Value	.0168

Appendix 3.7

One factor ANOVA for the effect of condition on the number of correct responses in the paired associate training task

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	2934.941	978.314	19.535	.0001
Residual	68	3405.379	50.079		

Dependent: No. correct responses in the paired associate training task

planned means comparisons

Comparison 1
Effect: CONDITION
Dependent: association training

	Cell Weight
condition 1	1.00
condition 3	-1.00

df	1
Sum of Squares	233.57
Mean Square	233.57
F-Value	4.66
P-Value	.0343

Comparison 2
Effect: CONDITION
Dependent: association training

	Cell Weight
condition 2	1.00
condition 4	-1.00

df	1
Sum of Squares	.25
Mean Square	.25
F-Value	4.99E-3
P-Value	.9439

Comparison 3
Effect: CONDITION
Dependent: association training

	Cell Weight
condition 1	.50
condition 2	-.50
condition 3	.50
condition 4	-.50

df	1
Sum of Squares	2759.72
Mean Square	2759.72
F-Value	55.11
P-Value	.0001

Appendix 3.8

one factor ANOVA for effect of condition on the total number of correct responses <2000 ms in the Association Tests

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	5	3685.091	737.018	14.761	.0001
Residual	102	5092.789	49.929		

Dependent: No. correct responses on the association test task

Planned means comparisons

Comparison 1
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 1	.33
condition 2	-.33
condition 3	.33
condition 4	-.33
condition 5	.33
condition 6	-.33

df	1
Sum of Squares	3409.06
Mean Square	3409.06
F-Value	68.28
P-Value	.0001

Comparison 2
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 1	.50
condition 3	.50
condition 5	-1.00

df	1
Sum of Squares	5.74
Mean Square	5.74
F-Value	.11
P-Value	.7353

Comparison 3
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 2	.50
condition 4	.50
condition 6	-1.00

df	1
Sum of Squares	49.34
Mean Square	49.34
F-Value	.99
P-Value	.3225

Comparison 4
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 1	1.00
condition 3	-1.00

df	1
Sum of Squares	39.18
Mean Square	39.18
F-Value	.78
P-Value	.3778

Comparison 5
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 3	1.00
condition 5	-1.00

df	1
Sum of Squares	1.09
Mean Square	1.09
F-Value	.02
P-Value	.8829

Comparison 6
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 1	1.00
condition 3	-1.00

df	1
Sum of Squares	39.18
Mean Square	39.18
F-Value	.78
P-Value	.3778

Comparison 7
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 2	1.00
condition 4	-1.00

df	1
Sum of Squares	200.69
Mean Square	200.69
F-Value	4.02
P-Value	.0476

Comparison 8
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 4	1.00
condition 6	-1.00

df	1
Sum of Squares	1.00
Mean Square	1.00
F-Value	.02
P-Value	.8877

Comparison 9
Effect: CONDITION
Dependent: p-p2/v-v2-EXP

	Cell Weight
condition 2	1.00
condition 6	-1.00

df	1
Sum of Squares	173.36
Mean Square	173.36
F-Value	3.47
P-Value	.0653

Appendix 3.9 a

Analysis of stimuli in the associative test tasks, Experiment 3.
Table showing the mean number of correct responses (+ *SD*) for each stimulus in each stimulus set.

	Stimulus							
	Control				Experimental			
	1	2	3	4	1	2	3	4
Picture	.62	.64	.78	.69	1.44	1.29	1.36	1.18
n =45	(1.09)	(1.19)	(1.15)	(1.04)	(1.65)	(1.44)	(1.55)	(1.56)
Word	.73	.69	.8	.82	1.67	1.73	1.98	1.82
n = 45	(1.12)	(1.10)	(1.16)	(91.21)	(1.51)	(1.6)	(1.67)	(1.61)

Appendix 3.9

Mixed ANOVA for the mean number of correct pairs for each stimulus within each stimulus set (experimental or control) by condition

.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
stimulus type	1	14.17	14.17	1.92	.1689
Subject(Group)	88	648.04	7.36		
Stimulus set	1	125.83	125.83	24.14	.0001
Stimulus set * stimulus type	1	7.40	7.40	1.42	.2366
Stimulus set * Subject(Group)	88	458.64	5.21		
stimuli	3	1.98	.66	1.70	.1684
stimuli * stimulus type	3	1.25	.42	1.07	.3632
stimuli * Subject(Group)	264	102.89	.39		
Stimulus set * stimuli	3	.54	.18	.41	.7490
Stimulus set * stimuli * stimulus type	3	1.53	.51	1.15	.3285
Stimulus set * stimuli * Subject(Gr...	264	116.56	.44		

Dependent: #correct

Appendix 3.10

Analysis of stimulus set (experimental vs. control) by condition in Experiment 3

Appendix 3.10.a: Mixed ANOVA in which stimulus set is treated as the repeated variable, and condition as the between subjects variable. The IV was the correct number of responses.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	5	244.43	48.89	1.71	.1417
Subject(Group)	84	2404.40	28.62		
Stimulus set	1	503.34	503.34	26.00	.0001
Stimulus set * CONDITION	5	237.89	47.58	2.46	.0396
Stimulus set * Subject(Gro...	84	1626.27	19.36		

Dependent: mean #correct

Appendix 3.10 b Simple main effect for stimulus set (experimental or control) in Condition 1 of Experiment 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	0	•	•	•	•
Subject(Group)	14	625.87	44.70		
Stimulus set	1	197.63	197.63	6.82	.0205
Stimulus set * CONDITION	0	•	•	•	•
Stimulus set * Subject(Gro...	14	405.87	28.99		

Dependent: mean #correct

Appendix 3.10 c Simple main effect for stimulus set (experimental or control) in Condition 2 of Experiment 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	0	•	•	•	•
Subject(Group)	14	558.47	39.89		
Stimulus set	1	218.70	218.70	11.02	.0051
Stimulus set * CONDITION	0	•	•	•	•
Stimulus set * Subject(Gro...	14	277.80	19.84		

Dependent: mean #correct

Appendix 3.10 d Simple main effect for stimulus set (experimental or control) in Condition 3 of Experiment 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	0	•	•	•	•
Subject(Group)	14	307.47	21.96		
Stimulus set	1	264.03	264.03	11.29	.0047
Stimulus set * CONDITION	0	•	•	•	•
Stimulus set * Subject(Gro...	14	327.47	23.39		

Dependent: mean #correct

Appendix 3.10 e Simple main effect for stimulus set (experimental or control) in Condition 4 of Experiment 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	0	•	•	•	•
Subject(Group)	14	491.67	35.12		
Stimulus set	1	45.63	45.63	4.60	.0500
Stimulus set * CONDITION	0	•	•	•	•
Stimulus set * Subject(Gro...	14	138.87	9.92		

Dependent: mean #correct

Appendix 3.10 f Simple main effect for stimulus set (experimental or control) in Condition 5 of Experiment 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	0	•	•	•	•
Subject(Group)	14	213.47	15.25		
Stimulus set	1	14.70	14.70	.94	.3486
Stimulus set * CONDITION	0	•	•	•	•
Stimulus set * Subject(Gro...	14	218.80	15.63		

Dependent: mean #correct

Appendix 3.10 g Simple main effect for stimulus set (experimental or control) in Condition 6 of Experiment

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
CONDITION	0	•	•	•	•
Subject(Group)	14	207.47	14.82		
Stimulus set	1	.53	.53	.03	.8672
Stimulus set * CONDITION	0	•	•	•	•
Stimulus set * Subject(Gro...	14	257.47	18.39		

Dependent: mean #correct

Appendix 3.10.h: Planned means comparisons between condition and the interaction of stimulus set with condition in Experiment 3.

Comparison 1
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	1.00
FIVE	-1.00

df	1
Sum of Squares	48.60
Mean Square	48.60
F-Value	1.70
P-Value	.1961

Interaction of Stimulus set with Comparison 1
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	1.00
FIVE	-1.00

df	1
Sum of Squares	52.27
Mean Square	52.27
F-Value	2.70
P-Value	.1041

Comparison 2
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
THREE	1.00
FIVE	-1.00

df	1
Sum of Squares	41.67
Mean Square	41.67
F-Value	1.46
P-Value	.2310

Interaction of Stimulus set with Comparison 2
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
THREE	1.00
FIVE	-1.00

df	1
Sum of Squares	77.07
Mean Square	77.07
F-Value	3.98
P-Value	.0493

Appendix 3.10.h: Planned means comparisons between condition, and the interaction of stimulus set with condition in Experiment 3.

Comparison 3
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	1.00
THREE	-1.00

df	1
Sum of Squares	.27
Mean Square	.27
F-Value	.01
P-Value	.9233

Interaction of Stimulus set with Comparison 3
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	1.00
THREE	-1.00

df	1
Sum of Squares	2.40
Mean Square	2.40
F-Value	.12
P-Value	.7257

Comparison 4
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
TWO	1.00
SIX	-1.00

df	1
Sum of Squares	126.15
Mean Square	126.15
F-Value	4.41
P-Value	.0388

Interaction of Stimulus set with Comparison 4
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
TWO	1.00
SIX	-1.00

df	1
Sum of Squares	120.42
Mean Square	120.42
F-Value	6.22
P-Value	.0146

Comparison 5
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
FOUR	1.00
SIX	-1.00

df	1
Sum of Squares	43.35
Mean Square	43.35
F-Value	1.51
P-Value	.2219

Interaction of Stimulus set with Comparison 5
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
FOUR	1.00
SIX	-1.00

df	1
Sum of Squares	28.02
Mean Square	28.02
F-Value	1.45
P-Value	.2324

Appendix 3.10.h: Planned means comparisons between condition, and the interaction of stimulus set with condition in Experiment 3.

Comparison 6
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
TWO	1.00
FOUR	-1.00

df	1
Sum of Squares	21.60
Mean Square	21.60
F-Value	.75
P-Value	.3875

Interaction of Stimulus set with Comparison 6
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
TWO	1.00
FOUR	-1.00

df	1
Sum of Squares	32.27
Mean Square	32.27
F-Value	1.67
P-Value	.2003

Comparison 7
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	1.00
TWO	-1.00

df	1
Sum of Squares	2.40
Mean Square	2.40
F-Value	.08
P-Value	.7729

Interaction of Stimulus set with Comparison 7
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	1.00
TWO	-1.00

df	1
Sum of Squares	.27
Mean Square	.27
F-Value	.01
P-Value	.9069

Comparison 8
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
THREE	1.00
FOUR	-1.00

df	1
Sum of Squares	32.27
Mean Square	32.27
F-Value	1.13
P-Value	.2914

Interaction of Stimulus set with Comparison 8
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
THREE	1.00
FOUR	-1.00

df	1
Sum of Squares	45.07
Mean Square	45.07
F-Value	2.33
P-Value	.1308

Appendix 3.10.h: Planned means comparisons between condition, and the interaction of stimulus set with condition in Experiment 3

Comparison 9
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	.33
TWO	-.33
THREE	.33
FOUR	-.33
FIVE	.33
SIX	-.33

df	1
Sum of Squares	56.67
Mean Square	56.67
F-Value	1.98
P-Value	.1631

Interaction of Stimulus set with Comparison 9
Effect: CONDITION
Dependent: mean #correct

	Cell Weight
ONE	.33
TWO	-.33
THREE	.33
FOUR	-.33
FIVE	.33
SIX	-.33

df	1
Sum of Squares	29.61
Mean Square	29.61
F-Value	1.53
P-Value	.2197

Appendix 3.11

Analysis of the number of vocabulary training trials in Experiment 3

Appendix 3.11 a: A mixed ANOVA with the number of responses as the DV. The total number of responses, and the number of correct responses for picture-word trials and word-picture-trials were treated as repeated measure. Condition was the between subjects variable.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	5	19302.47	3860.49	2.35	.0481
Subject(Group)	84	138219.43	1645.47		
responses	1	3854.68	3854.68	67.70	.0001
responses * condition	5	425.99	85.20	1.50	.1997
responses * Subject(Group)	84	4782.83	56.94		
trial type	1	15.21	15.21	4.53	.0363
trial type * condition	5	25.06	5.01	1.49	.2013
trial type * Subject(Group)	84	282.23	3.36		
responses * trial type	1	10.00	10.00	3.25	.0751
responses * trial type * condition	5	15.80	3.16	1.03	.4077
responses * trial type * Subject(...	84	258.70	3.08		

Dependent: # TRIALS

Appendix 3.12

Analysis of paired association training task in Experiment 3

Appendix 3.12.a. One way ANOVA for the between subjects variable of condition, and mean response time.

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
condition	3	469512.844	156504.281	.907	.4439	2.720	.230
Residual	54	9319749.124	172587.947				

	Count	Mean	Std. Dev.	Std. Err.
condition 1	15	1410.620	620.021	160.089
condition 2	14	1256.634	290.882	77.742
condition 3	15	1353.627	380.278	98.187
condition 4	14	1175.581	250.117	66.847

Appendix 3.12.b. One way ANOVA for the between subjects variable of condition, and the number of responses.

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
condition	3	3328.983	1109.661	2.727	.0529	8.182	.625
Residual	54	21970.948	406.869				

	Count	Mean	Std. Dev.	Std. Err.
condition 1	15	24.867	10.439	2.695
condition 2	14	45.214	23.965	6.405
condition 3	15	40.000	21.902	5.655
condition 4	14	34.286	21.949	5.866

Fisher's PLSD for Count
Effect: condition
Significance Level: 5 %

	Mean Diff.	Crit. Diff	P-Value	
condition 1, condition 2	-20.348	15.028	.0089	S
condition 1, condition 3	-15.133	14.767	.0448	S
condition 1, condition 4	-9.419	15.028	.2143	
condition 2, condition 3	5.214	15.028	.4896	
condition 2, condition 4	10.929	15.285	.1575	
condition 3, condition 4	5.714	15.028	.4492	

Appendix 3.12b. Planned means comparisons between condition, and response time

Comparison 1
Effect: condition
Dependent: RT

	Cell Weight
condition 1	.50
condition 2	.50
condition 3	-.50
condition 4	-.50

df	1
Sum of Squares	1131624.38
Mean Square	1131624.38
F-Value	21.71
P-Value	.0001

Interaction of RT with Comparison 1
Effect: condition
Dependent: RT

	Cell Weight
condition 1	.50
condition 2	.50
condition 3	-.50
condition 4	-.50

df	1
Sum of Squares	81192.71
Mean Square	81192.71
F-Value	5.69
P-Value	.0193

Comparison 2
Effect: condition
Dependent: RT

	Cell Weight
condition 1	.50
condition 2	.50
condition 5	-.50
condition 6	-.50

df	1
Sum of Squares	133536.34
Mean Square	133536.34
F-Value	2.56
P-Value	.1132

Interaction of RT with Comparison 2
Effect: condition
Dependent: RT

	Cell Weight
condition 1	.50
condition 2	.50
condition 5	-.50
condition 6	-.50

df	1
Sum of Squares	107306.32
Mean Square	107306.32
F-Value	7.52
P-Value	.0075

Comparison 3
Effect: condition
Dependent: RT

	Cell Weight
condition 3	.50
condition 4	.50
condition 5	-.50
condition 6	-.50

df	1
Sum of Squares	487695.66
Mean Square	487695.66
F-Value	9.36
P-Value	.0030

Interaction of RT with Comparison 3
Effect: condition
Dependent: RT

	Cell Weight
condition 3	.50
condition 4	.50
condition 5	-.50
condition 6	-.50

df	1
Sum of Squares	1817.58
Mean Square	1817.58
F-Value	.13
P-Value	.7221

Appendix 3.13

Analysis of response times to trial type in each condition of the vocabulary task of Experiment 3

A repeated measures ANOVA for response time: trial type (picture-word vs. word picture) were treated as repeated measures, and condition as the between subjects variable

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	5	1280859.76	256171.95	4.92	.0005
Subject(Group)	84	4377513.13	52113.25		
RT	1	1416776.60	1416776.60	99.26	.0001
RT * condition	5	205643.38	41128.68	2.88	.0189
RT * Subject(Group)	84	1198915.61	14272.80		

Dependent: RT

Appendix 3.14

Table of participant's verbal reports of their rational for selecting the paired associates in the test association task of Experiment 3

condition	subject	Verbal report	awareness
one	A.E.	F and M like the radio, alphabetically R and S - just stuff tha meant something so I could remember the pairs	unaware
one	B.K.	played snap - the easiest way - so I didn't have to think	unaware
one	C.R.	Not convinced that there was any rationale. Tried to find pairs that sounded like peoples names - a Christian name and a surname.	unaware
one	D.L.	I paired the ones from the first session in their original pairings, the lulafet and the rosilof, and the senidar and the milabon. Paired the first new ones diagonally, so paired the other two by default	aware
one	D.C.	The look of the word- usually the first letter, or the formation of the letters. Same rationale for both sets.	unaware
one	J.T.	Used the corresponding picture pairs for one set. New words ones that sounded nice together. I named the pictures with my own names, senidar the leafy thing; milabon, lettuce thing; rosilof, paint can, and lulafet the engine cam.	aware
one	J.S.	Words that sounded like they had come from a fantasy novel, two words made a Russian-English spy, a Mediterranean holiday resort and a fruit that grows there stuff like that.	unaware
one	J.C.	Paired the old words how I tried to remember from the rest of the experiment. New ones diagonally opposite the first time.	aware
one	K.M.	Matched the word to itself in all cases	unaware
one	L.B.	Tried to visualise the pictures and find a correspondence with the first letter.	unaware
one	L.P.	I put the words as in the picture pairs, the others were guesswork.	aware
one	M.W.	The named ones I tried to follow the picture pairings, unnamed ones I just guessed and tried to be consistent.	aware

one	M.S.	The previously learned ones I associated with the picture pairs, it was a process of elimination, the others I just tried to be consistent.	aware
one	P.P	The words from the first one I think I remembered the name of the Milabon and the one that went with it before. The other lot I couldn't see any connection but S and M went together in the first, the other pair had a vowel similarity.	aware
one	S.T.	Some words I recalled their pictures being matched together, I could remember their names from before, the others I was just guessing.	aware
two	A.M.	Ones not seen before just guessed. The ones with names that went together stayed together.	aware
two	B.M.	New ones - meaty Vs. bony pictures. I forgot the names of the other ones so I looked for a visual link.	unaware
two	C.J.	Was there something that triggered something else? Was there any visual link at all? I couldn't even learn the names - I just learned the initials.	unaware
two	C.M.	Used the shapes that had string tied to them, or rope tied to them, and there were always the other two left over.	unaware
two	D.G.	Similarity between the outer shape and the direction of the straight lines internally. I used the same rule for the ones with and without names - I didn't think about the names.	unaware
two	D.H.	One group I hadn't seen before - I had no idea. The others I grouped by the word pairs that I had seen before.	aware
two	E.Y.	There was a connection between the name association and the word association for some. I don't know about the others.	aware
two	F.B.W.	I made stories about the pictures, a sprouting bean, and a hatchet like in Jack and the Beanstalk. A telephone and a goat with specs. A person with a belt, and a rubbish heap. had a problems with the names because they seemed wrong senidar looked like a leaf so it should have been called rosilof	unaware
two	F.W.	I paired the ones seen before based on the word association, the others I chose and stuck with it I tried not to think about those ones too much.	aware
two	H.R.	Some of them I matched like to like, and the others were fa ones together, and thin ones together.	unaware
two	K.F.	New objects like the chicken head I paired like to like. The ones from the second trial I tried to pick those that I had previously paired together.	aware

two	M.D.	I matched them to the same as the middle one.	unaware
two	O.B.	A form of visual mnemonics - a fairy on top of the Christmas tree. Size pairings, thin ones together, fat ones together, large ones together. I didn't think about the earlier experiments.	unaware
two	O.R.	I trie d to use the word association, the others I don't know I chose two and tried to be consistent.	aware
two	S.W.	The ones I knew were the milabon and the senidar, I paired them in the same way (they sounded French). The lulafet and the rosilof I tried to say in a Slavonic accent. The others I paired according to the direction of the lines.	aware
three	A.M.	Familiar words I tried to remember the picture pairs and use their names, the new ones I don't know.	aware
three	F.G.C.	The ones that sounded better together went together. Some of the pictures looked like things there was a paint can, a shell, and a ship. I can't remember if I put the same ones together.	unaware
three	H.K.	I associated the words that were up before with the picture pairs that were up before. I've no idea why I paired the new ones the way I did, but I tried to be consistent	aware
three	H.G.	The four familiar words I paired according to the pictures. senidar looked like a boat paired with milabon the seashell. In the other four, there were two that sounded similar. I tried to be consistent.	aware
three	J.G.	I just recognised the words and matched them to themselves.	unaware
three	L.H.	I recognised some, I remembered the corresponding picture paired association. I don't know about the new ones - I just stuck with my original pairings.	aware
three	M.B.	Two sorts - the ones that I had been exposed to I paired according to the picture pairings (but I'd used my own names for them -shell, leaf, cotton reel, coal scuttle). The others M and G. like in my name.	aware
three	M.D.	The ones I'd seen before I tried to pair together - I tried to relate the symbols to the words and to the previous pairings. The new words I just paired and tried to be consistent.	aware
three	M.C.	Picture pairings from phase two, names from phase three so I used the same pairings in phase four. The others were arbitrary pairings and I remained constant.	aware
three	R.Q.	Having no pictures was difficult - word tasks are harder so I just made patterns.	unaware

three	S.W.	Matched like to like	unaware
three	T.B.	Senidar looked like a duck,; milabon looked like fish and chips, --duck and chips go together, rosilof and lulafet the two with sticky out things. The others S and M went together in the first set so I stuck with that.	aware
three	V.R.	I paired the words that were linked by the pictures in the first place. I named the pictures, and then I linked the names that I gave them to the names in the second test. The control words I paired randomly, but G and M more often.	aware
three	V.S.	I don't really know the ones that sounded like mango and fruit? How should I know which ones went together?	unaware
three	Z.B.	The first ones I have no idea I randomly chose and tried to be consistent. Lulafet, et cetera, were out of Phase 3 and had a picture. At some point I might have paired them, I forget, but on the last task I gave them names like chip wrapper and seed germinal and tried to form associations between these names based on what they looked like.	unaware
four	B.S.	I instinctively put the two most visually similar together. Then I carried on with these pairings	unaware
four	C.W.	One set that went with the words, I tried to use the name pairs, the others I looked for visual similarities.	aware
four	C.WW	The first ones were the same as those before so I linked them with the words given before. The others I paired pointy shapes and round shapes.	aware
four	D.L.	I gave the images pictures of familiar things so jugs and bananas, bird, pint of beer, then I used the names that I'd made for these pictures to try and think of a reason why the might go together.	unaware
four	D.J.	Random structure, I looked for similarities in the shape and structure,for example. fish like ones.	unaware
four	E.W.	Just repeated squiggle crown to myself. I tried to relate th pictures to known objects.	unaware
four	I.S.	I used the name associations. The others - I don't know.	aware
four	J.S.	By order of presentation and by visual similarity, for example, two logs and a dead beetle.	unaware
four	L.C.	Matched them to themselves.	unaware
four	M.T.J.	No rationale I just tried the way that seemed simplest - tha was similar shapes. I think I might have recognised a couple of the pictures - were they on before?	unaware

four	M.O.C.	Visual matching - they looked like marine micro animals	unaware
four	P.B.	according to visual similarity until the end when I thought I knew the connection between the experiments.	unaware
four	S,H.	no system	unaware
four	S.C.	I used letter pairings not words, I associated the first letters and I associated the first letters with the picture form for the named ones. I labelled the other ones.	aware
four	S.D.	I tried to see something in the pictures like the two shell like ones, I used this to help me associate them, but I struggled with this picture - picture task.	unaware
five	A.S.	I matched senidar with milabon, and lulafet and rosilof because they looked like they might share some properties.	unaware
five	C.G.	The words that were easy to learn Vs. the words that were harder	unaware
five	C.E.	No idea why I paired them but O tried to be consistent.	unaware
five	E.W.	I paired them by the sounds of the first letter, except milabon that seemed like an odd one out so I paired it with itself.	unaware
five	E.G.	No not really the ones that had plant like pictures in the las test I put together.	unaware
five	G.F.	There were two different sets of four. Eventually paired S and M words in each set, and the left over pairs.	unaware
five	H.W.	I tried to see which ones looked like each other spelling wise and I tried to remember what they looked like. The other set ~I just pressed any button.	unaware
five	J.D.	I made my own reasons, for example, G and F was gorillas eat fruit.	unaware
five	L.B.	I recognised some I remembered them from the picture word pairings. I chose tried to stick to my original choices	unaware
five	M.H.	No rationale to begin with and then S and M were paired.	unaware
five	R.M.N.	Matched them to themselves	unaware
five	S.M.	Alphabetically for some, and I referred to the pictures for the name words and paired them if they looked like plants.	unaware
five	S.A.P.	Alphabetically	unaware
five	SP.	Matched like to like	unaware

five	T.W.	I recalled the referent pictures: rosilof reminded me of a bul and senidar of a bird so I put the two animals together. The others ones that sounded good together.	unaware
six	A.H.	I've no idea I picked them and tried to be consistent.	unaware
six	B.M.	lulafet and senidar I chose like that two sweet wrappers together.	unaware
six	B.P.	There was no feedback, but I tried to remain consistent. I arbitrarily picked two from the ones I'd seen before, and the other shapes I picked the two most similar.	unaware
six	C.D.P.	Just visual similarity, looked like fish and hen, pairs with a lot of detailed lines.	unaware
six	C.H.	Pairs that would physically fit together, or matching to themselves	unaware
six	C.L.	Matched like to like. In the learning the names trials I gave them my own names like Ross the dog	unaware
six	D.H.	Brain and backbone went together, two rough ones, two curved ones together.	unaware
six	E.R.	Matched them to themselves for both sets	unaware
six	J.C.	Not a clue. I matched them to self and tried to think of familiar objects like trumpet or boat. I need a name to learn them.	unaware
six	K.R.	Some pictures were from the trial before. I paired similar shapes.	unaware
six	L.K.	Lamb chop (L for lulafet) matched with the pile of sick, and the reindeer went with the bone. I couldn't keep to a pairing for the new ones.	unaware
six	N.H.	According to the shape - if one picture has a lot of vertical lines. I paired pictures that had the same features, so a leaf shape was paired with another leaf.	unaware
six	P.L.	One set had two fat ones and two thin ones, the other one backbone and one kidney, and two left over.	unaware
six	S.J.	No idea, I just guessed - ones that looked like each other. I can't remember their names either.	unaware
six	S.J.S.	If they looked similar	unaware

Appendix 3.15

Analysis of the number of correct responses obtained by participants categorised as aware or unaware of the transitive associations between stimuli the training tasks and the test task.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE	1	1284.18	1284.18	82.81	.0001
Subject(Group)	88	1364.65	15.51		
Stimulus set	1	1007.58	1007.58	86.85	.0001
Stimulus set * AWARE	1	843.18	843.18	72.68	.0001
Stimulus set * Subjec...	88	1020.98	11.60		

Dependent: mean #correct

A repeated measures ANOVA in which stimulus set (experimental vs. control) was the repeated measure and awareness was the between subjects measure. The DV was the number of correct responses.

Appendix 3.16

Analysis of the number of correct responses made by aware and unaware participants in each condition for each stimulus set.

A mixed ANOVA in which awareness and condition were treated as between subjects variables and stimulus set (experimental or control) was the repeated measure. The DV was the number of correct associates selected.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE	1	1077.04	1077.04	67.56	.0001
CONDITION	5	61.91	12.38	.78	.5694
AWARE * CONDITION	3	24.53	8.18	.51	.6746
Subject(Group)	80	1275.26	15.94		
Stimulus set	1	649.14	649.14	52.88	.0001
Stimulus set * AWARE	1	610.51	610.51	49.73	.0001
Stimulus set * CONDITION	5	15.99	3.20	.26	.9333
Stimulus set * AWARE * CON...	3	23.15	7.72	.63	.5987
Stimulus set * Subject(Group)	80	982.09	12.28		

Dependent: mean #correct

Appendix 3.15b: Means table for the effect of awareness on stimulus set in each condition of Experiment 3

Means Table
Effect: Stimulus set * AWARE * CONDITION
Dependent: mean #correct

	Count	Mean	Std. Dev.	Std. Error
experimental, AWARE, ONE	8	14.75	1.28	.45
experimental, AWARE, TWO	7	13.57	2.57	.97
experimental, AWARE, THREE	9	12.44	3.78	1.26
experimental, AWARE, FOUR	4	12.75	2.22	1.11
experimental, UNAWARE, ONE	7	1.00	1.91	.72
experimental, UNAWARE, TWO	8	3.25	4.83	1.71
experimental, UNAWARE, THREE	6	2.83	3.19	1.30
experimental, UNAWARE, FOUR	11	2.73	3.80	1.14
experimental, UNAWARE, FIVE	15	4.67	3.56	.92
experimental, UNAWARE, SIX	15	2.33	3.90	1.01
control, AWARE, ONE	8	3.88	5.59	1.98
control, AWARE, TWO	7	4.14	5.55	2.10
control, AWARE, THREE	9	3.00	3.00	1.00
control, AWARE, FOUR	4	3.75	1.71	.85
control, UNAWARE, ONE	7	2.43	3.31	1.25
control, UNAWARE, TWO	8	1.38	1.77	.62
control, UNAWARE, THREE	6	2.17	3.54	1.45
control, UNAWARE, FOUR	11	2.64	4.06	1.22
control, UNAWARE, FIVE	15	3.27	4.27	1.10
control, UNAWARE, SIX	15	2.60	4.24	1.09

Appendix 4

Appendix 4.1.a: the stimulus pairs for the lexical decision tasks

Lexical Decision Task 1			Lexical Decision Task 2	
Prime	Target	Pair type	Prime	Target
milabon	senidar	related experimental yes	milabon	senidar
senidar	milabon	related experimental yes	senidar	milabon
lulafet	rosilof	related experimental yes	lulafet	rosilof
rosilof	lulafet	related experimental yes	rosilof	lulafet
milabon	rosilof	unrelated experimental yes	milabon	rosilof
rosilof	senidar	unrelated experimental yes	rosilof	senidar
lulafet	milabon	unrelated experimental yes	lulafet	milabon
senidar	lulafet	unrelated experimental yes	senidar	lulafet
falofut	golabus	control-control yes	falofut	sumapor
golabus	falofut	control-control yes	golabus	maragon
maragon	sumapor	control-control yes	maragon	golabus
sumapor	maragon	control-control yes	sumapor	falofut
penidet	milabon	foil-experimental yes	jodisor	milabon
funisep	senidar	foil-experimental yes	hebicit	senidar
busetek	rosilof	foil-experimental yes	dosadon	rosilof
hebicor	lulafet	foil-experimental yes	lanagur	lulafet

Lexical Decision Task 1			Lexical Decision Task 2	
Prime	Target	Pair type	Prime	Target
piravos	risalan	foil-foil no	dipados	farador
goradon	kisomak	foil-foil no	cusapon	tutalin
basiven	conacug	foil-foil no	tifilin	gonarus
filisug	sanofet	foil-foil no	visatik	hemosed
falofut	balorit	foil-foil no	falofut	bicanum
golabus	cobiram	foil-foil no	golabus	visatek
caraton	kesimar	foil-foil no	caraton	bidiged
fulodon	maloron	foil-foil no	fulodon	fubecay
milabon	puniset n	experimental-foil no	milabon	guloyed
senidar	gavatep	experimental-foil no	senidar	tomucos
lulafet	horitat	experimental-foil no	lulafet	ronidum
rosilof	nesamon	experimental-foil no	rosilof	loritek
falofut	dekatin	control-foil no	falofut	ronidum
golabus	lisogop	control-foil no	golabus	boterin
maragon	tibelin	control-foil no	maragon	gosetay
sumapor	kinetos	control-foil no	sumapor	harimed

The picture stimuli had the same picture-prime relations. The stimuli are shown in Appendix 3.1.b.

Appendix 4.1.b Novel picture stimuli taken from Kroll and Potter, (1984)

Experimental stimuli related	Experimental stimuli unrelated	Control stimuli

Third Party material excluded from digitised copy. Please refer to original text to see this material.

Appendix 4.2: A semi structured interview sheet on which participant's responses were recorded.

Name:	Condition:

Vocabulary Training Task

Do you feel that you managed to learn the names of the pictures?

Did you use any mnemonic strategy to learn the names?

Paired Association Training Task

Do you think that you have learned the picture / word* pairs?

Did you use any strategy to learn them?

Test Association Task 1

What was your rationale for the pairs you selcted?

Did you notice that there were two sets of pictures* / words* ?

Did you treat both sets in the same way?

Test Association Task 2

Again, what was your rationale for the pairs you selected? Was it the same as the last time you did this task?

Were you able to make the connection between this task and the training tasks where you learned the names of the pictures and the associations between the pictures* / words* ?

* picture or word depending on condition.

Appendix 4.3

Analysis of Test Association Task 1: stimulus set (experimental and control) by condition.
An mixed ANOVA was performed; condition was the between subjects variable and stimulus set was the within subjects variable. The IV was the number of correct responses for each stimulus type

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	148.962	49.654	1.526	.2151
Subject(Group)	73	2376.012	32.548		
stimulus set	1	996.506	996.506	39.188	.0001
stimulus set * condition	3	155.042	51.681	2.032	.1168
stimulus set * Subject(...	73	1856.296	25.429		

Dependent: #correct test 1

The effect of stimulus set on each condition was examined using simple main effects.

Appendix 4.3.b Simple main effect of stimulus set for condition 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	577.842	32.102		
stimulus set	1	114.632	114.632	3.847	.0655
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(...	18	536.368	29.798		

Dependent: #correct test 1

Appendix 4.3.c Simple main effect of stimulus set on condition 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	475.842	26.436		
stimulus set	1	273.789	273.789	14.615	.0012
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(...	18	337.211	18.734		

Dependent: #correct test 1

Appendix 4.3.d: Simple main effect of stimulus set on condition 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	549.053	30.503		
stimulus set	1	648.658	648.658	25.670	.0001
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(...	18	454.842	25.269		

Dependent: #correct test 1

Appendix 4.3.e : Simple main effect of stimulus set on condition 4

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	19	773.275	40.699		
stimulus set	1	105.625	105.625	3.802	.0661
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(...	19	527.875	27.783		

Dependent: #correct test 1

Appendix 4.4 : A χ^2 test of independence performed on the number of people in each condition who were categorised as aware or unaware of the transitive relations between the training and test task after the first association test task.

Observed Frequencies for condition, AWARE1st

	aware	unaware	Totals
Condition 1	8	11	19
Condition 2	7	12	19
Condition 3	13	6	19
Condition 4	5	15	20
Totals	33	44	77

Expected Values for condition, AWARE1st

	aware	unaware	Totals
Condition 1	8.143	10.857	19.000
Condition 2	8.143	10.857	19.000
Condition 3	8.143	10.857	19.000
Condition 4	8.571	11.429	20.000
Totals	33.000	44.000	77.000

Summary Table for condition, AWARE1st

Num. Missing	0
DF	3
Chi Square	7.959
Chi Square P-Va...	.0469
G-Squared	8.103
G-Squared P-Va...	.0439
Contingency Coef.	.306
Cramer's V	.322

1

Cell Chi Squares for condition, AWARE1st

	aware	unaware
Condition 1	.003	.002
Condition 2	.160	.120
Condition 3	2.897	2.173
Condition 4	1.488	1.116

Appendix 4.5

Mixed ANOVA with condition and awareness (after first association test) treated as between subject variables and stimulus set (experimental or control) as the within subject variable. DV is the number of correct responses for the control and experimental stimuli

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	1010.977	1010.977	51.232	.0001
AWARE 1st * condition	3	11.084	3.695	.187	.9047
condition	3	6.973	2.324	.118	.9494
Subject(Group)	69	1361.590	19.733		
stimulus set	1	1100.015	1100.015	61.769	.0001
stimulus set * AWARE 1st	1	602.515	602.515	33.833	.0001
stimulus set * AWARE 1st * condition	3	31.549	10.516	.591	.6233
stimulus set * condition	3	47.448	15.816	.888	.4517
stimulus set * Subject(Group)	69	1228.789	17.809		

Dependent: #correct test 1

Appendix 4.5.b: Simple main effect analyis for aware (excluding unaware) on condition and stimulus set

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	0	•	•	•	•
AWARE 1st * condition	0	•	•	•	•
condition	3	17.489	5.830	.340	.7963
Subject(Group)	29	496.784	17.130		
stimulus set	1	1455.661	1455.661	78.270	.0001
stimulus set * AWARE 1st	0	•	•	•	•
stimulus set * AWARE 1st * condition	0	•	•	•	•
stimulus set * condition	3	66.147	22.049	1.186	.3324
stimulus set * Subject(Group)	29	539.338	18.598		

Dependent: #correct test 1

Appendix 4.5.c: Simple main effect analyis for unaware (excluding aware) on condition and stimulus set

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	0	•	•	•	•
AWARE 1st * condition	0	•	•	•	•
condition	3	.319	.106	.005	.9995
Subject(Group)	40	864.806	21.620		
stimulus set	1	43.408	43.408	2.518	.1204
stimulus set * AWARE 1st	0	•	•	•	•
stimulus set * AWARE 1st * condition	0	•	•	•	•
stimulus set * condition	3	4.492	1.497	.087	.9668
stimulus set * Subject(Group)	40	689.452	17.236		

Dependent: #correct test 1

Appendix 4.6a

Two way ANOVA for condition x awareness after first association test; DV is the number of correct responses on the vocabulary test (maximum score = 16)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	24.33	24.33	1.19	.2788
AWARE 1st * condition	3	43.52	14.51	.71	.5491
condition	3	22.24	7.41	.36	.7798
Residual	69	1408.96	20.42		

Dependent: vocab

Appendix 4.6b

Two way ANOVA for condition x awareness after first association test; DV is the number of correct responses on the trained associate recall test (maximum score = 8)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	6.48	2.16	.44	.7286
condition * AWARE 1st	3	18.25	6.08	1.23	.3072
AWARE 1st	1	2.81	2.81	.57	.4546
Residual	69	342.56	4.96		

Dependent: PAL recall

Appendix 4.6c

*Two way ANOVA for condition x awareness after first association test; DV is product of the vocabulary recall score * trained associate recall score.*

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	2741.77	913.92	.46	.7115
condition * AWARE 1st	3	8087.16	2695.72	1.36	.2638
AWARE 1st	1	3386.81	3386.81	1.70	.1963
Residual	69	137247.58	1989.10		

Dependent: vocab x PAL

Means Table
Effect: condition * AWARE 1st
Dependent: vocab x PAL

	Count	Mean	Std. Dev.	Std. Error
Condition 1, aware	8	74.12	56.34	19.92
Condition 1, unaware	11	95.18	47.56	14.34
Condition 2, aware	7	100.29	27.91	10.55
Condition 2, unaware	12	82.67	49.31	14.23
Condition 3, aware	13	109.23	34.07	9.45
Condition 3, unaware	6	86.33	48.70	19.88
Condition 4, aware	5	120.00	8.00	3.58
Condition 4, unaware	15	82.67	49.97	12.90

Appendix 4.7

Analysis of Test Association Task 2: stimulus set (experimental and control) by condition
An mixed ANOVA was performed; condition was the between subjects variable and stimulus set was the within subjects variable. The IV was the number of correct responses for each stimulus type in association Test Task 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	44.55	14.85	.45	.7166
Subject(Group)	73	2398.07	32.85		
stimulus set	1	2272.19	2272.19	79.67	.0001
stimulus set * condition	3	34.60	11.53	.40	.7503
stimulus set * Subject(Group)	73	2081.84	28.52		

Dependent: # correct test 2

Appendix 4.7.b: Simple main effect for stimulus set on condition 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	629.00	34.94		
stimulus set	1	404.63	404.63	12.77	.0022
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(Group)	18	570.37	31.69		

Dependent: # correct test 2

Appendix 4.7.c: Simple main effect for stimulus set on condition 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	417.58	23.20		
stimulus set	1	665.29	665.29	30.38	.0001
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(Group)	18	394.21	21.90		

Dependent: # correct test 2

Appendix 4.7.d: Simple main effect for stimulus set on condition 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	669.89	37.22		
stimulus set	1	742.74	742.74	32.83	.0001
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(Group)	18	407.26	22.63		

Dependent: # correct test 2

Appendix 4.7.e: Simple main effect for stimulus set on condition 4

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	19	681.60	35.87		
stimulus set	1	490.00	490.00	13.11	.0018
stimulus set * condition	0	•	•	•	•
stimulus set * Subject(Group)	19	710.00	37.37		

Dependent: # correct test 2

Appendix 4.8

Analysis of the number of participants in each condition who were categorised as aware or unaware of the transitive relations between the training tasks and Test Task 2.

A χ^2 test of independence was performed on the number of people in each condition who were categorised as aware or unaware of the transitive relations between the training during Test Task 2.

Summary Table for condition, AWARE 2nd

Num. Missing	0
DF	3
Chi Square	4.41
Chi Square P-Value	.2207
G-Squared	4.80
G-Squared P-Value	.1873
Contingency Coef.	.23
Cramer's V	.24

Cell Chi Squares for condition, AWARE 2nd

	aware	unaware
Condition 1	.15	.27
Condition 2	.01	.02
Condition 3	1.09	2.01
Condition 4	.30	.56

Observed Frequencies for condition, AWARE 2nd

	aware	unaware	Totals
Condition 1	11	8	19
Condition 2	12	7	19
Condition 3	16	3	19
Condition 4	11	9	20
Totals	50	27	77

Expected Values for condition, AWARE 2nd

	aware	unaware	Totals
Condition 1	12.34	6.66	19.00
Condition 2	12.34	6.66	19.00
Condition 3	12.34	6.66	19.00
Condition 4	12.99	7.01	20.00
Totals	50.00	27.00	77.00

Appendix 4.9

Analysis of the effect of "awareness of transitive relations between training tasks and test association Task 2

A mixed ANOVA was carried out in which awareness(after Test Task 2) and condition were treated as between subjects variables and stimulus set was the within subjects variable. the DV was the mean number of correct responses.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 2nd	1	249.70	249.70	8.53	.0047
AWARE 2nd * condition	3	195.54	65.18	2.23	.0928
condition	3	22.88	7.63	.26	.8536
Subject(Group)	69	2020.17	29.28		
stimulus set	1	1272.59	1272.59	52.79	.0001
stimulus set * AWARE 2nd	1	399.69	399.69	16.58	.0001
stimulus set * AWARE 2nd * condition	3	29.94	9.98	.41	.7435
stimulus set * condition	3	19.59	6.53	.27	.8462
stimulus set * Subject(Group)	69	1663.48	24.11		

Dependent: # correct test 2

Appendix 4.10.

Analysis of awareness after Test Task 2 and recall of the training tasks.

Appendix 4.10a

Two way ANOVA for condition x awareness after second association test; DV is the number of correct responses on the vocabulary test (maximum score = 16)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	27.62	9.21	.44	.7237
AWARE 2nd	1	1.15	1.15	.06	.8147
condition * AWARE 2nd	3	32.74	10.91	.52	.6672
Residual	69	1437.21	20.83		

Dependent: vocab recall

Appendix 4.10b

Two way ANOVA for condition x awareness after second association test; DV is the number of correct responses on the trained associate recall test (maximum score = 8)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	4.63	1.54	.31	.8171
AWARE 2nd	1	10.83	10.83	2.19	.1438
condition * AWARE 2nd	3	11.44	3.81	.77	.5147
Residual	69	341.79	4.95		

Dependent: PAL recall

Appendix 4.10c

*Two way ANOVA for condition x awareness after second association test; DV is product of the vocabulary recall score * trained associate recall score.*

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	588.74	196.25	.09	.9640
AWARE 2nd	1	818.10	818.10	.38	.5370
condition * AWARE 2nd	3	903.89	301.30	.14	.9346
Residual	69	146640.77	2125.23		

Dependent: vocab x PAL

Appendix 4.11

Analysis of number of correct responses for Decision task

A mixed ANOVA in which condition was the between subject variable and prime type was the within subject variable. DV = number of correct responses 1 (4 = maximum number of correct responses).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	.99	.33	1.80	.1555
Subject(Group)	73	13.38	.18		
prime-target	2	.04	.02	.09	.9114
prime-target * condition	6	.63	.11	.53	.7810
prime-target * Subject(Group)	146	28.67	.20		

Dependent: RT<2000 + 3SD

Appendix 4.12

Analysis of mean response times for Decision Task 1

A mixed ANOVA in which condition was the between subject variable and prime type was the within subject variable. DV = mean response time

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	84412.12	28137.37	.69	.5635
Subject(Group)	73	2994252.08	41017.15		
prime type	2	2885.30	1442.65	.22	.8005
prime type * condition	6	43166.42	7194.40	1.11	.3585
prime type * Subject(Group)	146	945134.02	6473.52		

Dependent: priming 1<2000

Appendix 4.12.b: Simple main effect of prime type for condition 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	919404.16	51078.01		
prime type	2	990.02	495.01	.06	.9398
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	36	286305.44	7952.93		

Dependent: priming 1<2000

Appendix 4.12.c: Simple main effect of prime type for condition 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	826930.67	45940.59		
prime type	2	20908.98	10454.49	1.08	.3495
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	36	347620.65	9656.13		

Dependent: priming 1<2000

Appendix 4.12.d: Simple main effect of prime type for condition 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	18	596398.67	33133.26		
prime type	2	22481.23	11240.61	2.30	.1147
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	36	175894.68	4885.96		

Dependent: priming 1<2000

Appendix 4.12.e: Simple main effect of prime type for condition 4

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	19	651518.58	34290.45		
prime type	2	1607.12	803.56	.23	.7990
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	38	135313.24	3560.87		

Dependent: priming 1<2000

Appendix 4.12.f: Planned means comparisons for object vs. lexical decision task (conditions 2 and 4 vs. conditions 1 and 3)

Comparison 1
Effect: condition
Dependent: priming 1<2000

	Cell Weight
Condition 1	.50
Condition 2	-.50
Condition 3	.50
Condition 4	-.50

df	1
Sum of Squares	36499.15
Mean Square	36499.15
F-Value	.89
P-Value	.3486

Interaction of prime type with
Comparison 1
Effect: condition
Dependent: priming 1<2000

	Cell Weight
Condition 1	.50
Condition 2	-.50
Condition 3	.50
Condition 4	-.50

df	2
Sum of Squares	10390.78
Mean Square	5195.39
F-Value	.80
P-Value	.4501

Appendix 4.13

Analysis of effect of awareness on Decision Task 1.

Mixed ANOVA in which awareness is the between subjects variable and prime type (associated, categorical and unrelated) is the between subjects variable.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	208.61	208.61	.01	.9434
Subject(Group)	75	3078455.59	41046.07		
prime type	2	8359.00	4179.50	.69	.5037
prime type * AWARE 1st	2	78220.39	39110.20	6.45	.0021
prime type * Subject(Group)	150	910080.04	6067.20		

Dependent: priming 1<2000

Appendix 4.13.b. Simple main effect analysis of prime type for aware participants

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	0	•	•	•	•
Subject(Group)	32	1408937.17	44029.29		
prime type	2	59903.95	29951.98	5.49	.0063
prime type * AWARE 1st	0	•	•	•	•
prime type * Subject(Group)	64	349438.65	5459.98		

Dependent: priming 1<2000

Appendix 4.13.c. Planned means comparisons of prime type for aware.

Comparison 1
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	49350.34
Mean Square	49350.34
F-Value	9.04
P-Value	.0038
G-G	.0074
H-F	.0068

Comparison 2
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	40016.86
Mean Square	40016.86
F-Value	7.33
P-Value	.0087
G-G	.0145
H-F	.0136

Comparison 3
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	488.73
Mean Square	488.73
F-Value	.09
P-Value	.7658
G-G	.6950
H-F	.7057

Appendix 4.13.d: Simple main effect analysis of prime type for unaware participants

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	0	•	•	•	•
Subject(Group)	43	1669518.42	38826.01		
prime type	2	21137.36	10568.68	1.62	.2036
prime type * AWARE 1st	0	•	•	•	•
prime type * Subject(Group)	86	560641.40	6519.09		

Dependent: priming 1<2000

. Appendix 4.13.e. Planned means comparisons of prime type for unaware

Comparison 1
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	19229.67
Mean Square	19229.67
F-Value	2.95
P-Value	.0895
G-G	.0956
H-F	.0944

Comparison 2
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	11483.50
Mean Square	11483.50
F-Value	1.76
P-Value	.1879
G-G	.1871
H-F	.1874

Comparison 3
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	992.88
Mean Square	992.88
F-Value	.15
P-Value	.6973
G-G	.6539
H-F	.6632

Appendix 4.14.a. Analysis of effect of awareness and prime type on condition.

A mixed ANOVA was performed in which condition and awareness were between subject variables and prime type was the repeated measure. DV was response time.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	50.89	50.89	1.21E-3	.9723
AWARE 1st * condition	3	96596.23	32198.74	.77	.5164
condition	3	118462.23	39487.41	.94	.4259
Subject(Group)	69	2896800.24	41982.61		
prime type	2	5847.73	2923.86	.47	.6288
prime type * AWARE 1st	2	74046.90	37023.45	5.89	.0035
prime type * AWARE 1st * condition	6	5861.78	976.96	.16	.9877
prime type * condition	6	37606.49	6267.75	1.00	.4294
prime type * Subject(Group)	138	866790.25	6281.09		

Dependent: priming 1<2000

Appendix 4.14.b: Simple main effects analysis of awareness and prime type on condition 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	8770.61	8770.61	.16	.6908
AWARE 1st * condition	0	•	•	•	•
condition	0	•	•	•	•
Subject(Group)	17	910633.56	53566.68		
prime type	2	822.10	411.05	.05	.9500
prime type * AWARE 1st	2	14300.47	7150.24	.89	.4185
prime type * AWARE 1st * condition	0	•	•	•	•
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	34	272004.97	8000.15		

Dependent: priming 1<2000

Appendix 4.14.c: Simple main effects analysis of awareness and prime type on condition 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	43085.82	43085.82	.93	.3473
AWARE 1st * condition	0	•	•	•	•
condition	0	•	•	•	•
Subject(Group)	17	783844.85	46108.52		
prime type	2	22471.05	11235.52	1.13	.3343
prime type * AWARE 1st	2	10068.97	5034.48	.51	.6067
prime type * AWARE 1st * condition	0	•	•	•	•
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	34	337551.69	9927.99		

Dependent: priming 1<2000

Appendix 4.14.d: Simple main effects analysis of awareness and prime type on condition 3

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	3543.32	3543.32	.10	.7538
AWARE 1st * condition	0	•	•	•	•
condition	0	•	•	•	•
Subject(Group)	17	592855.35	34873.84		
prime type	2	11029.94	5514.97	1.30	.2846
prime type * AWARE 1st	2	32132.69	16066.35	3.80	.0324
prime type * AWARE 1st * condition	0	•	•	•	•
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	34	143761.99	4228.29		

Dependent: priming 1<2000

Appendix 4.14.e: Simple main effects analysis of awareness and prime type on condition 4

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	42052.09	42052.09	1.24	.2798
AWARE 1st * condition	0	•	•	•	•
condition	0	•	•	•	•
Subject(Group)	18	609466.49	33859.25		
prime type	2	8779.05	4389.52	1.39	.2615
prime type * AWARE 1st	2	21841.64	10920.82	3.46	.0421
prime type * AWARE 1st * condition	0	•	•	•	•
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	36	113471.61	3151.99		

Dependent: priming 1<2000

Appendix 4.14.f: Planned means comparisons between prime types in condition 1

Comparison 1
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	4109.13
Mean Square	4109.13
F-Value	.82
P-Value	.3802
G-G	.3621
H-F	.3802

Comparison 2
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	6323.43
Mean Square	6323.43
F-Value	1.26
P-Value	.2799
G-G	.2723
H-F	.2799

Comparison 3
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	237.70
Mean Square	237.70
F-Value	.05
P-Value	.8306
G-G	.7882
H-F	.8306

Appendix 4.14.g: Planned means comparisons between prime types in condition 2

Comparison 1
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	349.20
Mean Square	349.20
F-Value	.03
P-Value	.8742
G-G	.7076
H-F	.7141

Comparison 2
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	15845.79
Mean Square	15845.79
F-Value	1.19
P-Value	.2974
G-G	.2594
H-F	.2609

Comparison 3
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	11490.37
Mean Square	11490.37
F-Value	.86
P-Value	.3719
G-G	.3074
H-F	.3097

Appendix 4.14.h: Planned means comparisons between prime types in condition 3

Comparison 1
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	42842.75
Mean Square	42842.75
F-Value	15.00
P-Value	.0007
G-G	.0034
H-F	.0027

Comparison 2
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	11125.01
Mean Square	11125.01
F-Value	3.90
P-Value	.0600
G-G	.0774
H-F	.0748

Comparison 3
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	10304.22
Mean Square	10304.22
F-Value	3.61
P-Value	.0696
G-G	.0864
H-F	.0839

Appendix 4.14.i: Planned means comparisons between prime types in condition 4

Comparison 1
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	17892.90
Mean Square	17892.90
F-Value	6.18
P-Value	.0378
G-G	.0610
H-F	.0490

Comparison 2
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	8895.31
Mean Square	8895.31
F-Value	3.07
P-Value	.1177
G-G	.1367
H-F	.1282

Comparison 3
Effect: prime type
Dependent: priming 1<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	1556.26
Mean Square	1556.26
F-Value	.54
P-Value	.4844
G-G	.4166
H-F	.4508

Appendix 4.15

Analysis of errors in Decision Task 2

One way ANOVA performed on the number of correct responses for each prime type.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	76	7.84	.10		
prime type	2	.08	.04	.33	.7191
prime type * Subject	152	17.92	.12		

Dependent: # errors P2

Appendix 4.16

Analysis of errors in each condition of Decision Task 2

A mixed ANOVA was performed in which prime type was the within subjects variable and condition the between subjects variable. The DV was the number of correct responses

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	.19	.06	.62	.6058
Subject(Group)	73	7.65	.10		
prime type	2	.07	.04	.31	.7336
prime type * condition	6	.96	.16	1.38	.2282
prime type * Subject(...	146	16.96	.12		

Dependent: #correct P2

Appendix 4.16.b. Planned means Comparisons of Lexical Decision tasks (conditions 1 and 3) and Object Decision Tasks (conditions 2 and 4).

Comparison 1
Effect: condition
Dependent: #correct P2

	Cell Weight
Condition 1	.50
Condition 2	-.50
Condition 3	.50
Condition 4	-.50

df	1
Sum of Squares	.09
Mean Square	.09
F-Value	.88
P-Value	.3520

Interaction of prime type with Comparison 1
Effect: condition
Dependent: #correct P2

	Cell Weight
Condition 1	.50
Condition 2	-.50
Condition 3	.50
Condition 4	-.50

df	2
Sum of Squares	.27
Mean Square	.14
F-Value	1.16
P-Value	.3154

Appendix 4.16: Analysis of response times for each prime type (associated categorical and unrelated) for Decision Task 2.

A repeated measures ANOVA with prime type as within subjects variable and response time as the DV.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject	4	123604.98	30901.24		
prime type	2	1347.47	673.73	.32	.7344
prime type * Subject	8	16797.96	2099.74		

Dependent: priming 2<2000

Appendix 4.17

Analysis of response times for each condition in Decision Task 2

A mixed ANOVA was performed: condition was the between subjects variable and prime type the within subjects variable. The DV was response time.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	31756.57	10585.52	.38	.7703
Subject(Group)	73	2052813.61	28120.73		
prime type	2	5511.70	2755.85	1.04	.3558
prime type * condition	6	23725.53	3954.26	1.49	.1844
prime type * Subject(Group)	146	386633.86	2648.18		

Dependent: priming 2<2000

Appendix 4.17.b: Planned means comparisons of each task: Lexical Decision (conditions 1 and 3) and Object Decision (conditions 2 and 4)

Comparison 1
Effect: condition
Dependent: priming 2<2000

	Cell Weight
Condition 1	.50
Condition 2	-.50
Condition 3	.50
Condition 4	-.50

df	1
Sum of Squares	28533.35
Mean Square	28533.35
F-Value	1.01
P-Value	.3171

Interaction of prime type with Comparison 1
Effect: condition
Dependent: priming 2<2000

	Cell Weight
Condition 1	.50
Condition 2	-.50
Condition 3	.50
Condition 4	-.50

df	2
Sum of Squares	14638.83
Mean Square	7319.41
F-Value	2.76
P-Value	.0663

Appendix 4.18

Analysis of effect of awareness of the transitive relations between the training tasks and Test Task 1 on Decision Task 2

A mixed ANOVA was performed in which prime type was the within subject variable and 'Awareness after Test Task 1' was the between subjects variable. The DV was response time.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	1	64706.65	64706.65	2.40	.1253
Subject(Group)	75	2019863.54	26931.51		
prime type	2	7939.72	3969.86	1.52	.2214
prime type * AWARE 1st	2	19419.70	9709.85	3.73	.0264
prime type * Subject(Group)	150	390939.69	2606.26		

Dependent: priming 2<2000

Appendix 4.18.b Simple main effect of awareness after Test Task 1 on prime type in Decision Task 1 (excluding unaware)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	0	•	•	•	•
Subject(Group)	32	841335.88	26291.75		
prime type	2	22337.18	11168.59	5.38	.0069
prime type * AWARE 1st	0	•	•	•	•
prime type * Subject(Group)	64	132961.81	2077.53		

Dependent: priming 2<2000

Appendix 4.18.c: Planned means comparisons of Prime type for 'Aware after Test Task 1"

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	643.97
Mean Square	643.97
F-Value	.31
P-Value	.5796
G-G	.5170
H-F	.5253

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	13194.03
Mean Square	13194.03
F-Value	6.35
P-Value	.0142
G-G	.0222
H-F	.0210

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	19667.77
Mean Square	19667.77
F-Value	9.47
P-Value	.0031
G-G	.0066
H-F	.0060

Appendix 4.18.d Simple main effect of "Unaware after Test Task 1 on Decision Task 2 (excluding aware)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 1st	0	•	•	•	•
Subject(Group)	43	1178527.66	27407.62		
prime type	2	2136.42	1068.21	.36	.7014
prime type * AWARE 1st	0	•	•	•	•
prime type * Subject(Group)	86	257977.88	2999.74		

Dependent: priming 2<2000

Appendix 4.18.e: Planned means comparisons of Prime type for 'Unaware after Test Task 1"

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	982.03
Mean Square	982.03
F-Value	.33
P-Value	.5687
G-G	.5121
H-F	.5185

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	189.22
Mean Square	189.22
F-Value	.06
P-Value	.8023
G-G	.7341
H-F	.7421

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	2033.38
Mean Square	2033.38
F-Value	.68
P-Value	.4126
G-G	.3768
H-F	.3808

Appendix 4.19

Analysis of effect of Awareness 2 on Decision Task 2.
Mixed ANOVA in which awareness was the between subjects variable and prime type (associated, categorical and unrelated) was the between subjects variable.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 2nd	1	19673.75	19673.75	.71	.4006
Subject(Group)	75	2064896.43	27531.95		
prime type	2	793.19	396.59	.16	.8559
prime type * AWARE 2nd	2	28558.37	14279.18	5.61	.0045
prime type * Subject(Group)	150	381801.03	2545.34		

Dependent: priming 2<2000

Appendix 4.19.b: Simple main effect of Awareness 2 on prime type in Decision Task 2 (unaware excluded)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 2nd	0	•	•	•	•
Subject(Group)	49	1290975.92	26346.45		
prime type	2	23938.19	11969.10	5.03	.0084
prime type * AWARE 2nd	0	•	•	•	•
prime type * Subject(Group)	98	233336.81	2380.99		

Dependent: priming 2<2000

Appendix 4.19.c: Planned means comparisons for prime type x Awareness 2 (aware only)

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	488.14
Mean Square	488.14
F-Value	.21
P-Value	.6517
G-G	.5953
H-F	.6022

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	14779.51
Mean Square	14779.51
F-Value	6.21
P-Value	.0144
G-G	.0206
H-F	.0198

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	20639.63
Mean Square	20639.63
F-Value	8.67
P-Value	.0040
G-G	.0072
H-F	.0067

Appendix 4.19.d: Simple main effect of Unawareness 2 on prime type in Decision Task 2 (aware excluded)

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 2nd	0	•	•	•	•
Subject(Group)	26	773920.52	29766.17		
prime type	2	9674.07	4837.04	1.69	.1937
prime type * AWARE 2nd	0	•	•	•	•
prime type * Subject(Group)	52	148464.22	2855.08		

Dependent: priming 2<2000

Appendix 4.19.e: Planned means comparisons for prime type x awareness 2 (unaware only)

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	1765.31
Mean Square	1765.31
F-Value	.62
P-Value	.4352
G-G	.3693
H-F	.3735

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	3137.00
Mean Square	3137.00
F-Value	1.10
P-Value	.2994
G-G	.2675
H-F	.2697

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	9608.80
Mean Square	9608.80
F-Value	3.37
P-Value	.0723
G-G	.0882
H-F	.0874

Appendix 4.20:

Analysis of the number of errors in Decision Test Task 2 for "Aware 1" (Awareness of the transitive relations between the training tasks and Test Task 1).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Intercept	1	8.96	8.96		
AWARE 1st	1	.13	.13	.42	.5191
Residual	75	23.40	.31		

Dependent: P2 #excl. exp. trials

Means Table
Effect: AWARE 1st
Dependent: P2 #excl. exp. trials

	Count	Mean	Std. Dev.	Std. Error
aware	33	.30	.59	.10
unaware	44	.39	.54	.08

Appendix 4.21

Analysis of the number of errors in Decision Test Task 2 for "Aware 2" (Awareness of the transitive relations between the training tasks and Test Task 2).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
AWARE 2nd	1	.13	.13	.43	.5143
Residual	75	23.40	.31		

Dependent: P2 #excl. exp. trials

Means Table
Effect: AWARE 2nd
Dependent: P2 #excl. exp. trials

	Count	Mean	Std. Dev.	Std. Error
aware	50	.32	.55	.08
unaware	27	.41	.57	.11

Appendix 4.22

Analysis of response times in Decision Task 2 for Aware

Appendix 4.22.a A mixed ANOVA in which condition was the between subjects variable and prime type was the within subjects variable. Response time was the DV. Data from participants rated as unaware of the transitive relations between the training tasks and Assoicaiton Test Task 1 were excluded.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	5020.86	1673.62	.06	.9813
Subject(Group)	29	836315.01	28838.45		
prime type	2	11487.55	5743.77	2.79	.0694
prime type * condition	6	13729.10	2288.18	1.11	.3660
prime type * Subject(Group)	58	119232.71	2055.74		

Dependent: priming 2<2000

Appendix 4.22.b Simple main effects of Condition 1 and prime type for Aware 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	7	83820.94	11974.42		
prime type	2	10762.62	5381.31	2.34	.1327
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	14	32178.06	2298.43		

Dependent: priming 2<2000

Appendix 4.22c Planned means comparisons of prime type for aware 1 in Condition 1

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	1053.49
Mean Square	1053.49
F-Value	.46
P-Value	.5094
G-G	.4920
H-F	.5094

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	4775.50
Mean Square	4775.50
F-Value	2.08
P-Value	.1715
G-G	.1732
H-F	.1715

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	10314.94
Mean Square	10314.94
F-Value	4.49
P-Value	.0525
G-G	.0573
H-F	.0525

Appendix 4.22.d: Simple main effects of condition 2 and prime type for aware 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	6	58332.95	9722.16		
prime type	2	1351.82	675.91	.44	.6557
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	12	18547.98	1545.66		

Dependent: priming 2<2000

Appendix 4.22.e Planned means comparisons of prime type for aware 1 in condition 2

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	27.64
Mean Square	27.64
F-Value	.02
P-Value	.8958
G-G	.8753
H-F	.8958

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	834.38
Mean Square	834.38
F-Value	.54
P-Value	.4766
G-G	.4606
H-F	.4766

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	1165.72
Mean Square	1165.72
F-Value	.75
P-Value	.4022
G-G	.3906
H-F	.4022

Appendix 4.22.f: Simple main effects of condition 3 and prime type for aware 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	12	570556.15	47546.35		
prime type	2	22604.37	11302.19	5.25	.0129
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	24	51708.72	2154.53		

Dependent: priming 2<2000

Appendix 4.22.g Planned means comparisons of prime type and aware 1 in condition 3

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	.11
Mean Square	.11
F-Value	4.98E-5
P-Value	.9944
G-G	.9710
H-F	.9773

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	16995.87
Mean Square	16995.87
F-Value	7.89
P-Value	.0097
G-G	.0205
H-F	.0184

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	16910.58
Mean Square	16910.58
F-Value	7.85
P-Value	.0099
G-G	.0208
H-F	.0186

Appendix 4.22.h: Simple main effects of condition 4 and prime type for aware 1

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	4	123604.98	30901.24		
prime type	2	1347.47	673.73	.32	.7344
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	8	16797.96	2099.74		

Dependent: priming 2<2000

Appendix 4.22.i Planned means comparisons of prime type for aware 1 in condition 4

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	340.24
Mean Square	340.24
F-Value	.16
P-Value	.6978
G-G	.5510
H-F	.5692

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	1347.46
Mean Square	1347.46
F-Value	.64
P-Value	.4462
G-G	.3670
H-F	.3768

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	333.51
Mean Square	333.51
F-Value	.16
P-Value	.7007
G-G	.5533
H-F	.5716

Appendix 4.23

Analysis of response times in Decision Task 2 for Aware 2

Appendix 4.23.a A mixed ANOVA in which condition was the between subjects variable and prime type was the within subjects variable. Response time was the DV. Data from participants rated as unaware of the transitive relations between the training tasks and Association Test Task 2 were excluded.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	3	74088.95	24696.32	.93	.4322
Subject(Group)	46	1216886.96	26454.06		
prime type	2	21812.17	10906.08	4.55	.0130
prime type * condition	6	13006.43	2167.74	.91	.4949
prime type * Subject(Group)	92	220330.38	2394.90		

Dependent: priming 2<2000

Appendix 4.23.b Simple main effect ofcondition 1 and prime type for aware 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	10	103137.33	10313.73		
prime type	2	17336.47	8668.24	4.76	.0203
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	20	36398.42	1819.92		

Dependent: priming 2<2000

Appendix 4.23.c. Planned means comparisons of prime type for aware 2 in condition 1

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	435.03
Mean Square	435.03
F-Value	.24
P-Value	.6302
G-G	.6068
H-F	.6302

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	10436.54
Mean Square	10436.54
F-Value	5.73
P-Value	.0265
G-G	.0304
H-F	.0265

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	15133.14
Mean Square	15133.14
F-Value	8.32
P-Value	.0092
G-G	.0114
H-F	.0092

Appendix 4.23.d Simple main effect of condition 2 and prime type for aware 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	11	275214.32	25019.48		
prime type	2	6129.19	3064.59	1.46	.2528
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	22	46023.79	2091.99		

Dependent: priming 2<2000

Appendix 4.23.e. Planned means comparisons of prime type for aware 2 in condition 2

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	64.88
Mean Square	64.88
F-Value	.03
P-Value	.8618
G-G	.8306
H-F	.8618

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	5107.67
Mean Square	5107.67
F-Value	2.44
P-Value	.1324
G-G	.1363
H-F	.1324

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	4021.23
Mean Square	4021.23
F-Value	1.92
P-Value	.1795
G-G	.1805
H-F	.1795

Appendix 4.23.f Simple main effect of condition 3 and prime type for aware 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	15	596060.81	39737.39		
prime type	2	12950.32	6475.16	2.50	.0991
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	30	77708.22	2590.27		

Dependent: priming 2<2000

Appendix 4.23.g. Planned means comparisons of prime type for aware 2 in condition 3

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	378.68
Mean Square	378.68
F-Value	.15
P-Value	.7049
G-G	.5883
H-F	.6011

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	7633.85
Mean Square	7633.85
F-Value	2.95
P-Value	.0963
G-G	.1107
H-F	.1096

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	11412.96
Mean Square	11412.96
F-Value	4.41
P-Value	.0443
G-G	.0626
H-F	.0608

Appendix 4.23.b Simple main effect of condition 4 and prime type for aware 2

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
condition	0	•	•	•	•
Subject(Group)	10	242474.51	24247.45		
prime type	2	528.64	264.32	.09	.9163
prime type * condition	0	•	•	•	•
prime type * Subject(Group)	20	60199.94	3010.00		

Dependent: priming 2<2000

Appendix 4.23.c. Planned means comparisons of prime type for aware 2 in condition 4

Comparison 1
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
catagorical	-1.00

df	1
Sum of Squares	125.24
Mean Square	125.24
F-Value	.04
P-Value	.8404
G-G	.7966
H-F	.8366

Comparison 2
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
associated	1.00
unrelated	-1.00

df	1
Sum of Squares	528.51
Mean Square	528.51
F-Value	.18
P-Value	.6797
G-G	.6351
H-F	.6756

Comparison 3
Effect: prime type
Dependent: priming 2<2000

	Cell Weight
catagorical	1.00
unrelated	-1.00

df	1
Sum of Squares	139.21
Mean Square	139.21
F-Value	.05
P-Value	.8319
G-G	.7876
H-F	.8280

Appendix 4.24: Participants' responses to the post task interview questions.

Condition		Training tasks	Test Task 1	Test Task 2	Aware Task 1	Aware Task 2
ONE	N.D.	1.VOCAB : The types of pictures saw as either plants or shells. Milabon looked like a shell so I thought of Malibu beach. Senidar looked like a plant 2.P-P: Saying the names of the pictures as I saw them I ended up with pairs.	Words that were different rather than similar - the vowels in it - so Maragon and Golabus ended with an O sound so they couldn't go together. I am not sure that I used a rationale. A pair started and I carried on with it	I think I was doing this before - I used the same pairs for the pictures as I did last time. I found concentrating on the pictures confusing for the new words without pictures confusing. I think I muddled them so they weren't paired a: before. But it did help with th ones I'd seen before. I was able to remember the picture pairs and names	No	No
ONE	D.S.	1.VOCAB: Using the first couple o letters of the names I gave my own names to the four shapes - something they looked like: squiggle, plant, bird cabbage 2.P-P I learned the picture pairs sc Bird and Squiggle, Cabbage and Plant	W-W1: I used the beginning letters like before : so M&S went together in both sets	W-W2: Yes - the same rationale as last time Yes I could make the connection between the tasks.	No	Yes

ONE	D.B.	1.VOCAB: Lulafet - Loop, M-one Milabon, shaped like a mountain, M shaped. Sidar-curves. Rosilof - a chunk of meat - Turkish stew. 2.P-P: Don't think I've learned them. Had difficulty with this task I figured out the gist of it. The pictures based on the previous trials using my names attached tc make the difference.	W-W1: Initially S&F - political parties Sinn Fein, but then I realised that there were two Ss this was a complication, so then I did it alphabetically SR, but I don't know if this was any better.	W-W2: I tried the new way but it went to pieces, and I got confused so I went back to the alphabet. I couldn't really connect the picture pairs and the names	No	No
ONE	G.O.C.	1.VOCAB: I learned them eventually, the first one stuck immediately the others took ages I remembered a central portion of each picture for each name. 2.P-P: A process of elimination. I learned the first two that came up, then that left the other two.	W-W1: I paired them up by the pictures in the previous one. The other set I chose another new word and tried to stay witl it.	W-W2: The same as last time Yes - I was able to make the connection	Yes	Yes

ONE	ElW.W.	1.VOCAB: I think I learned them. The one in the shape of a rose - Rosilof, the tins of paint with a line - Lilac paint. The leaf one - a sweet pea? but I couldn't make the name correspond, Menth? one reminded me of coelacanth. 2.P-P: Eventually, the rose and the paint - like painting a picture, other two were more like parts of a flower - geranium and leaf	W-W1: Things that the words remind me so Milabon is like a melon, G- Galapagos island and reptiles, Rosa and filament. I'd seen the Rosa one before. Both sets treated the same way	W-W2:I don't know I tried to make the connection	No	No
ONE	El.Wa.	1.VOCAB: No, sorry, I looked for the formation of the letters in the pictures - I picked one letter from the word so L looked like a vertebrae - Lumbar vertebra, another one had an 'r' in its name and there was an 'r' in its shape 2.P-P: I related to how I looked at them last time - the two with bits hanging down	W-W1: I used the letters 'R' and 'S' so those ending 'or' and 'os", 2 began with R' and "S" so I paired them; mila and another one with an "I" and an "i" so I paired them and 2 just looked right. Noticed there were 2 sets and treated them in the same way	W-W2: I used both ways I managed to make the connection for some but I had trouble remembering what the pictures looked like.	No	No

ONE	R.P.	1.VOCAB: I used the first letter of each word instead of the name. I looked at the pictures and tried to see the initial letter in them 2.P-P: I looked for letters in the pictures and remembered those. The other set I paired the ones with "G" and "F" I didn't know why but I paired them as they were left over	W-W1: I connected them by the initial letters from the first trial time	W-W2: The same as the last	No	No
ONE	S.M.	1.VOCAB: yes - I think so, I looked at the shape and tried to see something in it - like the "S" one reminded me of a bird - a Seagull - S for name and for seagull, Milabon - sweet wrapper - bonbon, and the other two I just remembered. 2.P-P: I remembered how I'd named them previously: sweet and seagull, and tin can and rose.	W-W1: The ones I hadn't seen before M & G like the car and the other two followed. The other lot I used the link from the pairs before so I carried on with that.	W-W2: same as before	Yes	Yes

ONE	M.T.	1.VOCAB: I tried to see things in the pictures: The Milabon - lots of sweets. The Lulafet - a strange loofah, v The Senidar - like a sentry, the Rosilof- the other thing that didn't look like any thing. 2.P-P: I just learned one: fish and pile of sweets and if it wasn't tha the other two odd ones.	W-W1: Tried to use the relationship from the previous ones.	W-W2: same -m but I made a mistake - I should have selected Rosilof.	Yes	Yes
ONE	R.T.	1.VOCAB: I used the whole words - I just looked at them 2.P-P: The spiky one and the kicking one (Lulafet and Rosilof) went together so that left the other two that had to go together.	W-W1: I used the same pairs as the pictures for the new words I just guessed for the other set	W-W2: Yes	Yes	Yes

ONE	I.H.	1.VOCAB: pretty much learned the names. The symbol like the tail of a fish = Millpond - the first letters of the "Mil" word. The "Lula" something I pictured as a swirly sound and the picture looked swirly, one of the words ended in "lef" and the picture it linked t o looked like a leaf(lef). The last pair just clicked - the firs picture I saw stuck. 2.P-P: Just two links to learn so its a lot easier than the first	W-W1: I tried to select the words that appeared before, in the same way as I linked the pictures in the experiment before. The other set I just made links and stuck to them.	W-W2: Yes	Yes	Yes
ONE	P.K.	1.VOCAB: Pretty much learned them: One looked like a fish - A word that had bone on the end. A leaf was Senidar, a flat one with the end of the word "Lof" like loaf, candle one was Lulafet. I learned the ones with picture word connections first. 2.P-P: loaf and can fish and leaf	W-W1: Paired it to itself, chose the same word. noticed there were two sets of words and treated both sets the same way.	W-W2: The old ones I paired like you said and the new ones I just pressed anything. I was able to make the connection between the names of the pictures and then the pairs between the pictures.	No	Yes

ONE	K.G.	1.VOCAB: If I had them in front of me I could sort them out I don't know if I can remember them. I picked out things that I could associate. The one with a horseshoe reminded me of Rosalyn. The pair of wings was Send. The seashell was Mil and the other one was Lopf. I shortened the names to remember them. 2.P-P: Once I'd got a picture in my mind of the first two then it was elimination - the other two. The horseshoe and the "Lul" are the two that I remember, if it wasn't them then it had to be the other two...	W-W1: I matched them with the same word. I wanted to match it to something else like in the other two but then I thought why not match it with what it is. They weren't all the same words. I treated them all in the same way.	W-W2: I paired them in the same way in the end because I couldn't easily make a connection between the last tasks and this one. No	No	No
ONE	S.S.	1.VOCAB: Saw a backward S in the picture to link it to the name the S& M were the easiest to see. I saw an "R" but the other one was just left over - I managed to see an "L" in the end. 2.P-P: The "s" and the "M" pictures went together and so the other two went together.	W-W1: It was hard. I think it went alphabetically R,S; L&M G,F, Treated both sets the same way.	W-W2: I think I paired the same things with the same words. I got confused not doing things alphabetically. It's difficult when it doesn't tell you if you've done it right. I couldn't really make the association because there were twice as many words.	No	No

ONE	Ang J.	1.VOCAB: Quite difficult to begin with. I tried to learn them one at a time. I learned the whole one. The tubey one was Lulafet. 2.P-P: When it showed you one pair and then the other two had to go together. The second pair I was shown I learned better - the Rosilof and the tubey-one -Lulafet	W-W1: I don't know if I did it right. I just made pairs and I tried to stick with the pairs but sometimes I pressed the wrong button. I tried to put them the same as the pictures but I think I got it wrong. The ones I hadn't seem before chose the one on top of the one underneath and stuck to the pair.	W-W2: It was easier knowing the rule in advance - if I remembered them the right way round.	Yes	Yes
ONE	A.J	1.VOCAB: I didn't name the symbols but I looked for something in them. I looked for the first letter and tried to associate it with something in the picture - but it didn't always work so then I looked for something in the picture that I could associate with the picture. R had a horseshoe, another picture looked like an M with a bit missing. L Long ship, S picture - Sailboat. 2.P-P: Same symbols as before so the horseshoe with the long one so the mountain had to go with the snail.	W-W1: I looked for similarities in the beginning of the words and that didn't work, so I looked at the vowels and O in one and the O and the A so I matched those two. Another two had I in them. I noticed there were two sets of words ad I treated them in the same way.	W-W2: I recalled my original patterns M word with S word because of images of mountain and sail, and the long image with the horseshoe, and the other set I used the same vowel system as I'd used before.	No	No

ONE	H.M.	1.VOCAB: I think I learned the names. "Sil" - Sailboat; Lulafet the first one, "Ros" like a Rotisserie 2.P-P: Same as before. Instead - Instead of remembering the names from before I remembered the names that I'd given them - the things that they reminded me of. The rotisserie and the back bone together which left the other two behind.	W-W1: I played it like snap - I matched the word in the middl to the same one round the edge. I treated both sets in the same way.	W-W2: I managed to do it like you said. I wasn't sure about the ones with no pictures so I just matched them up like snap. I think I made the connection Lulafet was backbone, Rosilof rotisserie sc they went together which left the other two	no	yes
ONE	D.W.	1.VOCAB: Two shapes, one big one small, Senidar was a flower sc Rosilof was then on its own. Lalofout was the big one and Senidar and the other one small. paired the shapes and learned the names. 2.P-P: Easy the first 2 or 3 I got wrong - I paired two together before but hey were opposite so one of them had to go with a different one.	W-W1: The same words I pairec off as the pictures. The other set I tried to pair them F&G anc the other two left over.	W-W2: Easier due to knowing the pairs	yes	yes

ONE	C.P.	1.VOCAB: Yep I think so. Senidar was like a flag, Rosilof had a hook shape thing, Milabon was s the first one and it stuck Lulafet was a strange shaped thing 2.P-P: Hook and strange shape; Flag and the other shape. The hook and the strange shape were the most strange objects	W-W1: One set like the picture: Snider and Milabon together every time. The other set I chose one pair at the start and then I kept them together and so I put the other two together.	W-W2: The same as last time.	Yes	Yes
TWO	R.B.	1.VOCAB: When I saw the picture could recognise the word. I made my own names up using the first character. 2.W-W: I split the words to the first character - L,R ,M&S	P-P1: Chose the one that was the same. I noticed there were four new ones but I didn't notice they were blocked. Both sets were treated in the same way.	P-P2: I think I twigged the ones that I'd seen before-It was har then. I used the names that I' given them but nothing for the second set.	No	Yes - eventua
TWO	C.W.	1.VOCAB: I think I learned the names S was a heart one. One looked like a saddle and the word had an S in it. I tried to see something in the pictures. 2.W-W: No strategy to learn the word pairs.	P-P1: Two were associated wit the letter S I'd learned earlier so I matched those word pairs. Others I was just guessing. Noticed there were 2 sets of pictures and treated them differently.	P-P2: Same as before - it was a bit easier this time.	No	No

TWO	K.R.	1.VOCAB: I gave all the pictures names based on what they lookec like. e.g. Lulafet looks like an L for cup - the object looks like a cup. Word beginning with M, so M for flower; S for bird and the othe a trumpet. 2.W-W: The first two letters : S with M L with R	P-P1: Simplicity. 2 pairs were simple - they looked like one thing in the middle, two on the end. Another pair from the first experiment - the ones I found harder - I put them together. Noticed there were two sets and treated them both in the same way.	P-P2: I think so. I couldn't make the connection between this task and the others. I think it is because I only learned the first letters withou concentrating on the words.	No	No
TWO	P.R.	1.VOCAB: I gave the pictures descriptions : Lulafet - beer jug; M thing crumpled up piece of paper; Senidar one left out; R one with the hook 2.W-W: I said them out loud - repetition.	P-P1: The ones I'd seen before used the name pairing. Noticec that there were two sets and the 2nd set just chose a pair and kept with it.	same	yes	yes

TWO	Ju.Ri.	1.VOCAB: I think I learned them eventually. I know what goes witl what but I couldn't pronounce the names. Slunder or something looks like a slinky that goes down stairs. There was a big drum that matched with the letter L. Malibu I just always got right. 2.W-W: I just remembered that Slinky goes with Malibu	P-P1: The first lot I kept with the word pairs so Slinky went with Malibu. The second set I started all wrong but I changed it. Flags with block of wood with circle on top. Bag and black bag.	P-P2: Same - Slinky with Malibu.	Yes	Yes
TWO	D.J.	1.VOCAB: Yes I learned the names. One looked like the sail ot a boat - Senidar - put the S together. One had got the sound boon in it that was stripy, Rose word and duster and cotton reel was the other word. 2.W-W: The first two Rose and Lufa (like bath loofah) went together and that left the other two.	P-P1: Some I think were paired earlier and I tried to stick with this. I noticed there were two sets. The artists pallet and the stars and moon painting	P-P2: Same as last time. Once or twice I couldn't find the picture I was looking for. Hear type to phone	Yes	Yes
TWO	A.H.	1.VOCAB: I said the words out loud and studied the picture. 2.W-W: I used the initials R-L: M-S	P-P1: I've no idea. The first ones I did R-L and M-S from las time. Noticed that there were two sets - didn't treat them in the same way.	P-P2: Same. It was a bit easier.	Yes	Yes

TWO	V.D.	1.VOCAB: I used imagery to try and see something in it. Rosilof looked like a rabbit. two words really stuck in my mind. Milibar like a seal and Lolive like a bath thing. 2.W-W: I paired the names in my mind and used my memory. M & : first two words and the other two Lolive and the other one - I used whole the words.	P-P1: Two pictures that referred to words - Milabon anc the one I paired before. The new shapes I waited for cues and went on my instincts.	P-P2: Yes but I found it much harder - I think I made mistakes.	Yes	Yes
TWO	D.B.	1.VOCAB: Learned the initials not the names. I just used the first letters and saw the letter in the picture itself. 2.W-W: S&M L&R	P-P1: Matched like to like Didn't notice there were two sets.	P-P2: Noticed that there were two sets. The first set I used the name association. 2nd set was blatant guesswork.	No	Yes

TWO	St.R.	1.VOCAB: Sort of learned the names. M was squishy in the middle. The one with a beak ended in "dar". I was confused by the two "S" ones with beaks. The other one began with "L" I learned that first. 2.W-W: S went with M, L went with R I rehearsed the paired letters.	P-P1: A bit of guesswork and what they looked like. Ones with sticky out bits. I matched two from the first ones with names beginning with S. Noticed there were two sets and treated both the same way.	P-P2: I tried to pair S&M - the squishy but I'm not sure if the S one I paired it with was the right one. I wasn't sure which ones the R and L were. I think L was a trumpet and R had only a sticky out bit. I paired the second set the same as last time.	No	No
TWO	L.H.	1.VOCAB: Some of the names looked like Albanian words, I associated Albanian words with the shapes. "Lul a" is flower in Albanian and I tried to make the picture look like a flower. Mil looked like a mountain, I looked at the peak shapes in the picture. the other two I just tried to remember. 2.W-W: I just used the first letter M,S L,and R. The L,R I remembered Lula - flower and Ros - Rose	P-P1: I used the previous experiment with the letters M-S and L-R. The other set I used 2 big ones together and 2 long thin ones together.	P-P2: It was more difficult when I was trying to remember 2 things.	Yes	Yes

TWO	R.F.	1.VOCAB: I think so. I related them to real objects. Senidar the picture reminded me of a flower. Rosilof a harp. There was a fish one.	P-P1: Mainly on shape and size. 2 thin ones, 2 that reminded me of bugs, the two that confused me in the beginning I put together.	P-P2: I tried to do it as you said - I think I made the connection. The other set I stuck with how I'd done it last time.	No	Yes
		2.W-W: I took the first letter M&S and paired them L&R	Treated both sets in the same way.			
TWO	F.C.	1.VOCAB: One was like a cylinder with the shape of an L on it. One was like a little bean with a leaf that looked like an S. the other two seemed to come up more often and I just remembered what they were.	P-P1: I tried to pick the two that seemed to fit together - that looked similar. Treated both sets in the same way.	P-P2: It was harder I tried to use the names for half of them. I'm fairly sure I connected the names and the shapes	No	Yes
		2.W-W: This was easier. I watched and learned L& R went together and M&S went together. I remembered the initials.				

TWO	K.K.	1.VOCAB: I sort of learned them. Two kept repeating so that was easy - when the other two startec it got harder. Picture looked a bit like a bird and was called - I can't remember. But the first two Milabon - fish and something beginning with L. 2.W-W: S&M or M&S the initials just got to go together Micro Soft, Marks and Spencer, and the other two.	P-P1: Funny thing and a bird; wiggly thing and a fish and a bunch of molluscs with no rules between them - 3 seemed similar and one different. Treated both sets the same way - I used visual cues because they were pictures what else would you use - small?	P-P2: I couldn't necessarily remember the names of all of them so I am not sure that I paired them up correctly. I don't know if I remembered th names of the pictures right.	No	Yes
TWO	A.S.	1.VOCAB: It was a struggle. the Rosilof looked like a trombone that was the first one. Lulafet looked like a flute. M was scrumpled up paper, I got it wron a few times and the one that looked like a leaf I found hard to associate. 2.W-W: The first ones were M&S associated so then L and R had tc go together. MS stands for Multiple Sclerosis	P-P1: The pictures that I had seen before I paired as I had done the words associated wit them. The second set I just hit a button and paired them like that after and that I left the other two together.	P-P2: This time it was easier the pictures I'd seen first time recognised more easily - I coul do it just by shapes without having to think of the name association. I could easily make the connections.	Yes	Yes

TWO	E.J.	1.VOCAB: Fairly confident Rosilof and Milibar I can't remember the other two S- Something. I tried t[o] associate them with something in the picture. The one with an S reminded me of a sailing ship, Milibar looked like a mountain. th[e] other two just fell into shape. 2.W-W: I stuck on identifying the first letters. I identified L with R and M with S. I just paired Lulafel and Rosilof.	P-P1: I matched the one in the centre to the one it matched on the outside. Treated both sets the same way.	P-P2: For most of them I just matched the pictures, but in one instance there wasn't a match so I selected the closes shape to the other one. I didn't make a connection to the names I just identified the shapes.	No	No
TWO	T.R.	1.VOCAB: I just remember - when I understood the game I remembered which ones go with the name. I learned Rosilof and Senidar easily. I was confused by Milabon and Lulafet. 2.W-W: Repetition of the words Rosilof and Senidar, Lulafet and Milabon.	P-P1: Picture that looked like a Teapot and the one like a bone similar shape. One of the first pictures looks like a bird in a saucer. I used the pictures tha[t] looked similar. The others had no names. Treated both sets i[n] the same way.	P-P2: I remembered the links between the images but not the links between the names.	No	No

TWO	J.G.	1.VOCAB: I used the whole word and just tried to recognise the picture 2.W-W: Just leaned them - used the whole words.	P-P1: Looked for similarities between them, pairs that had similar strands or shapes or structures.. I noticed that there were ones I'd seen before and ones I hadn't. I think I used the same way of pairing them	P-P2: I think I made the connections. I only used the same way as last time for the ones that didn't have names.	No	Yes
TWO	SiRe.	1.VOCAB: I used the first letters. I learned that the pork chop was called Menitob. I recognised the curve for the R and the L shape had an L on it and the curve of the bird made an S 2.W-W: This was easy S-M Sado Masochism and LR London Railway.	P-P1: I looked to find some similarity with real word referents, like the bones in the ear, parts of a tin opener, some with peculiar eyes and some that physically fitted together. I couldn't make any sense of it at all.	P-P2: I think I got them into pairs so that there was a porkchop - M with bird S. I made my connection. for some but I haven't got a letter for every picture	No	No
THREE	S.G.	1.P-P: Gradually yes. the first picture with stripes on either side of the base goes with the swirl effect and the other two belong together. Eventually I could look at it and realise what it was going to be before pressing shift. 2.VOCAB: Sort of I managed most of them but Rosilof kept foxing me - it kept escaping me.	W-W1: Lulafet and Rosilof wen together and Senidar and Milabon: These were tied in with the pictures. Gisalab and Falofut but I couldn't say why. I just made a decision and stucl to it.	W-W2: Same rationale	Yes	Yes

THREE	Em.B.	1.P-P: I hope I've learned the pairs I gave them names according to their shape: shell, something disgusting, bendy and unpleasant and a boat. 2.VOCAB: I learned the names but I'm not sure I can remember the paired shapes. I tried to think of how they looked: like Milabon tried to make it sound like a shell.	W-W1: A few pairs I paired differently and then I paired them by their picture names Rosilof and Boat recognised from the beginning. For the other two Go went with Mo and F and G - if there was an F and G?	W-W2: same rationale as last time. I think I did worse. I couldn't really remember the names of two of the pictures, but I tried to stick to the pairing I did before in this test, Rosilof and Senidar - I remembered these two from the pictures, but I can't remember the other two.	Yes	Yes
THREE	J.K.	1.P-P: Just about learned them. I had to name them to learn them. Named by visual similarity to something: leafy and teapot, and dollar sign with fish-fin like thing. 2.VOCAB: I had to invent an association between the experimental name and shape and mine: So Rosilof - tea pot, Rosilof an exotic brand of tea, Senidar - Leaf; imagine a tree called Senidar (cedar. Lulafet if you knock out 2 lines it will make an F and it has an F in it. Milabon looked like a swee - bonbon	W-W1: Selected the same matched pairs as on previous tasks. The new words I paired S&M like in the last lot so the other two odd ones out went together.	W-W2: Yes - same.	Yes	Yes

THREE	J.MG.	1.P-P: I assigned a name to the shapes to learn them. A city with something else. 2.VOCAB: I related the names to the names that I'd given them.	W-W1: Kept to the picture name pairs. The new ones I paired the two that were most pleasing to me.	W-W2: yes - same	Yes	Yes
THREE	J.P.W.	1.P-P : Err yes, I found it difficult to learn just pictures. I gave then names - one looked a bit like a sailing ship and that went with the one like a shell; vertebras went with the splodgy 2.VOCAB: I took part of the word rather than the whole -sometimes the last three letters and sometimes the first three.	W-W1: The sound of the word whether they had been associated before? I can't really work out how I paired them, but definitely based on how they sounded.	W-W2: I changed a bit but not much. I couldn't make the connection very well.	No	No
THREE	C.W.	1.P-P: Yes I learned the pairs. I tried to match the shapes - the curves. 2.VOCAB: I learned the first initials and used repetition - sometimes out loud.	W-W1: The one with pictures I matched to according to the pictures, another the second letters were O.	W-W2: Same - I could remember the connection	Yes y a	Yes y a

THREE	J.S.	1.P-P: I think so the one with the hook went with the cotton reel. I made them into familiar objects. The pile of leaves and the rubber duck. 2.VOCAB: I abbreviated the name: to the first letter. I had an imaginary arrow, RSML. Hook went with R, leafs with M, S with duck, that left the last ones L wit cotton reel.	W-W1: M&S paired together because of Marks and Spencer. M and R paired together on a calculator - memory recall. F and M the radio frequency so L and R just had to go together. I didn't realise there were two sets because I was only looking at the first letters - I only realised when my theory didn't work!	W-W2: It seemed harder. I made the same pairs but it seemed more difficult thinking about the pictures. I think I could remember the links.	no	yes
THREE	D.F.G.	1.P-P: I looked for the one that was the same and then the location of its pairmate. 2.VOCAB: It was hard but I think I got them. I tried to match the first letter with the shape but I trouble with the Lulafet that looked like a kettle. The Rosilof and the other two were easier. I learned the Senidar and the M one shapes were shells.	W-W1: Ones that were on before I tried to match the words with the shape words th S&M and The L&R. The others had no idea how to match them.	W-W2: I did the same for one set but the other set I couldn' remember how I had paired them.	yes	yes

THREE	E.W.	1.P-P: I thought one looked like a fish and one a leaf so biological pairs the other two looked like an organ and a saddle and I put them together. 2.VOCAB: Rosilof was the saddle and Milabon the fish, Senidar was a leaf and Lulafet the organ	W-W1: That was just mad. Rosilof and Lulafet went together like the two pictures, Senidar and the other fish like the pictures. I looked for similarity in sound in the other sets Golabus and Sumapor and Falofut and?	W-W2: Same - it was easier this time - but the new block was still difficult.	yes	yes
THREE	S.P.	1.P-P: One looked like a little horse and that went with the swirly pasta shape. One looked like a seashell that looked like a "P" or an upside down musical note. 2.VOCAB: The Senidar sounded like semaphore - p shaped one like a fly. Rosilof could be a horse that I knew and Milabon the name of a shell. Lulafet the tube of pasta.	W-W1: One began with G and another r had a G in the middle of it. The Lulafet and the Rosilof came after each other a lot in the previous test another two the R and the S went alphabetically. It was harder matching up the new words.	W-W2: much easier - I could make the connection - horse Rosilof went with pasta swirl Lulafet, P-flag Senidar went with shell - flags at the seaside, I think it came out the same but for a different reason.	No	Yes

THREE	G.E.S.	1.P-P: I named them all Penguin and chips and the paint and the squiggle 2.VOCAB: Lulafet had an L shape in it. Rosilof was the paint, S was the penguin and Malanon + meal + chips.	W-W1: I paired the name with the name Rosilof with Rosilof etc. I noticed some were words from past trials. I treated them all the same.	W-W2: The same as last time. I couldn't make the connection	No	No
THREE	Y.T.	1.P-P: I just learned the correspondence 2.VOCAB I didn't use a strategy - found it easier than matching the pictures. I learned the whole words.	W-W1: I used the words representing the pictures that I had already matched. The other set I just guessed.	W-W2: Same as the first.	Yes	Yes
THREE	A.P.	1.P-P: I learned them by associating them with things that recognised. That one that looks like a fish and another a bean sprout and they went together, and an oxtail and a lump and they went together. 2.VOCAB: I used the first couple of sounds and made nick names for the pictures: Sena - seed; Mila fish. I've forgotten the others.	W-W1: I remembered some form the previous experiments. I could see the images coming back. M& S, it was harder to remember the R&L pair. The other set I put M&G together like the car and that left, F&S.	W-W2: Same - it was easier this time after the first couple of goes.	yes	yes

THREE	A.H.	1.P-P: The one that looked like a shell went with the boat, and the bag and the wiggly thing went together. 2.VOCAB: I learned that Boat - sai begins with S so name beginning with S; Lulafet name just fitted the wiggly thing. Rosilof-bag and Milabon shell - the names just fitted.	W-W1: I tried to remember tha Senidar went with Milabon, and Lulafet went with Rosilof- how I'd matched the pictures up. The others were G & F and the other two alphabetically.	W-W2: Easier second time - I was recognising the words better. I might have made a mistake the first time.	yes	yes
THREE	D.C.	1.P-P: I think so I just paired them up. I just memorised the pictures and paired them up. 2.VOCAB: They didn't mean anything but I could associate them with the pictures. I studied the pictures and tried to get a bit of the word out that fitted the picture Lulafet - flute thing was easiest. Rosilof - bag thing with a flower coming from the side.	W-W1: The previous ones - witl the words from the previous exercise I put together so it made sense. The other set I just paired up with the same name.	W-W2: Same - but I made mistakes with the new ones. I could make the link with the previous ones.	yes	Yes

THREE	G.S.	1.P-P: Really difficult to begin witt so I gave them other associations Head-Handle: shell and instrument (a drum). 2.VOCAB Yep I sorted that one. Association within words Milabon, BON looked familiar and it went with shell so I said "Shell-bon". Then Lula went with Instrument Lula(la) singing. Head-Sen /Send-Head. handle-Rose or Rose-Handl(was the only one I could turn round and remember each way.	W-W1: Ros-Bon - a French connection Lala-Send sounds nice like telly tubbies. The other set Falofut came firs I matched it to itself. GolaBUS and Marabos I associated with Falo the wild card - it went witl BUS or BOS	W-W2: The same as last time till the very end Head-Send came back to me- I remembered the name link but I couldn't image pictures from the words. the word associations came readily because the words were there.	no	no
THREE	H.W.	1.P-P: I leamed seed and bag and the other two. 2.VOCAB: I used the first letters I was using it a bit like a language. I was trying to see something in the symbols that made sense. Seed began with S - Senidar and the bag was M I just used the firs letters.	W-W1: I paired like with like. It was the natural thing - much quicker. I noticed that filafup or something hadn't come up before.	W-W2: I remembered the seed and the bag so S&M and that ruled the others out. Lulafet and Roslof together. I just used S&M for the other set.	no	yes

THREE	P.S.	1.P-P: The thing that looked like a tin opener went with the upside down bird. The stork with a baby went with the tortoise 2.VOCAB: No strategy - I just remembered the words and the pictures.	W-W1: Galapus (or something) and a Falo something, Maragon and something with an S in it so M& S, so that made Rosilof and Lulafet and Senidar and Milabor (M and S).	W-W2: I think I messed it up and went back to my way. of thinking. I remember two but the Senidar and the Rosilof I couldn't remember which way round they went.	yes	yes
THREE	LG	1.P-P: I tried to work out a patten for where they would appear - 3 times opposite and 3 times side by side. 2.VOCAB: I just used association - I just looked at the picture and looked at the name.	W-W1: I pressed the word that previously came up so it cleared the screen and I could move on.	W-W2: I don't know - I don't think that this task allowed me to show what I had learned before I could make the links in my head but this task doesn't allow me to express it.	no	no
FOUR	D.K.R.	1.W-W: I don't know if I have learned the word pairs - I think so but I used the initial letters M&S and the other two. 2.VOCAB: Harder I learned it eventually. Milabon a type of cabbage, Senidar a seedpod, Lafayet a tin of eels, Rafael - the other one. The last two sounded french.	P-P1: The cabbage next to the seed and Lafayet with Rosilof. The other set the brain went with the telephone and then the other two	P-P2: I think it was the same but this time I made the connection	no	yes

FOUR	J.D.	1.W-W: It took me a while to realise that the pairs were consistent. I started by linking the first letters. Then I looked at the whole words. 2.VOCAB: I watched first and studied them. I saw picture similarities e.g. punk, boat, fish and something else. Rosalof-Rosalind-Punk Person; Senidar the name of a boat Milabon a fish name.	P-P1: It was hard I tried to stick with the same pair sequence - I tried to be consistent. I noticed that there were two sets of pictures but I didn't really think of the words that I had already seen, so I did it the same.	P-P2: I couldn't do it using the word pairing - it confused me - I tried and thought "sod this I'l do it how I did it before"	no	no
FOUR	B.P.	1.W-W: Lulafet and the other one sounded Russian and then the other two - I said them in silly voices. 2.VOCAB: I learned this quite quickly. Rosilof sounded Russian and had a sickle in the middle of it. I named the other pictures bird and Senidar could be a bird name, fish and chips was linked to Milabon and hot dog to the Lulafet.	P-P1: The ones I'd already seen were much harder. I tried to put the Russian things together - the sickle and the hot dog then the other two things. the other set I put fat things together and long things together	P-P2: same - yes I could link the name pairs.	yes	yes

FOUR	A.P.	1.W-W: I just tried to remember the first letters and I used repetition 2.VOCAB: I think I learned these by repetition and elimination. I learned two and then there were the other two. Milabon - fish and chips s was something else.	P-P1: I paired them to themselves or something that looked similar. Treated both sets the same way.	P-P2: Harder and slower - I think I could make the lien links.	no	yes
FOUR	J.H.	1.W-W: Vaguely yes - I used the first letters not the names. 2.VOCAB: I stayed with the first letters. I tried to see something familiar in the pictures like a fish and M goes with fish. Pod - Sena pod - S. The paint pot went with L and the remainder was indescribable so R.	P-P1: Indescribable had a hook so I paired fish and hook paint pot and pod - green pod green paint. In the second set the ship and the shell, but I changed my mind to chip and ship - this was less clear.	P-P2: The same - I couldn't make a connection between this and the previous tasks.	no	no
FOUR	A.T.	1.W-W: I learned the initial letters. L&R (left and right) and S&M (sadomasochistic) 2.VOCAB: Harder - but I think so. Miladoff kind of M shaped, Lulafet kind of L shaped, Romanof had a l shape Russia , and Senidar a senator drawing.	P-P1: The ones I knew the names for I paired by name. The other set: two rounded ones together and two straight ones together.	P-P2: same	yes	yes

FOUR	N.T.	1.W-W: Every time L came up R was the RIGHT one so the M and the S must go together. I just looked at the initials - I didn't really look at the rest. 2.VOCAB: I learned this by associations: Milabon - Bilabon - surfbrand -shell; Rosilof - hook - question mark -wRong; Senidar like a bird an fs shaped bird ; Lulafet - just the last one, squiggle shaped.	P-P1: First matched the previous ones that had been or the screen together and ones that were the same shape. I noticed that there were 2 sets of pictures and I think I treated them both in the same way.	P-P2: I used the word connection for the old ones and the others I did the same as last time. I remembered th R with the hook; R went with I which was the squiggle one.	no	yes
FOUR	La.P.	1.W-W: I just remember R&L and M&S 2.VOCAB: The one beginning with M was pointy like an M. The one beginning with S was swirly; the one beginning with L I could see an L in the picture; and the one beginning with R was the first one and I learned that.	P-P1: At first I was just guessing then I decided that one looked like an elephant anc another like another animal so I paired them. Then the one with stars on had a cross over on it so I matched that with th one that crossed over. Another two had R shapes in them. Treated both sets the same way - looking for things that were similar.	P-P2: I got all confused - I paired them up as before, I could do it - the elephant and the other animal that I didn't have a name for	no	no

FOUR	El.B.	1.W-W: I didn't use a strategy, just inter repetition and rehearsal - of the whole word and sometimes just the first letter 2.VOCAB: Not really - I just tried to memorise them.	P-P1: Two I paired up from the previous according to the names they were before - but the names I liked best. The others I paired on looking mos similar.	P-P2: Yes I could do it but it was more difficult than the way I did it before. It got easier as I went on	no	yes
FOUR	F.C.	1.W-W: I learned them - no strategy 2.VOCAB: No strategy I just looked and learned. S-Senidar-S for signal-looked like a flag; Lulafet was like a knife through butter; Rosilof-riding-a saddle - but you had to look for it; Milabon-M for mess.	P-P1: I used the old pair associations and kept them the same. The other set I made up a new set of associations and kept them the same.	P-P2: Same rationale	yes	yes
FOUR	M.MC.	1.W-W: Initials only-L&R, M&S 2.VOCAB: I tried to identify the first letters of each word with the picture - I tried to see the shape of the letter in the pictures.	P-P1: The ones I'd seen before the M & S words I put those pictures together. The other set I matched to self.	P-P2: same	yes	yes

FOUR	K.B.	1.W-W: Horrible to start with. I put the two first letters together 2.VOCAB: I don't know if I learned them. I was trying to associate something about the word to something in the picture two of them were easier -the picture of the horseshoe - I imagined someone called Ros on ε horse. The pile of ice-cream was Milo ice-cream. The Lilo thing I just connected with the picture.	P-P1: I didn't know what I was doing - I pressed anything. I didn't realise there were two sets of pictures.	P-P2: I did something - I was consistantish - it was a visual thing. I couldn't make a connection with the word pairs	no	no
FOUR	C.B.	1.W-W: I didn't learn the words just the first letters. I find new words confusing when I don't know how to say them so R&L an S&M. 2.VOCAB: Nearly learned them. I tried to deal with the whole words. I tried to see what the pictures looked like and link it to the words. Sender looked like a boat so "send it by boat" . The M word looked like a mountain. The L one like a musical instrument flute thing ; and one left over.	P-P1: The pictures that I'd seer before I remembered the pairings from first time around. The other ones I put together by how they looked: open ones and ones with lines closer together - then I changed my mind and put the more detailec ones together.	P-P2: The first few were harde because I had to remember, but then it was O.K.	yes	yes

FOUR	M.R.H.	1.W-W: I used the first three letters so Ros went with Lul and Mil with Sen. 2.VOCAB: I think I learned half of them. I just tried to remember them. Lulafet and Senidar looked a bit like L and R (from the end of Senidar)	P-P1: I remembered Lulafet anc Senidar so I kept them togethe so Rosilof and the other one I just paired. The other set I jus chose one in round 1 and kept it together with a thin one and then kept the other two.	P-P2: same pairs as last time. tried to remember the word pairs but I don't know if I pressed the keys right.	no	no
FOUR	LIPr	1.W-W: R opposite the word beginning with L (Right and Left) so obviously the other two made the other pair. 2.VOCAB: I didn't know what on earth the pictures wee supposed to be. I had to try and imagine the nearest image to the pictures and interact with the word. Bird-slender-Senidar. Milabon - chairs(picture)-millions of chairs. The one starting with R - two parts of petals-Rose petals. Lulafet - the first one.	P-P1: I matched them to the one that was the same ones. I noticed that some of the pictures were form before. Treated both sets the same way.	P-P2: I just paired the additional pictures. the origina pictures I think I managed to link - I could remember the firs few letters of the picture names and I could remember Right and Left and S&M.	no	yes

FOUR	D.K.	1.W-W: I couldn't repeat them, but I know the beginning letters. I'd recognise the words if I saw them, but I couldn't spell them to you now. Ros -L 2.VOCAB: I tried to see the first letter of the word in the picture. Cotton reel - L one. The shape that had an R in it was easy R. The curvy one was the S shape and the M one had straight lines ir the picture.	P-P1: The ones that I'd recognised from before I knew the word association from that one. The other set at first I picked the same one and then just chose the one opposite it. I couldn't find a reason for these ones.	P-P2 :Anticipating what I was going to see made it seem slower because I still had to look at the pictures. I probabl; didn't make any errors either.	yes	yes
FOUR	M.W.	1.W-W: I took the first phoneme of each word and joined them: Lulros and Senmil. 2.VOCAB: Well yeah I learned them: they reminded me of things or concepts - or I linked concepts to the pictures with concepts of the words, having chosen one I stuck with it. I chos(a feature from the picture: Milibar sounds like banana and there is a banana shape at the bottom of the picture. Rosilof had a banana shape shaded at the bottom. Sinibon? - ice-cream wafer like a sweet so food . The thing like a £ sign Lilifet the one.	P-P1: They were the same so I looked at part of the picture, a flag and some waves -seaside so I put them together, food with food, then I just started t(go for the same pictures without any rationale at all. I didn't notice that there were two sets.	P-P2: I couldn't remember the word link so I did it the same as last time. I tried not to think to see if they would come out right.	no	no

FOUR	J.O.	1.W-W: I remembered which ones have got an "F" in them two have and 2 haven't. 2.VOCAB: The Lulafet had two bits sticking out on the right like LL. The sendicot had a flag waving -sending messages. Milacot looked like Millefleure - like a fan flower. Rosilof one left had a horseshoe in the middle so I was thinking of weddings and roses and things.	P-P1: Two which were similarly long (one with flags) Two were rounded - a Cornish pasty and a telephone from the original horseshoe and flag sending things over so two together. Flowery one and fan are soft sc Lullaby and flowers. I treated both sets visually	P-P2: I think I remembered what the words were that I pu together at the beginning - I was saying them. Senidon and the Milabon, and the Rosilof, and the other one - Lulafet. I got it eventually. The other ones I just did what I did before.	no	yes
FOUR	J.S.	1.W-W: I used the initials - you know Marks and Spencer, Left and Right- M&S, L&R 2.VOCAB: Yes I got there in the end. I tried to see thing s in them e.g., I could see a cotton reel - that was Lulu, the one with the hook was Rosilof - the last one. One began with S -a sailboard type thing, and one was a heap of trash.	P-P1: The ones that I had learned from the previous experience The cotton reel and the sailboard were the first I learned so I put them together. The new pictures, a Roman ha and a breast plate and the other two were quite small with blobs on holes or stars.	P-P2: much the same as last time. but I don't thing the names corresponded - I was going more on the pictures than the words. Yes I could think back to the names but I had two lots of two to put together.	no.	no

FOUR	P.G.	1.W-W: There were only four words so I remembered which ones belonged with which. I used the whole word and the sound of the words 2.VOCAB: Yeah I learned the names by a strategy - a combination of concentrating on the prose stimuli I tried to remember the picture I was going to choose. I used elimination. I knew what something had to be - m I knew what it wasn't going to be. Rosilof had a small circular thing I used the O from Rosilof. Lulafet was vaguely L shaped - I started with this ad then it became irrelevant and I just knew it.	P-P1: Matched like to like except when there was no alternative and then I just guessed. I noticed that I recognised some of them but I picked a match for all of them.	P-P2: I couldn't really remember an association - it was pretty murky. I could remember the words they were associated with but I couldn't remember the link between the words.	no	no

Appendix 5

Appendix 5.1 Word lists for LDT

Practice List

prime	target	relationship
cow	HORSE	practice
rug	LAMP	practice
eye	COACH	practice
ladle	MALLET	practice
school	GRUTLOE	practice
jam	YUPSTIR	practice
chimney	MULT	practice
iron	WERSIT	practice
belt	FUTLAR	practice
farmer	ANTELOPE	practice

List1a

prime	target	relationship			
wagon	TRAIN	catass	bicycle	DOSUCT	nonword
athlete	FOOT	asscol	sandal	COUDGE	nonword
hand	MOUTH	catcol	money	BALENK	nonword
unicorn	LION	ass	tiger	BOLUST	nonword
zest	ORANGE	col	juice	CHALP	nonword
table	CHAIR	catasscol	bed	DITEG	nonword
doorway	DOOR	catass	popgroup	FROSH	nonword
corduroy	TROUSERS	asscol	wig	GITUNG	nonword
coat	GUITAR	unrelated	surgeon	JICK	nonword
lungs	HAT	unrelated	ward	LASSEL	nonword
vest	DOCTOR	unrelated	buttons	MORULL	nonword
window	NURSE	unrelated	drawer	NINK	nonword
tambourine	SHIRT	unrelated	braces	PUNG	nonword
bus	HEART	unrelated	pulse	THRAIGH	nonword
drum	TABLE	unrelated	stool	TRELK	nonword

List1b

prime	target	relationship			
STRINGS	guitar	asscol	ARM	tidge	nonword
JACKET	hat	cat	LEOPARD	vadge	nonword
STETHOSCOPE	doctor	ass	BANANA	whaig	nonword
UNIFORM	nurse	col	NAPKIN	wilp	nonword
TIE	shirt	catasscol	SWIVEL	butire	nonword
INTESTINE	heart	cat	SHORTS	paradosy	nonword
REFECTORY	table	ass	TEACHER	synerfalia	nonword
KNEE	train	unrelated	BANDAGE	gabash	nonword
CAT	foot	unrelated	POLICEMAN	hasact	nonword
ELEPHANT	mouth	unrelated	CHEST	steg	nonword
BENCH	lion	unrelated	TRANSPLANT	leasaile	nonword
COUCH	orange	unrelated	AIRPLANE	javarich	nonword
ZEBRA	chair	unrelated	SOCKS	keagh	nonword
KISS	door	unrelated	LEG	mought	nonword
FOOT	trousers	unrelated	VIOLIN	sleach	nonword

List2a

prime	*target*	*relationship*			
bicycle	TRAIN	cat	locomotive	WHOULT	nonword
sandal	FOOT	ass	soldiers	VEACH	nonword
money	MOUTH	col	foot	TRUNG	nonword
tiger	LION	catass	den	TREADGE	nonword
juice	ORANGE	asscol	pear	THRISS	nonword
bed	CHAIR	catcol	chest	STROUCH	nonword
drawer	DOOR	cat	steel	POUST	nonword
braces	TROUSERS	ass	cap	NIRE	nonword
straw	GUITAR	unrelated	hospital	MORIRE	nonword
bandage	HAT	unrelated	manager	MEAGH	nonword
tie	DOCTOR	unrelated	cotton	LASECK	nonword
glass	NURSE	unrelated	mat	KEAST	nonword
back	SHIRT	unrelated	leg	JAING	nonword
corduroy	HEART	unrelated	breast	FRENG	nonword
violin	TABLE	unrelated	napkin	FAROLK	nonword

List2b

prime	*target*	*relationship*			
POPGROUP	guitar	col	KNEE	bilect	nonword
COAT	hat	catasscol	ZEBRA	chedge	nonword
SURGEON	doctor	catass	MARMALADE	farink	nonword
WARD	nurse	asscol	DENTIST	frolp	nonword
JACKET	shirt	asscol	BENCH	gatilk	nonword
LUNGS	heart	catasscol	WINDOW	julp	nonword
STOOL	table	catass	WIG	kaist	nonword
ARM	train	unrelated	DALEK	lasack	nonword
SHOW	foot	unrelated	KNOCKER	leocta	nonword
LEOPARD	mouth	unrelated	PULSE	morile	nonword
COUCH	lion	unrelated	LIPSTICK	nact	nonword
REFECTORY	orange	unrelated	SHOES	noule	nonword
LEMON	chair	unrelated	BUS	paish	nonword
INTESTINE	door	unrelated	STRINGS	shodge	nonword
AIRPLANE	trousers	unrelated	BUTTONS	thraich	nonword

List3a

prime	*target*	*relationship*			
drum	GUITAR	catasscol	knee	BILECT	nonword
straw	HAT	asscol	elephant	CHEDGE	nonword
teacher	DOCTOR	catcol	lemon	FARINK	nonword
policeman	NURSE	cat	swivel	FROLP	nonword
buttons	SHIRT	ass	coat	JULP	nonword
transplant	HEART	asscol	dress	KAIST	nonword
bed	TABLE	catcol	vest	KOUSS	nonword
kiss	TRAIN	unrelated	window	LASACK	nonword
vest	FOOT	unrelated	ward	LEOCTA	nonword
unicorn	MOUTH	unrelated	lungs	MISH	nonword
chest	LION	unrelated	bus	NACT	nonword
map	ORANGE	unrelated	cymbals	NOULE	nonword
braces	CHAIR	unrelated	couch	PAISH	nonword
gold	DOOR	unrelated	king	SHODGE	nonword
stomach	TROUSERS	unrelated	sandal	THRAICH	nonword

List3b

prime	*target*	*relationship*			
SPOTTERS	train	col	WAGON	tielk	nonword
HAND	foot	catasscol	ATHLETE	rasect	nonword
CHEEK	mouth	catass	MONEY	onith	nonword
LEOPARD	lion	catcol	DEN	veach	nonword
BANANA	orange	cat	PEAR	wult	nonword
FIRESIDE	chair	ass	BENCH	zastra	nonword
BRICK	door	col	STRINGS	bolist	nonword
SHIRT	trousers	catasscol	STETHOSCOPI	furosh	nonword
STOVEPIPE	guitar	unrelated	UNIFORM	hasulp	nonword
MANAGER	hat	unrelated	LEG	jatock	nonword
TIE	doctor	unrelated	MAT	naller	nonword
DOORWAY	nurse	unrelated	NAPKIN	keast	nonword
GLASS	shirt	unrelated	SAXAPHONE	meagh	nonword
LOCOMOTIVE	heart	unrelated	INTESTINE	shodal	nonword
STEEL	table	unrelated	REFECTORY	tilkory	nonword

List4a

prime	target	relationship			
locomotive	TRAIN	ass	kiss	TIDGE	nonword
soldiers	FOOT	col	unicorn	VADGE	nonword
foot	MOUTH	catasscol	zest	WHAIG	nonword
den	LION	asscol	couch	WILP	nonword
pear	ORANGE	catcol	map	BUTIRE	nonword
chest	CHAIR	cat	window	BOLUG	nonword
mat	DOOR	ass	stovepipe	PARADOS	nonword
breast	HEART	catass	stethoscope	GABASH	nonword
wig	GUITAR	unrelated	tie	HASACT	nonword
dalek	HAT	unrelated	doorway	ELFAROS:	nonword
cotton	DOCTOR	unrelated	gold	LEASAILE	nonword
knocker	NURSE	unrelated	stomach	JAVARICI	nonword
arm	SHIRT	unrelated	corduroy	KEAGH	nonword
pulse	DOOR	unrelated	station	MOUGHT	nonword
lipstick	TROUSERS	unrelated	cymbals	SLEACH	nonword

List4b

prime	target	relationship			
STEEL	guitar	col	SPOTTERS	rasageon	nonword
CAP	hat	catass	HAND	tralpal	nonword
HOSPITAL	doctor	asscol	CHEEK	vankal	nonword
MANAGER	nurse	catcol	LEOPARD	yheng	nonword
COAT	shirt	cat	BANANA	aghatire	nonword
NAPKIN	table	asscol	FIRESIDE	brolist	nonword
LEG	trousers	col	DRUM	emalire	nonword
SANDAL	train	unrelated	STRAW	gatash	nonword
HAIR	foot	unrelated	TEACHER	horona	nonword
ZEBRA	mouth	unrelated	POLICEMAN	idosine	nonword
DENTIST	lion	unrelated	BUTTONS	kaross	nonword
BED	orange	unrelated	BRICK	kealine	nonword
SICKLE	chair	unrelated	SHIRT	morastine	nonword
BICYCLE	heart	unrelated	TRANSPLANT	pasatory	nonword
POPGROUP	table	unrelated	REFECTORY	thriss	nonword

List5a

prime	*target*	*relationship*			
airplane	TRAIN	catcol	leopard	TRALPAL	nonword
arm	FOOT	cat	banana	VANKAL	nonword
lipstick	MOUTH	ass	couch	WULT	nonword
elephant	LION	catasscol	teacher	BROLIST	nonword
grapefruit	ORANGE	catass	uniform	DASUG	nonword
dentist	CHAIR	asscol	hair	EMALIRE	nonword
chair	TABLE	catasscol	brick	FAROCH	nonword
ward	NURSE	asscol	intestine	HORONA	nonword
dress	GUITAR	unrelated	wagon	IDOSINE	nonword
bandage	HAT	unrelated	shoes	KAROSS	nonword
jacket	DOCTOR	unrelated	corduroy	KEALINE	nonword
drawer	NURSE	unrelated	steel	MORASTI	nonword
locomotive	SHIRT	unrelated	bus	NATEDGE	nonword
station	HEART	unrelated	zebra	PASATOR	nonword
hand	TROUSERS	unrelated	marmalade	THRISS	nonword

List5b

prime	*target*	*relationship*			
VIOLIN	guitar	cat	BICYCLE	tielk	nonword
STOVEPIPE	hat	col	SANDAL	rasect	nonword
NURSE	doctor	catasscol	MONEY	onith	nonword
GLASS	door	catcol	TIGER	veach	nonword
COTTON	shirt	asscol	JUICE	wult	nonword
GOLD	heart	col	POPGROUP	bolist	nonword
SOCKS	trousers	cat	BENCH	darlest	nonword
SOLDIERS	train	unrelated	COAT	edesarf	nonword
NAPKIN	foot	unrelated	SURGEON	furosh	nonword
DEN	mouth	unrelated	WARD	hasulp	nonword
BED	lion	unrelated	KNOCKER	jatock	nonword
NAPKIN	orange	unrelated	BRACES	naller	nonword
STOMACH	chair	unrelated	LUNGS	meagh	nonword
TAMBOURINE	table	unrelated	STOOL	shodal	nonword
BLOOD	door	unrelated	BACK	tilkory	nonword

List6a

prime	*target*	*relationship*			
station	TRAIN	asscol	soldiers	TIDGE	nonword
back	FOOT	catcol	pear	VADGE	nonword
stomach	MOUTH	cat	bed	WHAIG	nonword
king	LION	col	napkin	WILP	nonword
lemon	ORANGE	catasscol	fireside	BUTIRE	nonword
bench	CHAIR	catass	dress	ARLOGIA	nonword
pulse	HEART	ass	banker	PARADOS	nonword
map	TABLE	col	blood	GABASH	nonword
straw	GUITAR	unrelated	cheek	HASACT	nonword
hospital	HAT	unrelated	shorts	ELFAROS	nonword
hair	DOCTOR	unrelated	bus	STEG	nonword
mat	NURSE	unrelated	lungs	MEAGH	nonword
banana	SHIRT	unrelated	stool	SHODAL	nonword
transplant	DOOR	unrelated	marmalade	THRISS	nonword
kiss	TROUSERS	unrelated	hand	MORILE	nonword

List6b

prime	*target*	*relationship*			
TAMBOURINE	guitar	catcol	AIRPLANE	bilect	nonword
WIG	hat	ass	ATHLETE	dosolk	nonword
DALEK	doctor	col	LIPSTICK	chedge	nonword
DOCTOR	nurse	catasscol	ELEPHANT	frolp	nonword
VEST	shirt	catass	GRAPEFRUIT	gatilk	nonword
KNOCKER	door	asscol	DENTIST	goick	nonword
SHOES	trousers	catcol	VIOLIN	kaist	nonword
HAND	train	unrelated	STOVEPIPE	lasack	nonword
TIGER	mouth	unrelated	COAT	leocta	nonword
STOOL	orange	unrelated	WARD	mish	nonword
ARM	chair	unrelated	COTTON	morile	nonword
SPOTTER	heart	unrelated	LEG	nact	nonword
CYMBALS	table	unrelated	SOCKS	noule	nonword
BUTTONS	foot	unrelated	GOLD	shodge	nonword
CAP	lion	unrelated	CORDUROY	thraich	nonword

List7a

prime	*target*	*relationship*			
bus	TRAIN	catasscol	sandal	DOSUCT	nonword
knee	FOOT	catass	tiger	BALENK	nonword
kiss	MOUTH	asscol	juice	ALAGIVE	nonword
zebra	LION	cat	stool	CHALP	nonword
marmalade	ORANGE	ass	straw	FROSH	nonword
swivel	CHAIR	col	stethoscope	GADASH	nonword
blood	HEART	catcol	hospital	GITUNG	nonword
couch	TABLE	cat	tie	JICK	nonword
cap	GUITAR	unrelated	mat	LASELL	nonword
surgeon	HAT	unrelated	transplant	NINK	nonword
buttons	DOCTOR	unrelated	lungs	PUNG	nonword
brick	NURSE	unrelated	braces	STRILK	nonword
ears	SHIRT	unrelated	spotter	THRAIGH	nonword
breast	DOOR	unrelated	violin	TRELK	nonword
cheek	TROUSERS	unrelated	blood	GABASH	nonword

List7b

prime	*target*	*relationship*			
CYMBALS	guitar	catass	STATION	whoult	nonword
DRESS	hat	catcol	BACK	veach	nonword
BANKER	doctor	cat	STOMACH	trung	nonword
BANDAGE	nurse	ass	LEOPARD	treadge	nonword
HAIR	shirt	col	TAMBOURINE	poust	nonword
WINDOW	door	catasscol	WIG	nire	nonword
SHORTS	trousers	catass	WARD	morire	nonword
ATHLETE	train	unrelated	DOCTOR	meagh	nonword
COTTON	foot	unrelated	VEST	laseck	nonword
KING	mouth	unrelated	KNOCKER	keast	nonword
BED	lion	unrelated	SHOES	jaing	nonword
DRUM	orange	unrelated	PULSE	freng	nonword
BANDAGE	chair	unrelated	MAP	farolk	nonword
WAGON	heart	unrelated	GLASS	peadge	nonword
STRINGS	table	unrelated	SICKLE	shult	nonword

Appendix 5.2

Analysis of effect of Normative Relationship and Prime-Target Relations on RT

Appendix 5.2a A mixed 2 x 7 ANOVA was performed: repeated measure was Prime-Target Relations (related and unrelated) and between subjects was Normative Relationship, this had seven conditions (associative, collocational, categorical, associative + collocational, categorical + associative, categorical + collocational, and categorical + associative + collocational).; The DV was RT in ms..

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
relationship	6	253996.40	42332.73	.98	.4368
Subject(Group)	1151	49679196.22	43161.77		
priming	1	2615630.93	2615630.93	462.98	.0001
priming * relationship	6	282253.35	47042.22	8.33	.0001
priming * Subject(Group)	1151	6502704.04	5649.61		

Dependent: priming

relationship = Normative Relationship, priming = Prime-Target Relations

Appendix 5.2b Simple main effects for related vs. unrelated prime for each type of prime relation.

Normative relationship	df	mean square	f value	p value
associative	1, 165	701040.77	102.97	.0001
categorical	1,169	217731.81	28.3	.0001
colocational	1,156	157974.04	38.04	.0001
associative + collocational	1,157	750798.76	155.39	.0001
categorical + associative	1,170	270428.92	54.59	.0001
categorical+ collocational	1,167	150114.3	21.44	.0001
categorical+ associative+ collocational	1,167	661092.14	161.91	.0001

Appendix 5.2c Planned means comparisons for the interaction of normative relationship and prime-target relations.

Comparison 1
Effect: norm. rel
Dependent: priming

	Cell Weight
ass	1.00
asscol	-1.00

df	1
Sum of Squares	81.38
Mean Square	81.38
F-Value	1.89E-3
P-Value	.9654

Interaction of priming with Comparison 1
Effect: norm. rel
Dependent: priming

	Cell Weight
ass	1.00
asscol	-1.00

df	1
Sum of Squares	1261.94
Mean Square	1261.94
F-Value	.22
P-Value	.6366

Comparison 2
Effect: norm. rel
Dependent: priming

	Cell Weight
ass	1.00
cat	-1.00

df	1
Sum of Squares	14377.20
Mean Square	14377.20
F-Value	.33
P-Value	.5640

Interaction of priming with Comparison 2
Effect: norm. rel
Dependent: priming

	Cell Weight
ass	1.00
cat	-1.00

df	1
Sum of Squares	71600.56
Mean Square	71600.56
F-Value	12.67
P-Value	.0004

Comparison 3
Effect: norm. rel
Dependent: priming

	Cell Weight
ass	1.00
catass	-1.00

df	1
Sum of Squares	32683.09
Mean Square	32683.09
F-Value	.76
P-Value	.3844

Interaction of priming with Comparison 3
Effect: norm. rel
Dependent: priming

	Cell Weight
ass	1.00
catass	-1.00

df	1
Sum of Squares	53567.42
Mean Square	53567.42
F-Value	9.48
P-Value	.0021

Comparison 7
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
cat	-1.00

df	1
Sum of Squares	16248.91
Mean Square	16248.91
F-Value	.38
P-Value	.5396

Interaction of priming with
Comparison 7
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
cat	-1.00

df	1
Sum of Squares	89969.52
Mean Square	89969.52
F-Value	15.92
P-Value	.0001

Comparison 8
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
catass	-1.00

df	1
Sum of Squares	28703.15
Mean Square	28703.15
F-Value	.67
P-Value	.4150

Interaction of priming with
Comparison 8
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
catass	-1.00

df	1
Sum of Squares	69859.29
Mean Square	69859.29
F-Value	12.37
P-Value	.0005

Comparison 9
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
catasscol	-1.00

df	1
Sum of Squares	41610.83
Mean Square	41610.83
F-Value	.96
P-Value	.3264

Interaction of priming
with Comparison 9
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
catasscol	-1.00

df	1
Sum of Squares	4182.78
Mean Square	4182.78
F-Value	.74
P-Value	.3897

Comparison 10
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
catcol	-1.00

df	1
Sum of Squares	3794.80
Mean Square	3794.80
F-Value	.09
P-Value	.7669

Interaction of priming
with Comparison 10
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
catcol	-1.00

df	1
Sum of Squares	124110.87
Mean Square	124110.87
F-Value	21.97
P-Value	.0001

Comparison 11
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
col	-1.00

df	1
Sum of Squares	67879.59
Mean Square	67879.59
F-Value	1.57
P-Value	.2101

Interaction of priming
with Comparison 11
Effect: norm. rel
Dependent: priming

	Cell Weight
asscol	1.00
col	-1.00

df	1
Sum of Squares	109053.89
Mean Square	109053.89
F-Value	19.30
P-Value	.0001

Comparison 12
Effect: norm. rel
Dependent: priming

	Cell Weight
cat	1.00
catass	-1.00

df	1
Sum of Squares	91612.44
Mean Square	91612.44
F-Value	2.12
P-Value	.1454

Interaction of priming
with Comparison 12
Effect: norm. rel
Dependent: priming

	Cell Weight
cat	1.00
catass	-1.00

df	1
Sum of Squares	1350.11
Mean Square	1350.11
F-Value	.24
P-Value	.6250

Comparison 13
Effect: norm. rel
Dependent: priming

	Cell Weight
cat	1.00
catasscol	-1.00

df	1
Sum of Squares	6133.66
Mean Square	6133.66
F-Value	.14
P-Value	.7063

Interaction of priming with Comparison 13
Effect: norm. rel
Dependent: priming

	Cell Weight
cat	1.00
catasscol	-1.00

df	1
Sum of Squares	57026.44
Mean Square	57026.44
F-Value	10.09
P-Value	.0015

Comparison 14
Effect: norm. rel
Dependent: priming

	Cell Weight
cat	1.00
catcol	-1.00

df	1
Sum of Squares	4452.94
Mean Square	4452.94
F-Value	.10
P-Value	.7481

Interaction of priming with Comparison 14
Effect: norm. rel
Dependent: priming

	Cell Weight
cat	1.00
catcol	-1.00

df	1
Sum of Squares	2937.18
Mean Square	2937.18
F-Value	.52
P-Value	.4710

Comparison 15
Effect: norm. rel
Dependent: priming

	Cell Weight
catass	1.00
catasscol	-1.00

df	1
Sum of Squares	144557.99
Mean Square	144557.99
F-Value	3.35
P-Value	.0675

Interaction of priming with Comparison 15
Effect: norm. rel
Dependent: priming

	Cell Weight
catass	1.00
catasscol	-1.00

df	1
Sum of Squares	41012.43
Mean Square	41012.43
F-Value	7.26
P-Value	.0072

Comparison 16
Effect: norm. rel
Dependent: priming

	Cell Weight
catass	1.00
catcol	-1.00

df	1
Sum of Squares	55200.80
Mean Square	55200.80
F-Value	1.28
P-Value	.2583

Interaction of priming with
Comparison 16
Effect: norm. rel
Dependent: priming

	Cell Weight
catass	1.00
catcol	-1.00

df	1
Sum of Squares	8264.51
Mean Square	8264.51
F-Value	1.46
P-Value	.2267

Comparison 17
Effect: norm. rel
Dependent: priming

	Cell Weight
catass	1.00
col	-1.00

df	1
Sum of Squares	189014.77
Mean Square	189014.77
F-Value	4.38
P-Value	.0366

Interaction of priming
with Comparison 17
Effect: norm. rel
Dependent: priming

	Cell Weight
catass	1.00
col	-1.00

df	1
Sum of Squares	5299.91
Mean Square	5299.91
F-Value	.94
P-Value	.3330

Comparison 18
Effect: norm. rel
Dependent: priming

	Cell Weight
catasscol	1.00
catcol	-1.00

df	1
Sum of Squares	20915.18
Mean Square	20915.18
F-Value	.48
P-Value	.4865

Interaction of priming with
Comparison 18
Effect: norm. rel
Dependent: priming

	Cell Weight
catasscol	1.00
catcol	-1.00

df	1
Sum of Squares	85342.75
Mean Square	85342.75
F-Value	15.11
P-Value	.0001

Comparison 19
Effect: norm. rel
Dependent: priming

	Cell Weight
catasscol	1.00
col	-1.00

df	1
Sum of Squares	3701.10
Mean Square	3701.10
F-Value	.09
P-Value	.7697

Interaction of priming with Comparison 19
Effect: norm. rel
Dependent: priming

	Cell Weight
catasscol	1.00
col	-1.00

df	1
Sum of Squares	73264.90
Mean Square	73264.90
F-Value	12.97
P-Value	.0003

Comparison 20
Effect: norm. rel
Dependent: priming

	Cell Weight
catcol	-1.00
col	1.00

df	1
Sum of Squares	41204.52
Mean Square	41204.52
F-Value	.95
P-Value	.3287

Interaction of priming with Comparison 20
Effect: norm. rel
Dependent: priming

	Cell Weight
catcol	-1.00
col	1.00

df	1
Sum of Squares	271.38
Mean Square	271.38
F-Value	.05
P-Value	.8266

Appendix 5.3

Participant Generated Pairs: analysis of effect Normative Relations and Prime-Target Relations on RT

Appendix 5.3.a A mixed 2 x 7 ANOVA was performed on the Rt for Participant Generated Pairs. Normative Relationship was between subject variable and Prime-Target Relations (related vs. unrelated) was the within subjects variable. The DV was RT

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
relationship	6	158762.89	26460.48	.70	.6492
Subject(Group)	230	8683809.60	37755.69		
priming	1	252797.36	252797.36	59.89	.0001
priming * relationship	6	26017.18	4336.20	1.03	.4083
priming * Subject(Group)	230	970894.63	4221.28		

Dependent: priming

Note: relationship = Normative Relationship, priming = Prime-Target Relations

Appendix 5.3b Contingency tables for observed and expected frequencies of target words generated by the participants for each condition of normative related word pairs.

A χ^2 Test of independence to determine whether there was a difference in the number of Participant Generated pairs for each condition of Normative relationship

Summary Table for Rows, Columns

Num. Missing	0
DF	6
Chi Square	126.797
Chi Square P-Value	<.0001
G-Squared	147.787
G-Squared P-Value	<.0001
Contingency Coef.	.116
Cramer's V	.117

Observed Frequencies for Rows, Columns

	Column 1	Column 2	Totals
Row 1	64	1256	1320
Row 2	5	1315	1320
Row 3	31	1289	1320
Row 4	71	1249	1320
Row 5	28	1292	1320
Row 6	2	1318	1320
Row 7	36	1284	1320
Totals	237	9003	9240

Expected Values for Rows, Columns

	Column 1	Column 2	Totals
Row 1	33.857	1286.143	1320.000
Row 2	33.857	1286.143	1320.000
Row 3	33.857	1286.143	1320.000
Row 4	33.857	1286.143	1320.000
Row 5	33.857	1286.143	1320.000
Row 6	33.857	1286.143	1320.000
Row 7	33.857	1286.143	1320.000
Totals	237.000	9003.000	9240.000

Appendix 5.4a A mixed sample 7 x 2 ANOVA was performed: The between subjects variable was Normative relations and the within subjects variable was Prime-Target Relations. The DV was RT

Participant Unrelated Data set: Analysis of effect of prime-target relation and Normative Relationship on the priming effect for RT

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
relationship	6	375153.40	62525.57	1.43	.2100
Subject(Group)	107	4679779.18	43736.25		
priming	1	18830.00	18830.00	3.51	.0639
priming * relationship	6	66802.18	11133.70	2.07	.0624
priming * Subject(Group)	107	574786.19	5371.83		

Dependent: priming

Note: relationship = Normative Relationship, priming = Prime-Target Relations

Appendix 5.4b mean RT in ms (+SD) for each condition of Normative relationship and each condition of Prime-Target Relations for the Participant Unrelated data set.

Normative Relationship	*n*	Prime-Target Relations	
		Related mean (+ *SD*)	Unrelated mean (+ *SD*)
associative	10	666.3 (138.7)	672.1 (127)
categorical	24	595 (134.5)	627.29 (115.8)
collocational	41	707 (167.7)	723.34 (167.8)
associative+ collocational	1	668	886
categorical + associative	11	687.6 (147.4)	675.9 (167.9)
categorical + collocational	26	676.5 (160.7)	634.6 (180.8)
categorical + collocational + associative	1	579	654

Analysis of simple main effect for Prime-Target Relations

Appendix 5.4c: Simple main effects for collocates

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
relationship	0	•	•	•	•
Subject(Group)	40	2034098.44	50852.46		
priming	1	5490.74	5490.74	1.01	.3199
priming * relationship	0	•	•	•	•
priming * Subject(Group)	40	216517.76	5412.94		

Dependent: priming

Note: relationship = Normative Relationship, priming = Prime-Target Relations

Analysis of effect of Prime-Target Relations and Normative relations on RT for Participant Related Word Pairs (excluding Participant Generated word pairs)

Appendix 5.4d A mixed ANOVA was performed on RT for Participant related word-pairs (excluding Participant Generated word pairs).Nnormative Relationship was the between subjects variable and prime-target relations (related vs. unrelated) was the within subjects variable, the DV was RT.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
relationship	6	263482.29	43913.72	.98	.4346
Subject(Group)	800	35691944.08	44614.93		
priming	1	1942649.75	1942649.75	332.01	.0001
priming * relationship	6	174108.05	29018.01	4.96	.0001
priming * Subject(Group)	800	4680872.42	5851.09		

Dependent: priming

Note: relationship = Normative Relationship, priming = Prime-Target Relations

Appendix 5.4.e: mean RT in ms (+sd) for each condition of Normative Relations and prime-Target Relations for 'Participant Related word pairs excluding participant generated word pairs.

Normative Relationship	*n*	Prime-Target Relations	
		related mean RT	Unrelated mean RT
associative	92	593 (135)	701 (182)
categorical	141	648 (177)	700 (170)
collocational	85	629 (142)	681 (156)
associative+ collocational	86	614 (148)	708 (165)
categorical + associative	132	617 (140)	668 (153)
categorical + collocational	140	632 (156)	632 (156)
categorical + collocational + associative	131	637 (153)	720 (160)

Appendix 5.4.*f*

Dunn's post-hoc analysis of the interaction of Normative Relations and prime-Target Relations for Participant Related word pairs excluding participant generated word pairs.

Bonferroni/Dunn for priming
Effect: relationship
Significance Level: 5 %
Inclusion criteria: Criteria 1related only from RWAP-crect data prim1sv

	Mean Diff.	Crit. Diff	P-Value
ass, asscol	-14.334	68.278	.5225
ass, cat	-27.056	61.008	.1769
ass, catass	4.409	61.824	.8280
ass, catasscol	-31.824	61.921	.1177
ass, catcol	-13.963	61.094	.4863
ass, col	-7.755	68.485	.7301
asscol, cat	-12.722	62.283	.5337
asscol, catass	18.743	63.082	.3654
asscol, catasscol	-17.490	63.177	.3991
asscol, catcol	.371	62.367	.9856
asscol, col	6.579	69.623	.7734
cat, catass	31.465	55.131	.0823
cat, catasscol	-4.768	55.240	.7926
cat, catcol	13.093	54.312	.4627
cat, col	19.301	62.510	.3470
catass, catasscol	-36.233	56.140	.0495
catass, catcol	-18.373	55.226	.3109
catass, col	-12.164	63.306	.5583
catasscol, catcol	17.861	55.335	.3255
catasscol, col	24.069	63.401	.2476
catcol, col	6.208	62.594	.7625

Comparisons in this table are not significant unless the corresponding p-value is less than .0024.

Analysis of effect of Prime-Target Relations and Normative relations on RT for participant related word pairs

Appendix 5.4g A mixed ANOVA was performed on RT for Participant related word-pairs (including Participant Generated word pairs).Normative Relationship was the between subjects variable and prime-target relations (related vs. unrelated) was the within subjects variable, the DV was RT..

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
relationship	6	256717.54	42786.26	1.00	.4271
Subject(Group)	1037	44583394.41	42992.67		
priming	1	2722213.24	2722213.24	493.69	.0001
priming * relationship	6	182411.27	30401.88	5.51	.0001
priming * Subject(Group)	1037	5717977.61	5513.96		

Dependent: priming

Note: relationship = Normative Relationship, priming = Prime-Target Relations

Appendix 5.4.h: mean RT in ms (+ *SD*) for the effects of prime-target relations and Normative relationship for Participant Related word pairs including Participant Generated word-pairs.

Condition	*n*	mean related prime - targets	mean RT unrelated prime - targets
associative	156	605 (137)	703 (167)
categorical	146	646 (175)	700 (168)
collocational	116	688 (160)	633 (147)
associative+ collocational	157	605 (137)	702 (159)
categorical + associative	160	607 (139)	669 (155)
categorical + collocational	142	631 (156)	689 (167)
categorical + collocational + associative	167	627 (152)	714 (160)

Appendix 5.4.i Dunn's post-hoc analysis of the interaction of prime-target relations and Normative relationship for Participant Related word pairs including Participant Generated word-pairs

Bonferroni/Dunn for priming
Effect: relationship
Significance Level: 5 %
Inclusion criteria: rleated and generated from RWAP-crect data prim1sv

	Mean Diff.	Crit. Diff	P-Value
ass, asscol	.584	50.479	.9719
ass, cat	-18.901	51.418	.2632
ass, catass	15.813	50.243	.3380
ass, catasscol	-16.505	49.720	.3123
ass, catcol	-5.691	51.791	.7379
ass, col	-6.803	54.745	.7052
asscol, cat	-19.485	51.339	.2480
asscol, catass	15.229	50.162	.3554
asscol, catasscol	-17.089	49.638	.2947
asscol, catcol	-6.275	51.712	.7118
asscol, col	-7.387	54.671	.6808
cat, catass	34.714	51.107	.0388
cat, catasscol	2.396	50.593	.8853
cat, catcol	13.210	52.629	.4448
cat, col	12.098	55.539	.5072
catass, catasscol	-32.318	49.398	.0466
catass, catcol	-21.504	51.482	.2036
catass, col	-22.616	54.453	.2062
catasscol, catcol	10.814	50.972	.5183
catasscol, col	9.702	53.971	.5842
catcol, col	-1.112	55.884	.9517

Comparisons in this table are not significant unless the corresponding p-value is less than .0024.

s

Appendix 5.5

Analysis of Participants classification of the word-pairs: Participant Generated, Participant related, Participant Unrelated.

Appendix 5.5a A mixed samples 3x 2 ANOVA was performed. Participants classification of the word pairs (Participant Generated, Participant Related and Participant Unrelated) was treated as the between subjects variable, the within subject variable was Prime-target Relations (related or unrelated), the DV was RT.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
related	2	80261.17	40130.59	.93	.3949
Subject(Group)	1155	49852931.45	43162.71		
priming	1	961258.17	961258.17	170.98	.0001
priming * related	2	291476.74	145738.37	25.92	.0001
priming * Subject(Group)	1155	6493480.65	5622.06		

Dependent: priming

Note: related = participants classification of word-pairs, priming = Prime-Target Relations

Appendix 5.5b mean RT (+ SD) for Participant Generated, Participant Related and Participant Unrelated data sets.

Participants Classification	*n*	Related target	Unrelated target
Participant Generated	237	604 (135)	696 (153)
Participant Related	807	626 (153)	695 (165)
Participant Unrelated	114	669 (157)	675 (161)

Appendix 5.5c

Analysis of simple main effect for Participant Generated word-pairs

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
related	0	•	•	•	•
Subject(Group)	236	8842572.50	37468.53		
priming	1	995454.19	995454.19	235.65	.0001
priming * related	0	•	•	•	•
priming * Subject(Group)	236	996911.81	4224.20		

Dependent: priming

Note: related = participants classification of word-pairs, priming = Prime-Target Relations

Appendix 5.5d

Analysis of simple main effect for Participant Related word pairs

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
related	0	•	•	•	•
Subject(Group)	806	35955426.37	44609.71		
priming	1	1901311.53	1901311.53	315.65	.0001
priming * related	0	•	•	•	•
priming * Subject(Group)	806	4854980.47	6023.55		

Dependent: priming

Note: related = participants classification of word-pairs, priming = Prime-Target Relations

Appendix 5.5.e

Analysis of simple main effect forParticipant Unrelated word pairs

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
related	0	•	•	•	•
Subject(Group)	113	5054932.58	44733.92		
priming	1	1485.63	1485.63	.26	.6100
priming * related	0	•	•	•	•
priming * Subject(Group)	113	641588.37	5677.77		

Dependent: priming

Note: related = participants classification of word-pairs, priming = Prime-Target Relations

Appendix 5.5f

Planned means comparisons for Participant Generated word pairs versus Participant Related word-pairs..

Comparison 1
Effect: related
Dependent: priming

	Cell Weight
gen	1.00
rel	-1.00

df	1
Sum of Squares	42113.08
Mean Square	42113.08
F-Value	.98
P-Value	.3235

Interaction of priming with Comparison 1
Effect: related
Dependent: priming

	Cell Weight
gen	1.00
rel	-1.00

df	1
Sum of Squares	48496.60
Mean Square	48496.60
F-Value	8.63
P-Value	.0034

Appendix 5.6

Analysis of image-link and verbal link word associations.

Appendix 5.6a A mixed samples ANOVA with the class of Participant Related word pairs (image-link, verbal-link, both-link) treated as a between subjects variable and Prime-Target Relations (related vs. unrelated) was treated as the within subjects variable, the DV was RT

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
v / i	2	45379.71	22689.85	.53	.5904
Subject(Group)	1041	44794732.24	43030.48		
priming	1	2362715.85	2362715.85	447.30	.0001
priming * v/i	2	401696.93	200848.47	38.02	.0001
priming * Subject(Group)	1041	5498691.95	5282.12		

Dependent: priming

Note: v/i = Class of Participant related word pairs; priming = Prime-Target relations.

Appendix 5.6b

Table of mean RT (+ SD) for word pairs classed by as related through imagery, verbal association or through both imagery and verbal association

Class of Participant Relations	*n*	Prime-Target relations	
		Related Mean RT	Unrelated Mean RT
imagery	449	603	703
		(148)	(165)
verbal	463	640	683
		(151)	(161)
both	133	618	713
		(142)	(157)

Appendix 5.6c

Simple main effect of Prime-Target Relations on image-link

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
v / i	0	•	•	•	•
Subject(Group)	448	19321113.79	43127.49		
priming	1	2229526.75	2229526.75	377.85	.0001
priming * v/i	0	•	•	•	•
priming * Subjec...	448	2643464.75	5900.59		

Dependent: priming

Note: v/i = Class of Participant related word pairs; priming = Prime-Target relations

Appendix 5.6d

Simple main effect of Prime-Target Relations on verbal link condition

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
v / i	0	•	•	•	•
Subject(Group)	462	20414524.30	44187.28		
priming	1	419656.99	419656.99	97.24	.0001
priming * v/i	0	•	•	•	•
priming * Subjec...	462	1993747.51	4315.47		

Dependent: priming

Appendix 5.6e

Simple main effect of Prime-Target Relations on both-link condition

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
v / i	0	•	•	•	•
Subject(Group)	132	5068376.89	38396.79		
priming	1	597695.04	597695.04	91.12	.0001
priming * v/i	0	•	•	•	•
priming * Subjec...	132	865867.46	6559.60		

Dependent: priming

Note: v/i = Class of Participant related word pairs; priming = Prime-Target relations

Appendix 5.6f

Planned means comparisons between word pairs classed as related through both imagery and verbal associations

Comparison 1
Effect: v/i
Dependent: priming

	Cell Weight
image	1.00
verbal	-1.00

df	1
Sum of Squares	29908.74
Mean Square	29908.74
F-Value	.70
P-Value	.4045

Comparison 2
Effect: v/i
Dependent: priming

	Cell Weight
both	1.00
image	-1.00

df	1
Sum of Squares	31985.08
Mean Square	31985.08
F-Value	.74
P-Value	.3886

Comparison 3
Effect: v/i
Dependent: priming

	Cell Weight
both	1.00
verbal	-1.00

df	1
Sum of Squares	3973.02
Mean Square	3973.02
F-Value	.09
P-Value	.7612

Interaction of priming with Comparison 1
Effect: v/i
Dependent: priming

	Cell Weight
image	1.00
verbal	-1.00

df	1
Sum of Squares	371314.35
Mean Square	371314.35
F-Value	70.31
P-Value	.0001

Interaction of priming with Comparison 2
Effect: v/i
Dependent: priming

	Cell Weight
both	1.00
image	-1.00

df	1
Sum of Squares	1206.92
Mean Square	1206.92
F-Value	.23
P-Value	.6327

Interaction of priming with Comparison 3
Effect: v/i
Dependent: priming

	Cell Weight
both	1.00
verbal	-1.00

df	1
Sum of Squares	140916.05
Mean Square	140916.05
F-Value	26.68
P-Value	.0001

Appendix 5.7

Analysis of imagery relations

Appendix 5.7a A mixed samples ANOVA was performed with the type of imagery association (visual, sensory or motor) as the between subjects variable and Prime -Target Relations (related or unrelated) as the within subjects variable. The DV was RT

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
type	2	202009.12	101004.56	2.43	.0893
Subject(Group)	503	20928865.73	41608.08		
priming	1	232131.37	232131.37	37.34	.0001
priming * type	2	7527.22	3763.61	.61	.5463
priming * Subject(Group)	503	3127232.47	6217.16		

Dependent: priming

Note: type = type of imagery association; priming = Prime-Target relations

Appendix 5.7b

The mean RT (and SD) for conditions of Imagery-Link associations

Class of imagery	n	Prime-target Relations	
		Related mean	Unrelated mean
visual	421	599 (144)	699 (157)
sensory	78	631 (162)	739 (193)
motor	7	578 (110)	641 (104)

Appendix 5.8

Analysis of verbal relations

Appendix 5.8a A mixed ANOVA was performed, in which type of verbal association (category general knowledge, or lexical) was treated as the between subjects variable and priming (related or unrelated) was treated as the within subjects variable.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
type	2	36536.08	18268.04	.41	.6611
Subject(Group)	536	23640119.50	44104.70		
priming	1	597087.41	597087.41	135.08	.0001
priming * type	2	56245.57	28122.78	6.36	.0019
priming * Subject(Group)	536	2369242.52	4420.23		

Dependent: priming

Note: type = type of verbal association; priming = Prime-Target relations

Appendix 5.8b

Table of mean RT (+ SD) for categorical, lexical, and general knowledge verbal-link associations.

Class of verbal association	n	Prime-target Relations	
		Related mean	Unrelated mean
Category	271	271 (649)	683 (165)
General knowledge	189	632 (141)	695 (162)
Lexical	79	618 (133)	681 (151)

Appendix 5.8.c planned means comparisons for each condition of verbal link associations

Comparison 1
Effect: type
Dependent: priming

	Cell Weight
cat	1.00
gk	-1.00

df	1
Sum of Squares	985.28
Mean Square	985.28
F-Value	.02
P-Value	.8812

Comparison 2
Effect: type
Dependent: priming

	Cell Weight
cat	1.00
word	-1.00

df	1
Sum of Squares	35778.68
Mean Square	35778.68
F-Value	.81
P-Value	.3682

Comparison 3
Effect: type
Dependent: priming

	Cell Weight
gk	1.00
word	-1.00

df	1
Sum of Squares	25064.10
Mean Square	25064.10
F-Value	.57
P-Value	.4513

Interaction of priming with Comparison 1
Effect: type
Dependent: priming

	Cell Weight
cat	1.00
gk	-1.00

df	1
Sum of Squares	46874.95
Mean Square	46874.95
F-Value	10.60
P-Value	.0012

Interaction of priming with Comparison 2
Effect: type
Dependent: priming

	Cell Weight
cat	1.00
word	-1.00

df	1
Sum of Squares	25007.29
Mean Square	25007.29
F-Value	5.66
P-Value	.0177

Interaction of priming with Comparison 3
Effect: type
Dependent: priming

	Cell Weight
gk	1.00
word	-1.00

df	1
Sum of Squares	4.96
Mean Square	4.96
F-Value	1.12E-3
P-Value	.9733

Note: Priming = Prime-Target Relations, cat = categorical, gk = general knowledge, word = lexical

Appendix 5.9

Analysis effects of Normative relationship, participants classification of word pairs and Prime-Target relations on RT

A mixed ANOVA was performed in which Normative Relations was treated as a between subjects variable, as was Participant's classification of word pairs (image-link, verbal-link, both links). Prime-Target Relations were treated as the within subjects variable. The DV was RT..

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
norm. rel * participants class	12	288044.04	24003.67	.55	.8787
norm. rel	6	203719.82	33953.30	.78	.5819
participants class	2	18711.67	9355.84	.22	.8056
Subject(Group)	1023	44259435.35	43264.36		
priming	1	1724072.49	1724072.49	332.05	.0001
priming * norm. rel * partic...	12	80982.04	6748.50	1.30	.2125
priming * norm. rel	6	59829.58	9971.60	1.92	.0746
priming * participants class	2	288510.75	144255.37	27.78	.0001
priming * Subject(Group)	1023	5311636.46	5192.22		

Dependent: priming

Appendix 5.10

Effect of Prime Experience

A mixed ANOVA was performed in which reported prime experience (unaware of the prime, noticed the prime and noticed that some prime-target pairs were related) was treated as the between subjects variable and and prime type (related or unrelated) was treated as the between subjects variable, the DV was response time

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
prime recall	2	31445.71	15722.85	.36	.6950
Subject(Group)	1155	49901746.91	43204.98		
priming	1	1973353.01	1973353.01	336.34	.0001
priming * prime recall	2	8346.51	4173.26	.71	.4912
priming * Subject(Group)	1155	6776610.87	5867.20		

Dependent: priming

Note: prime recall = reprtd experience of prine; priming = Prime-Target relations

Appendix 5.11

Analysis of target words.

A mixed ANOVA in which the Target words were treated as between subject variables and and Prime-Target Relations were treated as within subject variables, and the DV was RT.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
target	15	516169.06	34411.27	.80	.6840
Subject(Group)	1142	49417023.56	43272.35		
priming	1	2243781.65	2243781.65	383.06	.0001
priming * target	15	95647.01	6376.47	1.09	.3621
priming * Subjec...	1142	6689310.38	5857.54		

Dependent: Prime-Target Relations

Appendix 5.11a

Analysis of list sequence.

A mixed ANOVA was performed in which list order was treated as the between subjects variable, Prime-target relations as the within subjects variable and DV was the RT

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
List	1	15.09	15.09	3.49E-4	.9851
Subject(Group)	1156	49933177.53	43194.79		
priming	1	2591443.72	2591443.72	441.75	.0001
priming * List	1	3511.61	3511.61	.60	.4393
priming * Subjec...	1156	6781445.77	5866.30		

Dependent: Prime-Target Relations

Appendix 5.11b

Mean RT (+SD) for each list sequence and Prime-Target Relations.

	Count	Mean	Std. Dev.	Std. Error
unrelated, A	607	694.60	158.34	6.43
unrelated, B	551	691.97	166.69	7.10
related, A	607	625.15	152.43	6.19
related, B	551	627.46	148.69	6.33

Appendix 5.11c A mixed samples ANOVA in which Normative Relationship and List order were treated as between subject variables and Prime-Target relations were treated as within subject variables. The DV was RT.

Analysis of the effect of list order on Normative Relationship and Prime-Target relations

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
List * Norm. Rel	13	404192.46	31091.73	.72	.7466
Subject(Group)	1144	49529000.16	43294.58		
priming	1	2601267.57	2601267.57	458.94	.0001
priming * List * ...	13	300781.39	23137.03	4.08	.0001
priming * Subjec...	1144	6484176.00	5667.99		

Dependent: Prime-Target Relations

Appendix 5.11.d A mixed samples ANOVA in which Response Button was treated as the between subjects variable and Prime-Target Relations as the within subject variable. The DV was RT

Effect of response key

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
BUTTON	1	129855.29	129855.29	3.01	.0828
Subject(Group)	1156	49803337.33	43082.47		
priming	1	2594472.02	2594472.02	443.08	.0001
priming * BUTTON	1	15956.52	15956.52	2.73	.0991
priming * Subjec...	1156	6769000.87	5855.54		

Dependent: Prime-Target Relations

Means for left handed "yes" response versus right handed "yes" response

	Count	Mean	Std. Dev.	Std. Error
unrelated, G	564	682.97	148.45	6.25
unrelated, R	594	703.20	173.99	7.14
related, G	564	621.26	141.65	5.96
related, R	594	630.99	158.61	6.51

Note G = green, the left hand button and r = red , the right hand button.

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