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Facilitation in perceptual and conceptual networks and rapid response learning: Two types of memory for priming in person recognition

Valt, Christian

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**Facilitation in perceptual and
conceptual networks and rapid
response learning: Two types of
memory for priming in person
recognition**

Christian Valt

Bangor University

PhD Thesis

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Abstract

Experience with a stimulus changes a person forever... if not forever, at least for 17 years (Mitchell, 2006). Any process engaged by the brain leaves a trace behind that affects similar future processing. This form of plasticity aims to optimize the brain toward more efficient interaction with stimuli that have been encountered before, adapting the individual to the environment. Similar adaptation manifests itself as faster and more accurate performance to repeated stimuli.

Repetition priming is the term used in the literature to describe this kind of facilitation. A crucial open question on repetition priming is whether experience makes stimulus processing more efficient or facilitates the selection of an appropriate response to a stimulus. In the literature these two alternatives are theorised respectively by facilitation in perceptual and conceptual networks and by rapid response learning (Chapter 1). In the work presented here, processing/response accounts are tested in person recognition.

This thesis presents evidence that repetition priming in person recognition is mostly produced by facilitation in perceptual and conceptual networks, but, when stimuli are repeated three or more times, additional facilitation due to rapid response learning occurs as well (Chapters 2 - 3 - 4). Orthogonal tasks were used to distinguish the contribution of perceptual/conceptual facilitation and rapid response learning in behavioural facilitation (Chapter 5). Furthermore, LRPs/ERPs shed light on the neural processes that generate rapid response learning in person recognition: the response accessed from rapid response learning interacts with the response obtained from stimulus re-processing and determines benefits when congruent and costs when incongruent (Chapter 6).

These results show that rapid response learning and facilitation in perceptual and conceptual networks refer to two complementary types of memory that can lead to

repetition priming. This thesis proposes a framework in which facilitation in perceptual and conceptual networks is supplemented, under specific circumstances, by rapid response learning (Chapter 7).

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Chapter 1: General Introduction

In the model of Atkinson & Shiffrin (1968) human memory is divided into three separate systems according to capacity and storage duration: sensory registry, short-term memory and long-term memory. Sensory registry stores a large amount of perceptual information for less than a second (Sperling, 1960). Short-term memory, nowadays called working memory (Baddeley, 2003; Baddeley & Hitch, 1974), stores around 5-10 bits of information (Miller, 1956) for as long as rehearsal processes are consciously employed (Craik & Watkins, 1973), otherwise its duration is on the order of few seconds. Long-term memory is thought to have unlimited capacity and information seems to be stored permanently.

Human long-term memory is not a unitary cognitive system but the sum of different memory systems (Squire & Zola, 1996; Tulving, 1972). The clearest evidence in support of multiple memory systems comes from the study of amnesia - a deficit that affects some types of memory but not others. The most notable example of the componential nature of memory comes from patient HM, who, despite suffering from profound amnesia, showed spared capacity to learn some memory tasks (Corkin, 2002). Patients with amnesia present deficits in the creation of new memories about facts or events, but they are able to learn, for instance, new motor skills (Milner, Corkin, & Teuber, 1968) or artificial grammars (Knowlton, Ramus, & Squire, 1992); moreover, their performance can be influenced by past events (Warrington & Weiskrantz, 1974), regardless of the fact that the event is not remembered (Graf, Squire, & Mandler, 1984). According to similar neuropsychological dissociations and functional imaging studies, Squire & Zola (1996) proposed a taxonomy of long-term memory in which different memory systems are divided into two classes: declarative and non-declarative memories. Declarative memories are memories associated

with feelings of awareness and depend on medial temporal lobe/diencephalon structures that are generally affected in amnesia. Declarative memories are memories for events (episodic memory) and facts (semantic memory). On the other hand, non-declarative memories are spared in amnesia, because they do not involve medial temporal lobe/diencephalon structures, and they do not require awareness. Memories numbered among the non-declarative class are procedural memory, priming, conditioning and non-associative learning.

1.1 Repetition priming

Repetition priming is the most prominent example of nondeclarative memory; it is mainly demonstrated by faster and more accurate responses when information is processed repeatedly (Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, 1993). Repetition priming, like all forms of nondeclarative memory, is not thought to rely on medial temporal lobe (Squire & Zola, 1996), since patients suffering from amnesia caused by medial temporal lobe damages usually demonstrate normal priming. For example, amnesic patients present a normal propensity in completing a three-letter word stem (like PER _ _ _) with a previously read word (PERIOD) than a different word (PERSON) when asked to use the first word that comes into their mind, but showed a deficit when asked to use the word that was previously read. This result indicates that repetition priming, unlike episodic memory, does not rely on the functioning of the medial temporal lobe (Graf et al., 1984).

Repetition priming is considered facilitation in performance as a consequence of a previous processing and so can be observed in a range of tasks and for different types of stimuli. For instance, having read a name before increases the possibility of perceiving the name in difficult threshold conditions (Jacoby & Dallas, 1981; Salasoo, Shiffrin, &

Feustel, 1985), of using that name again to complete a three-letter word stem (Graf et al., 1984) or fragmented words (Roediger, Weldon, Stadler, & Riegler, 1992). Importantly, repetition priming is not restricted to names. Having seen a picture of an object (or a face), for instance, facilitates processing the same object, or similar information, when it is presented again (Warren & Morton, 1982), even for extremely short presentation times or as a fragmented picture (for a review see Schacter, Delaney, & Merikle, 1990). In addition, repetition priming is not restricted to specific stimuli or stimulus domains but generalizes across different pictures of the same stimulus (Warren & Morton, 1982) and transfers from one domain to another: for example the written name of a celebrity primes the facial picture of the celebrity if the task requires semantic level decision, e.g. nationality (Burton, Kelly, & Bruce, 1998). Moreover, repetition priming has been shown in different sensory modalities: visual, acoustic (Schacter & Church, 1992), and olfactory (Olsson, 1999); and it generalizes between modalities: for instance an auditory stimulus primes a visual stimulus, and vice versa (Bassili, Smith, & MacLeod, 1989).

The main signatures of repetition priming are faster response times and greater accuracy in responding to stimuli that were presented before (primed) compared with stimuli presented for the first time (unprimed). Commonly used designs to investigate repetition priming generally consist of at least two phases: a study phase* and a test phase. In study phases stimuli are primed by presenting them to the participant; at test, stimuli are contrasted according to their priming history: stimuli that are presented for the first time at test are considered to be in the baseline condition, against which stimuli presented before at study are contrasted to determine facilitation that can be attributed to the different priming history.

* the use of the term study phase could be misleading because the term study implies actively encoding the materials in memory, however in priming experiments participants are not made aware that the studied materials will be presented again to prevent that the participants do not employ declarative forms of memory

In some cases repetition of a stimulus can result in impaired performance where response times are longer and accuracy lower for primed than unprimed stimuli (for a review see Mayr & Buchner, 2007). Costs are generally obtained for stimuli that are unattended at study in negative priming paradigms (Tipper, 1985) or when a task is repeatedly changed in task-switching paradigms (Allport & Wylie, 1999).

Repetition priming is a one-shot long-lived phenomenon. Facilitation is reliable after a single presentation and benefits marginally by successive presentations (Rugg et al., 1998); and it has been shown to last for months or even years (Cave, 1997; Mitchell, 2006). The longevity of repetition priming distinguishes this type of learning from other forms of priming that are short-lived: semantic priming (Bruce & Valentine, 1986) and self priming (Calder, 1996), for instance, do not survive delays longer than a few seconds.

As introduced earlier in the present chapter, repetition priming is not affected by amnesia. Other forms of priming, like priming for new associations, are abolished in amnesia (Shimamura & Squire, 1987). On the other hand, deficits in repetition priming are generally associated to damage to or neurodegeneration of the neocortex: deficits in perceptual repetition priming have been associated with occipital lobe damage (Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995; Keane, Gabrieli, Mapstone, Johnson, & Corkin, 1995), whereas temporal or frontal lobe damage often produces a deficit in conceptual repetition priming, for example in Alzheimer patients (Fleischman, Gabrieli, Reminger, Vaidya, & Bennett, 1998; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991).

Although separation between declarative and non-declarative memories is quite clear in amnesia, it is hard to draw a demarcation line between memory effects in normal subjects, because all the memory systems are constantly active and contribute to general performance. This problem is known in the literature as “memory contamination” and it is

particularly pervasive in priming experiments (for a review see Butler & Berry, 2001). Memory contamination may occur if participants incidentally encode the stimuli presented in the study phase in such a way that priming observed in the test phase may be biased by engagement of episodic memory (Jacoby, 1991). Many experimental approaches have been suggested to control for episodic memory contamination in priming studies: Among these approaches analysis of facilitation for stimuli in the absence of awareness has given the most convincing results (Rugg et al., 1998). In fact, awareness of previous encounter with a stimulus differentiates declarative from non-declarative memories. Interestingly, awareness does not interact with behavioural priming (Bowers & Schacter, 1990) and so awareness is rarely assessed in studies examining repetition priming.

Theories of repetition priming can be divided into two main categories: structural and episodic. Structural models assume that repetition priming results from structural modification within the representation system of a stimulus caused by previous encounter with the stimulus. Episodic models interpret repetition priming as the effect of retrieval and utilization of a memory trace created for each encounter with the stimulus. *Facilitation in perceptual and conceptual networks* (Burton, 1998) is the dominant structural model, while *rapid response learning* (Dobbins, Schnyer, Verfaellie, & Schacter, 2004), and its theoretical precursor instance theory (Logan, 1990), is an episodic model that has recently attracted a lot of attention. The *multiple-routes multiple-stages* framework (Horner & Henson, 2009) is a recent hybrid structural/episodic model. These three models are briefly described below; strengths and limits are highlighted according to empirical evidence.

1.1.1 Structural model: Facilitation in perceptual and conceptual networks

Currently dominating theoretical views on memory posit that repetition priming

reflects facilitation in perceptual and conceptual networks (Bruce & Young, 1986, 2012; Burton, 1998; Humphreys, Lamote, & Lloyd-Jones, 1995; Moscovitch, 1992; Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, 1993; Squire, 2004; Tulving & Schacter, 1990). Facilitation results from the strengthening of links between hierarchical processing stages for stimulus perception, recognition, identification and categorization (Burton, 1998; Burton, Bruce, & Johnston, 1990). These stages are summarized, for example, in the influential models for recognition and naming of objects, faces and words (Bruce & Young, 1986; Warren & Morton, 1982). Three main stores of knowledge about familiar stimuli can be sequentially accessed, according to task requirements, after a stimulus has been encoded and perceived. The first stores of the three models are pools of recognition units containing representations of known objects, familiar faces and possible words. The second stores are pools of identity-specific semantic representations containing semantic knowledge about objects, people (like nationality or occupation) or names. The last stores are pools of name codes, permitting naming the stimulus. Importantly, although the differences in how stimuli in the three domains are represented in the recognition units (pictogens for objects or logogen for words (Morton, 1979)), the functional organization of the recognition units is similar in the three domains (Bruce & Humphreys, 1994). A prediction that follows the hierarchical organization (Young, Hellawell, & De Haan, 1988) of the stores is that accessing semantic information occurs only after perceptual processing of the stimulus, and, similarly, naming occurs only after perceptual and semantic processing of the stimulus (except for words).

Bruce and Young's (1986) model for person recognition was later revised by Burton et al. (1990). After a stimulus has been structurally encoded and perceived as a face (Structural Encoding level), the associated FRU (Face Recognition Unit) is accessed. This unit communicates with the SIUs (Semantic Information Units) through PIN (Person

Identity Node). PINs can be activated not only by the face of familiar people but by the voice or the name (NRU) too (see Figure 1). An additional stage, often neglected, is lexical output, a pool of units essential for verbal responses, but no mention of a motor output stage is given in the model.

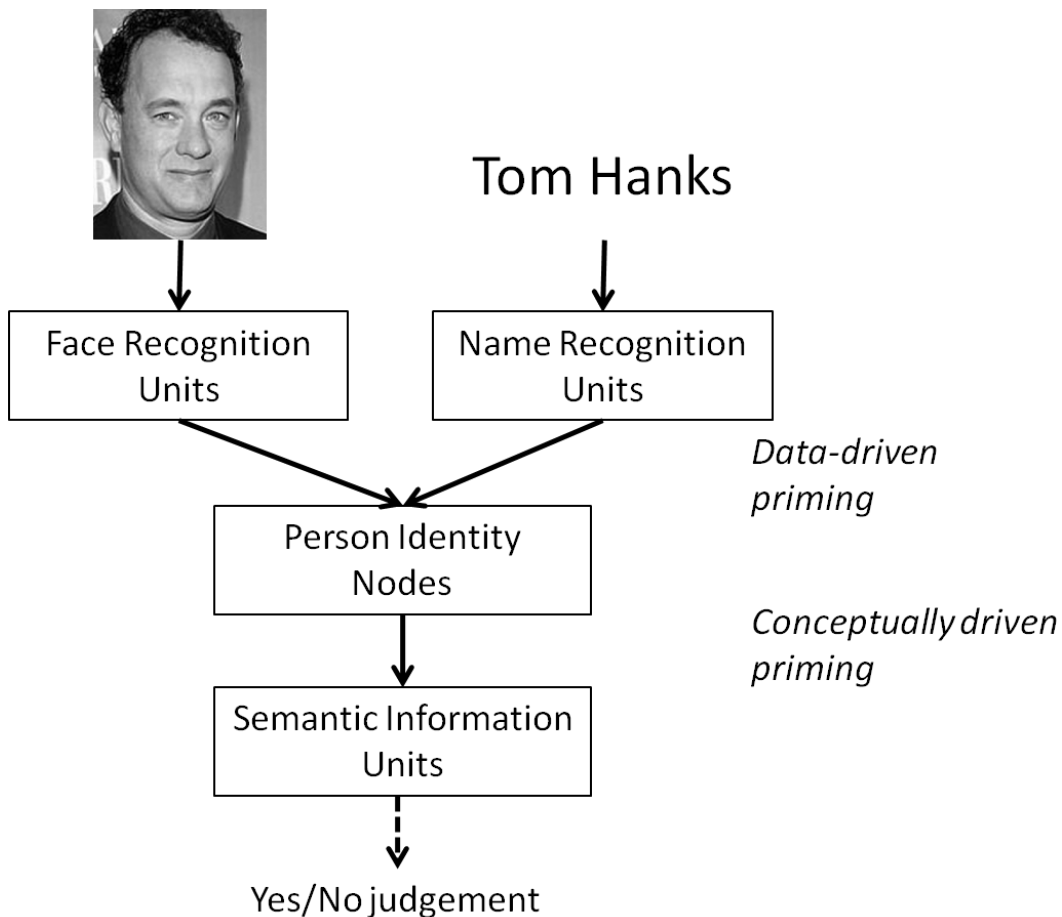


Figure 1 Illustration of Burton's (1998) model of person recognition. Solid arrows represent links that can be strengthened by repetition; dotted line represents the output of a speeded classification task that cannot be strengthened by repetition.

This person recognition model thus describes the perceptual and conceptual networks responsible for person perception and identification and explains repetition priming in person recognition by assuming that processing in perceptual and conceptual networks benefits from prior processing. Two main forms of facilitation can be distinguished, data-driven and conceptually driven priming (Jacoby, 1983; Richardson-

Klavehn & Bjork, 1988).

Data-driven priming for faces occurs when a face is repeatedly identified, for example, when it is recognized repeatedly as familiar in a familiarity task (Bruce & Valentine, 1985), and it is sensitive to (Boehm, Klostermann, Sommer, & Paller, 2006; Schweinberger, Pickering, Jentsch, Burton, & Kaufmann, 2002) or abolished by (Ellis, Flude, Young, & Burton, 1996; Johnston & Barry, 2006) perceptual manipulations of the stimuli between encounters (Bruce & Valentine, 1985; Ellis, Young, Flude, & Hay, 1987). Data-driven priming (see Figure 1) results from both improved structural encoding and strengthening of the link between a FRU and a PIN (Boehm et al., 2006; Burton, 1998). Thus, data-driven priming in person recognition, in fact, comprises two components, a stimulus-specific contribution from improved structural encoding, and an abstract contribution from strengthening the link between face and person representations (Boehm et al., 2006). Importantly, Ellis, Young and Flude (1990) showed that data-driven priming is absent in expression or sex decision tasks, but performing these tasks at study produces facilitation in familiarity judgement tasks (Bruce, Ellis, Gibling, & Young, 1987; Young, McWeeny, Hay, & Ellis, 1986), indicating, firstly, that identity of familiar faces is accessed automatically, even in tasks that are based on pure perceptual discrimination, secondly, sex and expression judgement are made by cognitive systems that are not affected by priming (but see McNeill, Burton, & Ellis, 2003) and, thirdly, data-driven priming takes place only in tasks that require identification of a face, like familiarity judgement, occupation or nationality judgements or naming.

Conceptually driven priming for faces, in contrast, occurs in conceptual tasks when a face is categorized based on semantic memory information, as in occupation or nationality judgment tasks, and is not disrupted by perceptual manipulations (Burton et al., 1998; Johnston & Barry, 2006). Conceptually driven priming (see Figure 1) results from a

strengthening of the links between PIN and SIUs (Burton, 1998). Activation of a PIN passes to all the associated SIUs determining equal strengthening of the links for all the semantic units associated to a person. However, Johnston & Barry (2006) reported reduction of priming after change of task, suggesting possible modulation of conceptually driven priming in relation to performing same or different tasks.

An additional form of facilitation was reported in studies that required naming faces (Burton & Bruce, 1992): priming can depend on accessing the same lexical entry at the level of lexical output. Producing the name of a celebrity from description, or reading the name, facilitates performance in a naming task but does not facilitate a familiarity judgement (Ellis et al., 1996).

On the other hand, giving the same motor response to a stimulus in two separate occasions did not produce any priming in expression or sex judgment (Ellis et al., 1990), and does not contribute significantly to overall priming in semantic classification judgment (Johnston & Barry, 2006). These results justify the absence of a motor output level in this model.

According to facilitation in perceptual and conceptual networks, the magnitude of priming is determined by the overlap of processes engaged at study and test. Priming is maximal when in study and test phases the same semantic judgement is performed on identical stimuli because of the combined effects of data-driven and conceptually driven priming (FRU-PIN and PIN-SIU links are strengthened). Performing familiarity judgement on identical stimuli in study and test phases expresses only data-driven priming because stimulus processing stops at PIN level and only FRU-PIN link is strengthened. On the other hand, performing the same semantic judgement on the name of the stimulus at study and on the picture of the stimulus at test leads to conceptually driven priming but not data-driven priming; PIN is accessed from two different recognition units (name at study and

face at test), therefore processing overlap occurs only at stages following PIN level and facilitation is produced only by strengthening of PIN-SIU links. Interestingly, the sum of data-driven and conceptually driven priming when invoked individually is identical to the amount of priming when data-driven and conceptually driven priming are invoked conjointly (Boehm & Sommer, 2012).

Although the networks facilitation offers many explanations for priming results in person recognition, the picture that emerges from similar attempts to account for priming in object and word recognition according to structural models is less clear. Data-driven priming for objects (similarly to data-driven priming for faces) is maximal for the identical pictures of a stimulus and reduced, but still significant, for different pictures of a stimulus, and abolished by the presentation of the name at study (Warren & Morton, 1982). However, the most conflicting result between facilitation in person recognition and facilitation in object or name recognition is the disappearance of data-driven and conceptually driven priming after a change of task, despite the fact that the same stimulus was presented at study and test (Bruce, Carson, Burton, & Ellis, 2000; Horner & Henson, 2009; Race, Badre, & Wagner, 2010; Vriezen, Moscovitch, & Bellos, 1995).

The existence of conceptually driven priming in object recognition is supported by the evidence that facilitation in performing two different semantic tasks is not affected by the format of the stimulus (name or picture) when natural/manmade judgement is required (Bruce et al., 2000; Vriezen et al., 1995); however, in one instance complete disruption of conceptually driven priming after change of stimuli format was shown in size judgement (Horner & Henson, 2011b).

Bruce et al. (2000) suggested that the requirement of computations associated with some tasks may be a crucial factor behind the expression of either data-driven or conceptually driven priming. That is, a crucial factor behind the expression of data-driven

and conceptually driven priming in object recognition is whether a semantic task is based on a pre-existent semantic entry or on semantic information that must be further computed to express an answer (see also Barsalou, 1983).

Facilitation in naming objects was reported by Wheeldon & Monsell (1992): naming the picture of an object was facilitated by having given the same name in response to a definition or having read the name before.

Regarding facilitation in giving the same motor response, Vriezen et al. (1995) did not find any significant effect of giving the same response as opposed to giving two different responses, but congruency of the responses has been widely reported as impacting significantly upon priming for objects and names (Dobbins et al., 2004; Horner & Henson, 2009).

In conclusion, facilitation in perceptual and conceptual networks accounts well for repetition priming in person recognition. However priming results in object, and name, recognition are difficult to fully reconcile with the structural networks view. In Bruce et al. (2000) a multiple memory systems approach, like the ones of Schacter (1994) and Moscovitch (1994), was suggested for object recognition, instead. In these models perceptual and conceptual systems are not accessed sequentially and tasks can affect facilitations in these networks independently. Recently, rapid response learning and multiple-routes multiple-stages framework have been proposed to account for results in object and word recognition, but not for priming in person recognition.

1.1.2 Episodic model: Rapid response learning

Instance theory (Logan, 1990) is an example of an episodic model of priming. When a stimulus is repeated instances of previous exposures with the stimulus are retrieved from

memory leading to faster and more accurate responding to repeated than not-repeated stimuli. Hommel (1998) supported a similar position with the concept of event-files: a binding between stimulus and response (stimulus-response binding). Retrieval of an instance or an event-file (memory-based processing) can be used to by-pass stimulus processing (algorithmic-based processing) and, consequently, be faster and more accurate in responding to repeated stimuli. The main prediction of instance theory is significant facilitation when study and test contexts are identical, but it is unclear how instance retrieval is managed after changes in perceptual (different stimulus) or conceptual (different task) aspects of the stimulus and the task at test. Logan & Etherton (1994) showed that an instance is retrieved even for stimuli partially similar to the encoded ones. However, it is not clear whether an instance is retrieved regardless of the task. After a change of task, retrieval of an instance can produce priming in response times but retrieved content could be inappropriate for the new task and so negative effects may be observed in accuracy performance. Otherwise, retrieval could be blocked when task instructions are changed; in this condition no priming is expected because algorithmic-based processing does not allow any facilitation.

Dobbins et al. (2004) presented the first clear evidences in favour of a blocking account of instance theory (see also Schacter, Dobbins, & Schnyer, 2004). In the Dobbins et al. (2004) paradigm, the same pictures of repeated stimuli were presented throughout the different phases of the experiment and tasks required always accessing and using the same semantic information; what differed from regular priming paradigms was the categorical cue that could determine a change of the output: categorical cues could be identical (i.e. “bigger than?” – Yes, “bigger than?” - Yes) or reversed (i.e. “smaller than?” – No, “bigger than?” - Yes). Importantly, the used design, in which perceptual and conceptual properties of the stimulus and task were unaltered, ruled out any possible modulation of facilitation in

perceptual and conceptual aspects on priming. On the other hand, retrieval of a prior episode for studied items was blocked by changing the direction of the categorical cue in a size judgement task (from “bigger than” to “smaller than” a shoebox). Behavioural and neuronal priming was observed when categorical cues at study and test were identical (i.e., when responses at study and test were identical) whereas both behavioural and neural priming effects were eliminated when categorical cues were reversed (i.e., when the previously given response was inverted).

Evidence that response reversal can lead to elimination of priming effects has been interpreted as rapid response learning (Dobbins et al., 2004). According to rapid response learning, stimuli at study are bound to a response; the obtained stimulus-response binding is then reactivated at test only when task instructions are identical. The main difference between instance theory and rapid response learning is that in the former instances are automatically activated every time a primed stimulus is presented, while in the latter stimulus-response binding is retrieved only for the identical but not the reversed task instruction. In this way, rapid response learning accounts for the absence of any facilitation in response times and no negative priming in accuracy for reversed task instruction condition. Importantly, inversion of categorical cue abolished priming, or generated negative priming, as predicted by pure episodic models (Waszak, Hommel, & Allport, 2003).

Schnyer, Dobbins, Nicholls, Schacter and Verfaellie (2006) replicated most of Dobbins' et al. (2004) results and showed that retrieval of stimulus-response binding is blocked not only when a stimulus is presented in a phase with different task instruction but also when task instructions have been changed before, for example when a test phase with reversed categorical cue is performed between study and test phases with identical task instruction. This finding further supports rapid response learning and advances the

understanding about how the cognitive system utilizes stimulus-response binding to produce repetition priming.

Having demonstrated that rapid response learning is a good model for repetition priming in object recognition, recent studies on the topic have focused on understanding the nature of the association between stimulus and response and the level of generalization of these two constituent elements.

Rapid response learning is considered a form of incidental associative learning dependent on medial temporal lobe structures. Amnesic patients do not show any benefit in giving the same response at study and test (Schnyer et al., 2006), which suggests that rapid response learning – and consequently priming – depends on cerebral structures assigned to episodic memory encoding and retrieval. Importantly, facilitation was not completely abolished in amnesic participants, particularly for stimuli primed at study by a single presentation, indicating the existence of alternative sources of facilitation not affected by amnesia. Contrary to other forms of associative learning, the creation of stimulus-response binding is incidental (Naveh-Benjamin et al., 2009) and therefore not affected by aging (Dew & Giovanello, 2010; Schnyer et al., 2006): inversion of categorical cue equally affects facilitation in both young and old age groups.

Schnyer et al. (2007) showed that stimulus-response effect does not generalize to different pictures of a stimulus, even for stimuli judged to be highly visually similar. This result was taken as an indication of high specificity to the primed stimulus of stimulus-response binding (for opposite results see: Denkinger & Koutstaal, 2009; Horner & Henson, 2011b; Wig, Buckner, & Schacter, 2009). Regarding the response constituent element of the binding, Schnyer et al. (2007) did not replicate the results of Dobbins et al. (2004) of specificity of the stimulus-response binding to motor mapping but instead found that changing the finger mapping did not affect the stimulus-response effect (but see

Dennis & Perfect, 2013) suggesting a more general response representation of the output. In agreement with Logan (1990), Schnyer et al. (2007) suggested that the association behind rapid response learning is a binding between a stimulus and an interpretation (“classification decision”). Although studies carried out by Schnyer et al. give strong support to rapid response learning, significant priming for reversed categorical cue, condition in which algorithmic-based processing is not by-passed, suggests the existence of secondary sources of facilitation, probably tuning of both perceptual and conceptual processing.

Rapid response learning can provide an account of priming when same task is used, as in most investigations on repetition priming (see previous section) but modulation of facilitation according to the specific exemplar or format of a stimulus is incompatible with high specificity of the input of stimulus-response binding (Horner & Henson, 2011b). However, the hardest challenge for rapid response learning is facilitation even when different tasks are used (Horner & Henson, 2009; Race et al., 2010) or the reference size is changed (Horner & Henson, 2011b), because retrieval of a memory trace created in a different task does not allow any facilitation in the new context. A similar facilitation is particularly evident in person recognition (Burton et al., 1998; Johnston & Barry, 2006), but not so much in object recognition as some studies have found that priming across tasks is weak and unreliable (Bruce et al., 2000; Vriezen et al., 1995).

In summary, rapid response learning accommodates for facilitation when categorical cues at study and test are identical (identical-question condition), but not significant facilitation when categorical cue at study and test are reversed (reversed-question condition). This last finding provides evidence against a pure memory-based model of priming, and demonstrates the need for a secondary form of facilitation not based on

retrieval of instances. A hybrid framework of structural and episodic models could provide a more reasonable account of significant priming for the reversed-question condition and significantly smaller priming in this condition compared to priming for the identical-question condition. The simultaneous occurrence of these effects indicates that structural and episodic models are not mutually exclusive but complementary.

1.1.3 Hybrid model

The multiple-routes multiple-stages framework (Horner & Henson, 2009) is a hybrid model of repetition priming (see Figure 2 for an example of the framework adapted to person recognition). It combines structural and episodic models to account for most priming results. According to this framework priming arises principally from memory-based processing - rapid response learning - however facilitation can be produced by algorithmic-based processing - facilitation in perceptual and conceptual networks - as well. On the first presentation, stimulus processing is tuned by strengthening of links between units/nodes of perceptual and conceptual networks and simultaneously a memory trace is created. For successive repetition of a stimulus, priming is determined by the interaction between response features retrieved from memory and response features obtained from stimulus reprocessing.

Larger facilitation for the identical-question than the reversed-question condition is caused by positive interaction between responses (for example yes-yes) when categorical cues are identical but similar interaction between responses (for example yes-no) is negative when categorical cues are reversed. According to an interaction account, the fastest route (the memory-based processing) is activated but the retrieved response is not expressed immediately because it must be first compared with the output of algorithmic-based processing, and so the generation of responses no more correct in new task contexts

is blocked. Interaction between responses can also explain larger priming for congruent than incongruent responses when a different task is used at test. Similar to the processes when categorical cues are reversed, interaction between responses allows facilitation when responses are congruent but not when responses are incongruent, even when categorical cue is changed.

However, response interaction is not the only source of priming because otherwise priming within tasks and across tasks in the two congruency conditions should be equal, whilst it is larger within tasks than across tasks (Horner & Henson, 2009). One explanation for the dissimilar pattern of priming effects across these conditions has been the incorporation of an additional stage in stimulus processing, a classification code. When a categorical judgement is performed, the stimulus is associated not only with a response but with a task-specific classification (stimulus-classification binding) that can be retrieved when the stimulus is presented again, and this represents an additional stage where priming can occur. In other words, having classified a stimulus as “bigger than” in a size judgement task allows one to be faster in the size judgement task independent of the direction of the question, but not in other tasks, like natural/manmade.

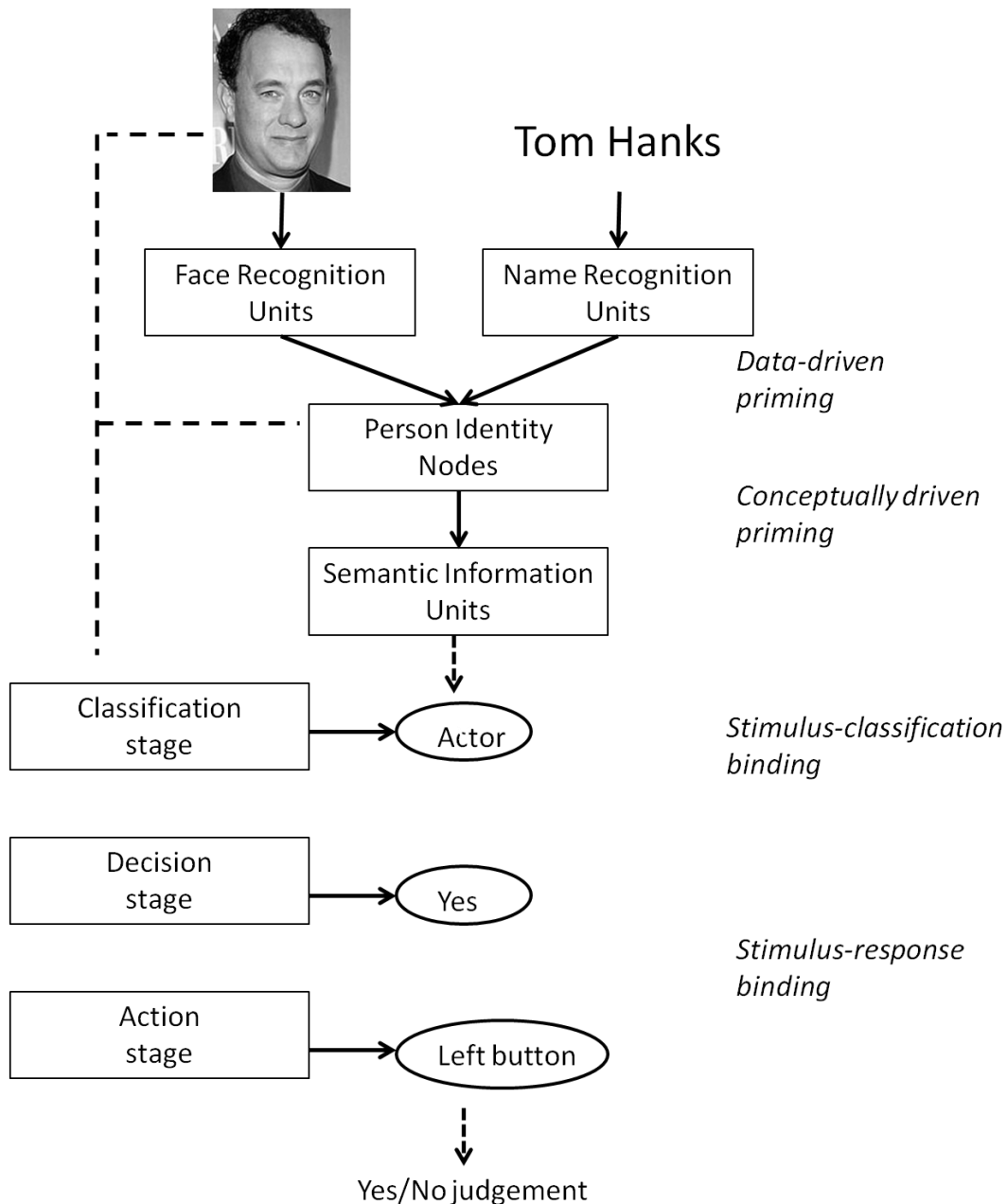


Figure 2 Illustration of the most relevant parts of multiple-routes multiple-stages framework (Horner & Henson, 2009) adapted for person recognition in a speeded classification of occupation. Solid arrows represent pre-existent links that can be strengthened by repetition; dotted lines represent the output that cannot be strengthened by repetition. Circles represent stages of interaction between the two routes from where most of repetition priming is generated.

It is important to underline that the interaction between responses can cause both facilitation and interference, as shown by negative priming in response time for incongruent responses across tasks (Race et al., 2010). A similar negative effect could be masked, but still exist, within tasks by larger facilitation due to classification.

Moutsopoulou & Waszak (2012) provided compelling evidence for how different response codes can operate independently in producing facilitation or interference. A match between outputs of the two routes in a stage determines facilitation, while a mismatch can determine interference. Dennis & Perfect (2013) showed that facilitation of a match for one stage can be cancelled by inhibition caused by a mismatch at another stage.

This framework explains repetition priming mainly as an effect of rapid response learning, whereby priming due to facilitation in perceptual and conceptual networks is considered possible but secondary to overall priming. In effect it seems that algorithmic-based processing is required only as a control to memory-based processing, but most of facilitation occurs beyond the semantic system, when classification and response codes interact. The clearest evidence in support of a similar interpretation is that repetition priming across tasks, if averaged between congruency condition to eliminate any facilitation or cost due to response codes, is not significant, ruling out potential contribution of facilitation in perceptual and conceptual networks. Moreover, significant within-task repetition priming is interpreted not as facilitated stimulus reprocessing (as predicted by facilitation in perceptual and conceptual networks) but positive retrieval of a stimulus-classification binding. Consequently, even if the multiple-routes multiple-stages framework is a hybrid model, it seems that facilitation associated with prior exposure is mainly the product of episodic memory compared to structural changes in long term perceptual and semantic stores.

The properties of stimulus-response binding have been further detailed to account for the modulation of repetition priming due to modification of the stimulus and task. Stimulus-response binding is not stimulus-specific but identity-specific. Retrieval of a memory trace affects performance when different pictures of objects are used in study and test phases (Denkinger & Koutstaal, 2009; Wig et al., 2009; but, see also Schnyer et al.,

2006), and even when names of objects are used at study and pictures of objects are used at test (Horner & Henson, 2011a, 2011b, 2012). However, priming is larger when the same stimulus is presented at study and test compared to a change of exemplar or a change of format: similar attenuation could be an effect of data-driven and conceptually driven priming occurring before the retrieval of the instance. An alternative explanation could be that the binding codes both stimulus-specific and identity-specific representations and both can contribute to repetition priming (Horner & Henson, 2011b).

Likewise, a reinterpretation of the response component of the binding has been necessary to accommodate some new results. Three different bindings are suggested (Horner & Henson, 2009): Classification (for example, „bigger“ or „smaller“), decision („yes“ or „no“), and action („left finger press“ for a positive manual response or „Yes“ for positive verbal response). Decision and action generally go together; therefore the umbrella term “response” is used to describe their combined contribution. Dennis & Perfect (2013) isolated the independent contribution of decision to repetition priming by changing task and response modality (verbal to manual); while the independent contribution of action was isolated by changing task and labelling buttons with a categorical name (bigger or smaller) instead of decision (yes or no). The findings showed that decision and action can contribute to priming independently. Classification has never been isolated from decision or action codes but, nevertheless, its influence on priming was analysed. Horner & Henson (2009) changed the size of the reference (from shoebox to wheelie-bin – to modulate the impact of classification) and the categorical cue (from smaller to bigger – to modulate the impact of response). Classification was assessed as the difference between amounts of priming for congruent classifications (an elephant is bigger than a shoebox and a wheelie-bin) and for incongruent classifications (a chair is bigger than a shoebox but smaller than a wheelie-bin); similarly response was assessed as

difference between amounts of priming for congruent decisions (yes-yes, no-no) and for incongruent decisions (yes-no, no-yes). Results showed larger priming for congruent than incongruent classification and larger priming for congruent than incongruent decisions: supporting the existence of both a stimulus-classification binding and stimulus-response binding.

According to the multiple-stages part of this framework, priming is greatest when questions at study and test are identical because of the contribution of stimulus-response and stimuli-classification binding, and reduced, but still significant, when the questions are reversed because of the absence or inhibition of stimulus-response binding. For different questions, only stimulus-response binding is involved in the interaction and positive or negative effects are obtained according to the congruency of responses given at study and test. Priming can be further modulated by the format of input but whether this effect is caused by different stimulus-specificity of memory-based binding or facilitation in perceptual and conceptual level is unclear.

The multiple-routes multiple-stages framework accounts quite well for most priming results in object recognition, particularly the absence of priming across tasks (Bruce et al., 2000; Vriezen et al., 1995). However, the predictive power of this framework is low in person recognition: firstly because no facilitation beyond the semantic system has ever been reported before in person recognition; secondly because of significant facilitation across tasks regardless of response congruency, thirdly because of the high sensitivity of priming to modification of the stimuli, for which the suggested explanation sounds unsatisfactory. Most of these difficulties could be solved by considering a higher impact of facilitation in algorithmic-based processing in repetition priming.

The multiple-routes multiple-stages framework presents a theoretical limitation. If the outputs of memory-based processing and algorithmic-based processing must be

compared before a response can be expressed, response times should be determined principally by the slowest, not the fastest, processing, therefore by algorithmic-based processing. Consequently, priming should mainly be determined by facilitation occurring in the algorithmic-based processing, and enhanced or inhibited by the successive interaction with rapid response learning. A similar interpretation if correct would completely reverse the weights of memory-based and algorithmic-based processing to priming, underlining the major contribution of the latter. However, no significant priming across tasks is incompatible with the expectation of significant data-driven and conceptually driven priming, unless retrieval of a stimulus-classification binding generates strong interference in new tasks. Alternatively, considering no facilitation in algorithmic-based processing, larger facilitation within tasks than across tasks could be determined by the utilization of a stimulus-classification binding to compute a response within tasks, but not across tasks. However, a similar interpretation presents the limit of how the cognitive system utilizes stimulus-classification binding when the size of the reference is changed, as in Horner & Henson (2009), determining the need of re-computing the size according to the new reference.

In conclusion, the multiple-routes multiple-stages framework seems to be the best model for repetition priming in object recognition, but the secondary role of facilitation in perceptual and conceptual networks makes it less powerful in accounting for repetition priming in person recognition. In addition, the dynamic interaction between the two routes at the different response stages is unclear.

1.1.4 Event-related potentials

Event-related potentials (ERPs) correlates of repetition priming have been

extensively investigated in the domain of person recognition. Most of the studies have used immediate repetition but the obtained effects did not survive longer lags between repetitions (Schweinberger, Pickering, Burton, & Kaufmann, 2002). The fast decay rate of these short-lag ERP correlates of stimulus repetition could index processes other than priming (Bentin & Peled, 1990). ERP components of short-lived priming were observed in the time-window 200-300 ms (Hertz, Porjesz, Begleiter, & Chorlian, 1994), particularly the so called N250r (Schweinberger, Pickering, Jentsch, et al., 2002). On the other hand, long-lived repetition priming has often been obtained as centro-parietal positivity in a later time-window, starting at around 400 ms (Henson, Rylands, Ross, Vuilleumeir, & Rugg, 2004; Schweinberger, Pickering, Burton, et al., 2002). Whether this effect indexes repetition priming or other types of memory is a matter of debate.

Episodic memory contamination represents a strong challenge for the interpretation of electrophysiological data (Rugg et al., 1998): electrophysiological correlates of stimulus repetition could be, in fact, an expression either of repetition priming or episodic memory. Many approaches, which do not rely directly on awareness, have been used to distinguish repetition priming from episodic memory. Most of these approaches employed analyses of how experimental manipulations that affects repetition priming but not episodic memory influence ERPs, and, vice versa, how ERPs are influenced by experimental manipulations that boost episodic memory but not repetition priming. Repetition priming, but not episodic memory, is modulated by perceptual changes in the stimulus material, such as presentation of words backward (Paller & Gross, 1998) or presentation of faces upside-down (Boehm, Klostermann, & Paller, 2006). Episodic memory, but not priming, is influenced, instead, by level of processing manipulation (Rugg et al., 1998), combination of brief presentation time and attentional engagement (Paller, Hutson, Miller, & Boehm, 2003) or by engaging subjects in a working memory task (Boehm & Sommer, 2005).

Neural correlates of long-lasting repetition priming have been identified as small brain potentials ($1\mu\text{V}$) whose time course and topography vary in relation to task and material, implying the existence of one or more specialized mechanisms in stimulus processing. For example, in the absence of awareness, the repetition of a picture of a face produces a negative potential over frontal electrodes between 200 and 300 ms (Paller et al., 2003), while repetition of a word produces a positive potential over parietal electrodes between 300 and 500 ms (Rugg et al., 1998). Whether the cognitive function indexed by these ERPs is perceptual or conceptual, is not clear yet.

The neural correlates of episodic memory are instead large potentials (around $2\mu\text{V}$) whose time course and topography are consistent across a large number of experiments and stimulus materials. ERP correlates of episodic memory have a frontal to central positivity around 300-500 ms, and a left parietal positivity around 500-800 ms (Rugg et al., 1998). These ERP correlates are generally called Old/New effects because they result from the contrast of correctly recognised studied stimuli as old and correctly recognised unstudied stimuli as new. Successive investigations have associated these two Old/New effects with qualitatively different memory processes: respectively, familiarity (mid-frontal Old/New effect) and recollection (parietal Old/New effect) in a dual-process model (Yonelinas, 2002). The mid-frontal Old/New effect is not affected by level-of-processing manipulations and occurs for all the correct recognitions, no matter the quality of the judgement, high-low certainty or with/without context. The parietal Old/New effect, instead, is present after deep encoding (Rugg & Yonelinas, 2003) and is associated with judgements in which the participants report a high confidence rate or are able to describe the study context.

In the time-window succeeding the parietal Old/New effect, there is often an inversion of polarity at parietal electrodes. This ERP correlates is an effect often evident in

episodic memory source judgement tasks, and it is called late posterior negativity (Hayama, Johnson, & Rugg, 2008; for a review see Johansson & Mecklinger, 2003). This effect has been decomposed into an early component of action monitoring in high-response conflict designs and a late component of post-retrieval processes (Herron, 2007).

ERPs can be used to distinguish facilitation in perceptual and conceptual networks from rapid response learning. A significant contrast between novel and repeated stimuli regardless of the question at study (identical, reversed or orthogonal) is a clear indication of data-driven and conceptually driven priming; further modulation of similar ERP components in relation to exemplar or format of the stimulus would give strong support to a similar interpretation. On the other hand, a significant difference between ERPs for repeated stimuli due to congruency or incongruency of responses at study and test is evidence of retrieval of a stimulus-response binding.

The first study carried out to distinguish ERP correlates of facilitation in perceptual and conceptual networks from ERP correlates of rapid response learning was conducted by Race et al. (2010) in object recognition. An ERP correlate of facilitation in perceptual and conceptual networks was found as a negativity around 400 ms (according to its timing this effect was interpreted as facilitation in conceptual networks). Stimulus-response binding was indexed by an ERP modulation caused by response congruency of response congruency around 450 ms after stimulus onset (two response-locked ERPs, one before and one after response time, were also reported); an ERP correlate of stimulus-classification binding was reported around 600 ms after stimulus onset. A second study was carried out by Horner & Henson (2012). They found an ERP correlate of networks facilitation in stimulus-locked analysis and an ERP correlate of rapid response learning in response-locked analysis. These data were supported by effects of networks facilitation

and rapid response learning in brain activity, measured with fMRI. In a recent study Hsu and Waszak (2012) found an ERP correlate of stimulus-classification binding but did not find any ERP correlates of facilitation in perceptual and conceptual networks or stimulus-response binding. However, ERP correlates of stimulus-classification binding might be correlates of facilitation in conceptual networks instead.

In summary, ERP studies have shown that electrophysiological correlates of rapid response learning have been regularly obtained when tested directly but they vary across experiments. ERP correlates of networks facilitation were also found in Race et al. (2010) and Horner & Henson (2012), but not in Hsu and Waszak (2012). Due to the high variability of the results, electrophysiological data do not support any specific interpretation of repetition priming.

1.1.5 Functional magnetic resonance imaging

Repetition of a stimulus results in a decrease of BOLD (blood-oxygenation level dependent) signal in specific areas of the brain: this phenomenon is called neural priming (Schacter & Buckner, 1998). When a picture of an object is repeated in, for example, a yes/no judgement task repetition related suppression effects are found throughout the brain typically including the occipital, infero-temporal and prefrontal regions of the cortex (Buckner et al., 1998).

Studies that have explored the relationship between repetition suppression and behavioural priming effects have found a correlation between neuronal priming and behavioural priming in frontal lobe, particularly in the left inferior frontal cortex for scenes and the left middle frontal gyrus for faces, but not in visual regions associated with stimulus processing (parahippocampal cortex and fusiform cortex) (Bunzeck & Düzel,

2006). Further support for a crucial role of the prefrontal cortex in repetition priming comes from transcranial magnetic stimulation (TMS) studies (Thiel et al., 2005; Wig, Grafton, Demos, & Kelley, 2005). TMS administered over left inferior frontal gyrus, but not over a control location, disrupts both neuronal priming in this region and behavioural repetition priming (Wig et al., 2005). Together, these results provide evidence for the involvement of a network of occipital, temporal and frontal areas in processing repeated stimuli, but only changes in frontal areas seems to be causally linked to repetition priming.

The relationship between episodic memory and repetition priming has attracted less attention in fMRI studies compared to ERP studies. The approach that has generally been used is the distinction of these two memory processes according to subsequent memory: at the end of a priming experiment, participants had to perform old/new judgement on repeated (primed) and novel stimuli: Hits represent primed stimuli with episodic memory while misses represent primed stimuli without episodic memory. Turk-Browne, Yi & Chun (2006) showed that neuronal priming and behavioural priming were significant for remembered stimuli, but not for forgotten stimuli; moreover, the correlation between neural and behavioural priming was significant in the fusiform gyrus, and nearly significant in the right inferior prefrontal cortex.

According to facilitation in conceptual and perceptual networks, activity reductions seen with fMRI associated with priming are thought to reflect facilitation in processing perceptual and conceptual information (Grill-Spector, Henson, & Martin, 2006; Henson, 2003; Schacter & Buckner, 1998). This interpretation is supported by three properties of neural priming: it takes place in brain regions involved in processing the stimulus material, it is not restricted to a single region but includes multiple brain regions, and it is task-dependent. Neural priming is considered to be result of a reduction in the number of

neurons engaged by processing repeated stimuli (sharpening model) or shorter processing time (facilitation model) in comparison to processing a stimulus for the first time (Grill-Spector et al., 2006).

Neural priming in the ventral temporal region is considered the manifestation of facilitation in perceptual networks: for example, repeated famous faces produce a decrease of the signal in the right lateral fusiform region (Henson, Shallice, Gorno-Tempini, & Dolan, 2002). Wig et al. (2009) further advance this point by showing that repetition of an object is accompanied by repetition suppression in the inferior temporal gyrus and the fusiform gyrus regardless of task instruction, and similar reduction of activity is modulated by the visual similarity of the stimuli: higher for the identical compared to a different picture of a stimulus. In addition, Vuilleumier et al. (2002) showed a different sensitivity to change of visual characteristics of objects (shape and viewpoint) in the left and the right fusiform region: neural priming was perceptual-specific in the right but not in the left fusiform region (Eger, Schweinberger, Dolan, & Henson, 2005; Koutstaal et al., 2001). Simons, Koutstaal, Prince, Wagner & Schacter (2003) replicated this laterality effect and found that only the left fusiform region benefits from lexical/semantic processing

Repetition suppression in left inferior prefrontal regions is thought to reflect facilitation in conceptual networks: neural priming for repeated words is significant for stimuli primed by both identical and different tasks, but larger for identical task (Wagner, Koutstaal, Maril, Schacter, & Buckner, 2000). Horner & Henson (2011a), found that occipito-temporal and prefrontal cortex undergo repetition suppression even for pictures of objects primed by names of objects regardless of task instruction: the absence of any possible contribution from data-driven priming in the present cross-domain design provides strong evidence of facilitation in conceptual networks in these two cortical areas.

On the other hand, rapid response learning offers a new interpretation of neural priming. Reduction in neural activity for repeated stimuli is not the effect of more efficient neuronal processing but from truncated processing as a consequence of by-passing these networks. A by-pass of stimulus processing stages for primed but not unprimed stimuli would result in signal decrease when activity for unprimed stimuli is subtracted from no activity, because processing stages are by-passed for primed stimuli.

Although Dobbins et al. (2004) found that reversing the task had an effect on repetition suppression even in temporal regions, including the fusiform area, most of the successive fMRI studies showed that rapid response learning could account only for modulations of activity in the prefrontal cortex (Dobbins et al., 2004; Horner & Henson, 2008, 2011a, 2012; Race, Shanker, & Wagner, 2009; Wig et al., 2009). Moreover, Race et al. (2008) found two distinct patterns of repetition suppression in lateral frontal cortex due to rapid response learning at the classification and decision/action levels: the first was more frontal than the second. It is important to underline that neural priming in the prefrontal cortex, generally interpreted as rapid response learning, co-occurred with neural priming in occipital and temporal regions, and these effects were interpreted as network facilitation (Horner & Henson, 2008, 2011a, 2012; Race et al. 2009; Wig et al., 2009; but see Dobbins et al., 2004).

To conclude, most neuroimaging studies have provided evidence in support of a hybrid model of repetition priming. Changing stimulus-response binding has typically been associated with an elimination of repetition suppression in the frontal lobes, suggesting that this region is involved in producing instance-based priming effects. In contrast, altering the perceptual properties of a stimulus has been shown to modulate repetition priming in visual regions of the occipital and temporal lobes, indicating that

repetition can induce changes in perceptual and conceptual brain networks.

1.2 Overview of the thesis

The general picture that emerges from the wide literature on repetition priming is that an episodic model can account quite well for repetition priming in object recognition, even better if retrieval of a memory trace interacts with some structural processing in consideration of new task requirements. The main behavioural evidences in support of a strong influence of memory-based processing in object recognition are: 1) larger priming for stimuli primed by an identical question compared to stimuli primed by a reversed question, 2) larger priming for congruent than incongruent response conditions across tasks, 3) negative priming for incongruent response conditions across tasks, 4) absence of any net priming across tasks when data are collapsed across congruency conditions.

On the other hand, facilitation in perceptual and conceptual networks provides a useful account of repetition priming in person recognition. It sounds unreasonable to consider any rapid response learning or multiple-routes multiple-stages framework in the domain of person recognition because priming across tasks is significant (against point 4), and congruency of responses across tasks does not have any significant impact on priming (against point 2), in fact priming across-task is positive even for incongruent responses (against point 3). Inversion of categorical cue has never been employed in person recognition, leaving open the possibility that repetition priming plays an important role within tasks (point 1).

In the present thesis the influence of a memory-based processing in repetition priming in person recognition is investigated.

Chapter 2 addresses the question: *Does rapid response learning significantly*

influence priming in person recognition? Experiment 1 employed a design as similar as possible to designs used in object recognition, adapted for person recognition. Participants had to make height judgement to repeated faces of celebrities presented three times at study and again at test among faces of celebrities never presented before. Categorical cues at study and test were identical in some study-test cycles (shorter-shorter or taller-taller) and reversed in others (shorter-taller or taller-shorter). Memory-based processing was assessed as a stimulus-response effect: a significant difference between the amount of priming for identical task instructions and the amount of priming for reversed task instructions. Significant stimulus-response effects would be unquestionable evidence of facilitation beyond perceptual and conceptual networks, a plausible consequence of retrieval of a memory trace. Absence of significant stimulus-response effects would be evidence, instead, for independence of repetition priming from memory-based processing.

A significant stimulus-response effect in Experiment 1 moved the investigation toward understanding the experimental conditions that favour rapid response learning in person recognition. Chapter 3 addresses the question: *Which experimental factor gives rise to rapid response learning in person recognition?* Three experimental factors were identified, according to the literature, as potential sources of the formation and use of a memory trace in the design. Task, arrangement of study and test phases, and number of stimulus repetitions were cumulatively subtracted from the design used in Experiment 1. In this way, step-by-step, the experimental design became similar to designs in which no evidence of rapid response learning in person recognition has yet been shown. Experiment 2 employed a regular categorical task for investigating person recognition, occupation judgement, instead of height judgement task, differently to Experiment 1; Experiment 3 employed a design made up of a single test phase preceded by two study phases, instead of study-test cycles, differently to Experiment 2; Experiment 4 employed single repetition of

stimuli at study, instead of triple presentations of stimuli at study, differently to Experiment 3. Subtraction of the crucial experimental factor would determine disappearance of the stimulus-response effect, indicating that rapid response learning is no longer effective in the specific experimental design. Disappearance of the stimulus-response effect is expected in the present series of experiments because Experiment 4 employed a design that has been widely used in person recognition and no evidence of facilitation due to retrieval of a stimulus-response binding has ever been reported previously. If the stimulus-response effect resists all this subtractions, this would indicate that rapid response learning in person recognition has never been isolated before because it has never been tested directly as in Experiment 1.

Chapter 4 further investigates which experimental factor is necessary for the creation and retrieval of a memory trace. Experiment 5 addressed the question: *Are multiple stimulus repetitions at study required for rapid response learning in person recognition?* Stimuli were repeated only once at study in a design made up of study-test cycles to investigate whether multiple presentations of stimuli at study are necessary for rapid response learning. If stimulus-response binding requires multiple stimulus repetitions at study, the stimulus-response effect should be not significant in this design, replicating results of Experiment 4. Experiment 6 addressed the question: *Is stimulus-response binding short-lived? Or does it require contiguity of phases with identical task instructions to be expressed?* The influence of the design used in Experiment 3 (study-study-test) is investigated with a focus on the effect of lag on rapid response learning. The separation between study phases is temporally expanded in such a way that lag-effect would abolish rapid response learning in this experiment. Alternatively, rapid response learning should be significant only when contiguity of phases with an identical categorical cue is not interrupted by an intervening phase with a reversed categorical cue.

In Chapter 5 the focus switches from rapid response learning to facilitation in the perceptual and conceptual networks. Two experiments address the question: *Is facilitation in the perceptual and conceptual networks obliterated by rapid response learning?* An orthogonal task was performed in a study-test cycle: response at test was congruent to responses given at study for half of the stimuli but incongruent for the other half. Significant across-task priming for incongruent response should be unquestionable evidence of facilitation in perceptual and conceptual networks, given that no facilitation can be generated by rapid response learning. None significant priming in this condition would argue otherwise: rapid response learning makes other forms of facilitation, generally present in other priming conditions, no longer behaviourally relevant to repetition priming in person recognition.

Chapter 6 aims to explore the processes behind rapid response learning. EEG signal was recorded to extract ERPs and lateralized readiness potentials (LRP) to address the question: *Is rapid response learning a benefit of giving the same response again or an effect of interaction between responses?* Electrophysiological activity associated with repetition priming was analysed to detect evidence of activation of the wrong response after inversion of a categorical cue. Such activation, evident in LRPs, would be clear evidence that stimulus-response binding is activated independent of the correctness of the associated response, because the retrieved output interacts with the output of stimulus re-processing determining facilitation or interference. The absence of a similar activation would give support to an interpretation of rapid response learning as retrieval of a stimulus-response binding exclusively when output is correct.

The results are discussed in Chapter 7 according to structural model – facilitation in conceptual and perceptual networks -, episodic model – rapid response learning – and hybrid model – multiple-routes multiple-stages framework.

Chapter 2

Rapid response learning has been extensively reported in speeded semantic classification tasks in the domain of objects but never in other domains. Consequently, at present, rapid response learning cannot be considered a general theory of priming because of the lack of evidence of its influence in domains other than objects. For instance, priming in the domain of person recognition is generally explained as facilitation in perceptual and conceptual networks, and no facilitation beyond these networks has ever been reported. Experiment 1 aimed to directly investigate rapid response learning in person recognition. A design as similar as possible to that used to study rapid response learning in object recognition was employed with faces as stimuli. Stimuli were presented three times at study, and once at test among new stimuli. A height judgement was required; categorical cue at test was *identical* to the categorical cue at study in two study-test cycles and *reversed* in two study-test cycles. Results showed that facilitation for repeated stimuli in response times was significantly smaller in cycles with reversed categorical cues compared to cycles with identical categorical instructions. This finding is the first direct demonstration of stimulus-response binding outside the domain of objects, showing that rapid response learning is not specific to object recognition.

Does rapid response learning influence significantly priming in person recognition?

2.1 Introduction

Since the publication of the groundbreaking paper by Dobbins et al. (2004), rapid response learning has been exclusively investigated in speeded semantic classification tasks of objects, using either pictures of objects (Denkinger & Koutstaal, 2009; Dew & Giovanello, 2010b; Dobbins et al., 2004; Horner & Henson, 2008, 2009, 2011a, 2011b, 2012; Hsu & Waszak, 2012; Moutsopoulou & Waszak, 2012; Schnyer et al., 2007; Schnyer et al., 2006; Wig et al., 2009) or names of objects (Dennis, Carder, & Perfect, 2010; Dennis & Perfect, 2013; Dennis & Schmidt, 2003; Hsu & Waszak, 2012; Race et al., 2010; Race et al., 2009) as test stimuli; even novel objects have been used to test rapid response learning in speeded perceptual classification tasks (Saggar, Miikkulainen, & Schnyer, 2010; Soldan, Clarke, Colleran, & Kuras, 2012). Although the extensive corpus of data in speeded semantic and perceptual classification of objects suggests that rapid response learning is able to account for most, or even all, repetition priming effects in object recognition (Horner & Henson, 2009), the status of universal interpretation of repetition priming cannot be granted yet.

Repetition priming is a form of memory present in recognition tasks of stimuli other than objects, such as, for example, person recognition (Bruce & Young, 1986). In fact, in person recognition many elegant theoretical achievements have been obtained in the interpretation of repetition priming (Boehm & Sommer, 2012), and the predictive power of Burton's (1998) model of person recognition is the clearest example. High homogeneity of the stimuli, human expertise and strong reliability of priming effects make person recognition the perfect proving ground for rapid response learning in a speeded classification task for stimuli other than objects. However, such an investigation has not

been conducted yet.

In speeded semantic classification tasks of objects, facilitation for repeated stimuli can be entirely explained by rapid response learning (Horner & Henson, 2009). According to rapid response learning, repetition priming is not the effect of facilitation across stages of stimulus processing (algorithmic-based processing) but the effect of by-passing these stages (memory-based processing; Logan, 1990; Schacter et al., 2004). Repeated stimuli are bound to a classification (stimulus-classification binding) and a response (stimulus-response binding) that can be retrieved to carry out the task without the need of any stimulus re-processing. From a similar perspective the amount of priming is determined by the equivalence of classification and response (decision and action) at study and test (Horner & Henson, 2009). Rapid response learning predicts that priming is significantly modulated by the correctness of the classification and the response retrieved from memory in the test context; a similar prediction is supported by the fact that after a change of task, priming is significant only when the response given at study is also correct at test, but not when a different response must be expressed (Race et al., 2010). Horner & Henson (2009) showed that priming was greatest when categorical cues at study and test were identical (for example: “bigger than...” at study to “bigger than...” at test) due to retrieval of stimulus-classification and stimulus-response bindings (within-task condition, identical-question); and reduced by inversion of the categorical cue (for example: “bigger than...” at study to “smaller than...” at test) because retrieval of stimulus-response binding does not produce any facilitation but facilitation arises by retrieval of stimulus-classification binding (within-task condition, reversed-question); and abolished by change in task when responses were incongruent (size judgement at study and natural/manmade judgement at test) because no facilitation can arise from retrieval of stimulus-classification binding or stimulus-response binding (across-task condition). In summary, rapid response learning at

multiple codes is able to account for most priming effects in speeded classification of objects.

On the other hand, over the years cumulative results in studies of person recognition have supported an interpretation of repetition priming as facilitation in perceptual and conceptual networks. Facilitation for repeated stimuli is thought to result from modifications in perceptual and conceptual networks assigned to stimulus processing (Bruce & Young, 1986, 2012; Burton, 1998; Burton et al., 1990; Humphreys et al., 1995). In relation to perceptual and/or conceptual overlap of processes engaged in successive encounters with a stimulus, repetition priming can be data-driven and/or conceptually driven (Jacoby, 1983; Richardson-Klavehn & Bjork, 1988). Data-driven priming is modulated by changes in stimulus material (different pictures of a stimulus at study and test) and abolished by changes in stimulus format (name at study and picture at test); conceptually driven priming is modulated by conceptual requirements of two different tasks (occupation at study and nationality at test) and blocked in perceptual or familiarity judgement tasks. The independence of these two types of facilitation for person recognition has been recently highlighted by Boehm & Sommer (2012). In two experiments they showed that priming for person recognition from faces or names was the combination of data-driven and conceptually driven priming. The amount of priming for a stimulus presented in study and test phases under the same perceptual (identical facial pictures of celebrities – data-driven priming) and conceptual conditions (occupation judgement both at study and test – conceptually driven priming) was identical to the sum of the amounts of priming for stimuli repeated respectively in designs in which perceptual properties (name at study, picture at test – no data-driven priming) and conceptual contexts (familiarity judgement at study, occupation judgement at test – no conceptually driven priming) were modified. The likeness was so perfect that no room for alternative

explanation was left.

These studies present a quite intriguing picture: rapid response learning produces repetition priming in object recognition while facilitation in perceptual and conceptual networks causes repetition priming in person recognition. Whether rapid response learning occurs in person recognition is a question that has never been addressed directly. However, some clues can be found in those experiments that have tested priming in person recognition within tasks and across tasks. As introduced earlier, a change of task obliterates facilitation from retrieval of stimulus-classification binding and blocks facilitation from retrieval of stimulus-response binding for some stimuli and not others. Therefore, studies that used across-task conditions represent a way to find preliminary indications of rapid response learning in person recognition. For instance, greater facilitation within tasks than across tasks in Johnston & Barry's (2006) Experiment 1 may indicate retrieval of stimulus-classification binding; however, this explanation is questionable because similar results would also be expected as modulation of facilitation in conceptual networks. On the other hand, evidence against any involvement of rapid response learning in person recognition is less controversial: across-task facilitation was as large as within-task facilitation when tested from faces to names or vice versa (Burton et al., 1998; Johnston & Barry, 2006), giving no indication of retrieval of stimulus-classification binding; moreover, effect of response congruency across tasks was not significant (Johnston & Barry, 2006), giving no indication of stimulus-classification binding.

Although rapid response learning for person recognition seems to be ruled out, design issues leave open the possibility that effects of binding retrieval have never been obtained before because processes occurring beyond perceptual and conceptual networks have never been properly tested. The use of tasks that do not differ in semantic

requirement but in the utilization of this semantic information allows a similar isolation (Dobbins et al., 2004). In a similar condition, the semantic information accessed to express a size judgement in comparison to a reference size (shoebox) is identical regardless of the categorical cue of the question, “bigger?” or “smaller?”, excluding any modulation of conceptually driven priming; at the same time, presenting the same stimulus at study and test excludes any modulation of data-driven priming. In similar designs any modulation of priming can be attributed exclusively to rapid response learning.

The aim of Experiment 1 was the direct investigation of rapid response learning for person recognition. A design as similar as possible to that employed to study rapid response learning for object recognition was adapted to be suitable in speeded classification tasks of facial pictures of celebrities.

2.2 Experiment 1

Experiment 1 employed a design ideal to study the effect of stimulus-response binding but with faces of celebrities as stimuli. The shoebox task was changed to a size judgement more suitable to be used with people: height judgement. Stimuli were presented three times in study phases and each study phase was followed immediately by the respective test phase where stimuli presented at study were presented again intermixed with new stimuli. The crucial factor, inversion of the direction of task, was implemented by using two categorical cues (taller and shorter) for the height judgement task. Thus, when the categorical cues at study and test were identical (*identical-question condition*) facilitation can be generated from stimulus-classification and stimulus-response bindings; when the categorical cues were different (*reversed-question condition*) response codes retrieved from stimulus-response binding had to be inverted (for example: ‘yes’ became ‘no’, ‘right button’ became ‘left button’) but facilitation can be generated by stimulus-

classification binding.

If repetition priming for person recognition results from rapid response learning, there should be a significant difference in the amount of facilitation in relation to task instruction performed at study (*stimulus-response effect*): priming should be larger in identical-question condition compared to reversed-question condition.

2.2.1 Materials and Methods

2.2.1.2 Participants

Forty-two healthy adults participated in return for course and print credits. The data from two participants were discarded because of technical problems. The mean age of the remaining forty participants (20 females) was 21 years (range 18-40). All participants had normal or corrected-to-normal vision, and four participants were left-handed by self-report. The study was approved by the ethics committee at the School of Psychology, Bangor University, and all participants gave written informed consent.

2.2.1.2 Stimuli

The stimulus set consisted of 272 black and white facial pictures of celebrities (among them: singers, actors, politician, athletes and TV stars). The stimulus set was made up of four sub-sets of 68 stimuli each: two for male celebrities (taller than the reference height vs. shorter than the reference height; for example Arnold Schwarzenegger and Danny DeVito) and two for female celebrities (for example Uma Thurman and Mother Teresa). The difference in average height between male and female celebrities was accounted for by selecting a reference height of 5'10" (178 cm) for male and of 5'05" (165 cm) for female celebrities. The selected celebrities had a height at least 1" above or

below the corresponding gender-specific reference height. The height of selected celebrities was obtained from web pages and internet forums.

An additional 28 pictures were used for practice runs: 7 stimuli for each gender/height sub-set.

2.2.1.3 Procedure

The experiment consisted of four study-test cycles, and initial practice runs. Participants were to express yes/no judgments on a categorical question about the height of famous people. Possible task instructions were “Is the celebrity taller than x?” or “Is the celebrity shorter than x?”, where x referred to the gender-specific reference height.

Male and female celebrities were presented in different cycles because of differences in reference heights, resulting in four cycles. Each cycle consisted of one study and one test phase. In two cycles (one for male celebrities, one for female celebrities), categorical cues in study and test phases were identical (at study “...taller...?” and at test “...taller...?” or at study “...shorter...?” and at test “...shorter...?”), and two cycles (one for each gender) had different categorical cues in study and test phases (“...shorter...?” “...taller...?” or “...taller...?” “...shorter...?”). Half of the participants performed “...taller...?” judgments in test phases, the other half performed “...shorter...?” judgments at test. The order of judgements at study was randomized across participants.

In study phases, 34 celebrities, with an equal proportion of celebrities taller than and shorter than the reference height, were presented three times in semi-random order (second presentation could start only after all the stimuli had been presented once, similarly for third presentation; in addition, immediate stimulus repetition was avoided). In test phases, studied celebrities were presented again (primed stimuli), randomly intermixed with 34 celebrities (17 taller than the reference height) not presented in the experiment before

(unprimed stimuli). Four experimental conditions were obtained: according to the relationship between categorical cues at study and test within the cycle stimuli could be primed at study under same (primed identical-question) or reversed (primed reversed-question) questions; similarly half of unprimed stimuli were incorporated in cycle with identical categorical cues in the two phases (unprimed identical-question) and half of primed stimuli were incorporated in cycles with different categorical cues (unprimed reversed-question).

At the beginning of each phase, task instruction was displayed (for cycles with female celebrities questions were: ‘Is the celebrity taller than 5’05” (165 cm)?’ or ‘Is the celebrity shorter than 5’05” (165 cm)?’; while in cycles with male celebrities the questions had a reference height of 5’10” (178 cm)). Reminders of the categorical cue (‘T’ for taller and ‘S’ for shorter) were placed on paper next to the keyboard, and participants were instructed to change them according to task instruction displayed at the beginning of each phase.

Throughout, stimuli were presented at a size of 11.3x15 deg for 2000 ms at the centre of the screen against a black background, separated for 500 ms by a white fixation cross. Participants pressed the F and J keys of a computer keyboard (labelled respectively ‘yes’ and ‘no’) with their left and right index fingers for ‘Yes’ and ‘No’ answers. Instructions emphasized both speed and accuracy.

At the beginning of the experiment, participants received written instructions about the tasks and had four short practice runs, one for each combination of categorical cue (taller; shorter) and gender (male; female), with seven stimuli each.

2.2.1.4 Data Analysis

Only accuracy and response times data from the final test phases are reported and

analysed (see Appendix 2 for data analysis of accuracy and response times in the study phases). Trials with missing or early responses (response time < 200 ms) in test phases were excluded. In response times analysis, but not in the analysis of accuracy, only correct trials were analysed, and, furthermore, primed stimuli, even if the correct response was given at test, were excluded from the calculation of the averages when at least a wrong response had been given at study; this is a standard procedure in investigations of rapid response learning in order to avoid analyzing primed trials with wrongly bound responses (see Appendix 1 for response times analysis when consistently incorrect trials were considered too).

Priming in the two conditions was assessed as the difference in accuracy and response times between primed and unprimed stimuli (priming identical-question = unprimed identical-question – primed identical-question; priming reversed-question = unprimed reversed-question – primed reversed-question); priming values were contrasted to assess rapid response learning (stimulus-response effect = priming identical-question – priming reversed-question).

Repeated measures ANOVAs were performed on response times and accuracy to check for any interaction of gender on main effects and stimulus-response effect.

Two-tailed paired-samples *t*-tests were applied to mean response times to determine effects of stimulus repetition and stimulus-response binding; for accuracy analyses, the non-parametric test, Wilcoxon signed-rank test was used, instead, because data did not fulfil the assumption of normality. The significance level was set at $\alpha = .05$ for all statistical tests.

Repeated measures ANOVA with categorical cue at test as between participants factors was applied to mean priming levels, to check for any interaction with stimulus-response effect.

2.2.2 Results

Although participants were faster and more accurate in responding to male than female celebrities, gender did not interact with priming or stimulus-response effect, both in accuracy, $F_s(1,39) < 1.66$, $p_s > .205$, and response times analysis, $F_s(1,39) < 0.94$, $p_s > .337$. In upcoming analyses, response times and accuracy data were collapsed across genders.

Missing and early responses (response time < 200 ms) accounted for 1.0% of trials. Accuracy in all the four conditions was significantly larger than change performance (50%), $z_s > 5.33$, $p_s > .001$. Repetition of a stimulus did not significantly improve accuracy, both for the identical-question condition, $z = 1.76$, $p = .079$, or the reversed-question condition, $z = 1.34$, $p = .179$ (see Table 1). The gain in accuracy for stimuli primed with identical categorical cue compared to that of stimuli primed with reversed categorical cue was not significantly larger, $z = 0.28$, $p = .778$.

Table 1
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 1.

Accuracy %	Identical	Reversed
Unprimed	62.6 (1.2)	61.5 (1.2)
Primed	65.1 (1.4)	63.3 (1.2)
Priming	2.5 (1.4)	1.8 (1.4)

A further 33.3% of the primed trials were excluded because of wrong responses at study. Responses to primed stimuli were significantly faster than those for unprimed stimuli regardless of categorical cue at study: for the identical-question condition, $t(39) = 12.53$, $p < .001$; for the reversed-question condition, $t(39) = 9.35$, $p < .001$ (See Table 2).

Table 2
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 1.

Response Times	Identical	Reversed
Unprimed	1053 (25)	1086 (27)
Primed	827 (22)	906 (20)
Priming	225 (18) ***	180 (19) ***

Note: *** $p < .001$.

The stimulus-response effect was significant, $t(39) = 2.28$, $p < .028$ (see Figure 3): facilitation was larger for the identical-question condition compared to the reversed-question condition.

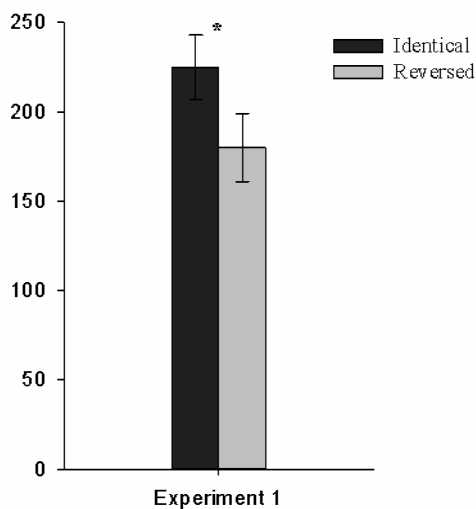


Figure 3 Mean priming (plus standard error) in Experiment 1.
 Note: * $p < .05$.

The between-subjects factor, categorical cue at test, did not interact with the stimulus-response effect, $F(1,38) = 1.58$, $p = .693$.

2.2.3 Discussion

Participants were significantly faster, but not significantly more accurate, in responding at test to stimuli primed in a study phase with identical categorical cue compared to stimuli primed in a study phase with reversed categorical cue. This is the first direct evidence of significant stimulus-response effect in speeded semantic classification task of person recognition and, consequently, indicates that rapid response learning generalizes to recognition of stimuli from domains other than objects, specifically the domain of faces.

Regardless of the identity of categorical cue at study, response times to primed stimuli were significantly faster, but not significantly more accurate, than response times to unprimed stimuli. Similar facilitation, particularly for reversed-question condition, could be either evidence of retrieval of stimulus-classification binding or evidence of facilitation in perceptual and conceptual networks. In fact, a task that requires a comparison of the height of a celebrity to a reference height, like the often used shoebox task, implies that the semantic information retrieved from memory (height of the celebrity) should be further computed (compared to reference height) so that a response can be generated. According to Horner & Henson (2009) a computation output is stored in memory as classification code and can be retrieved to generate a stimulus-classification effect. On the other hand, the same stimulus and the same semantic information were processed both in study and test phases, therefore priming in the reversed-question condition could result from facilitation in perceptual and conceptual networks. To discriminate between these two alternatives, a task that does not need any computation (like occupation judgement) would be preferable (see Chapter 3).

The height judgement task is a task that has never been used before. Low accuracy

demonstrates that participants had a feeling of how tall is a celebrity but this piece of information is probably secondary in the organization of the semantic system. This limitation, evident as low accuracy and high exclusion rate of inconsistent responses across phases, would suggest the replication of these results in an experiment with more regular categorical judgements, like nationality or occupation (see Chapter 3).

In conclusion, results of Experiment 1 show evidence of facilitation in person recognition, in a height judgement task, beyond perceptual and conceptual networks for face perception and recognition; this facilitation is the product of retrieval of a stimulus-response binding, in other words, of rapid response learning.

2.3 General discussion

The present experiment was conducted to directly investigate whether rapid response learning plays any role in person recognition. Reversing the categorical cue at test significantly increased response times compared to keeping categorical cue at test identical: this result is clear evidence of retrieval of a stimulus-response binding in person recognition. In a wider perspective, these results indicate that rapid response learning is not a form of facilitation restricted to recognition of objects, but it generalizes to recognition of people from faces as well.

An important question that emerges from Experiment 1 is why this stimulus-response effect has never been reported before, ruling out rapid response learning in person recognition, and consequently why facilitation in perceptual and conceptual networks has been able to account perfectly for whole priming effects when faces are used as stimuli. Possible reasons could be found in the numerous differences between experimental designs used to study rapid response learning (like the one used in

Experiment 1) and experimental designs generally used to study data-driven and conceptually driven priming. Identification of the experimental “factor x” that involves rapid response learning in the generation of facilitation in performance for repeated stimuli is a crucial piece of knowledge for advancing our understanding of the memory processes supporting priming (see Chapter 3 and Chapter 4).

Whether rapid response learning is a global interpretation of priming remains an open question. Residual priming for the reversed-question condition could, indeed, represent facilitation in perceptual and conceptual networks; in this case, rapid response learning would not be the exclusive mechanism of priming but a complementary explanation. A design that rules out any facilitation from bindings’ retrieval is recommended to shed more light on this critical point: complete abolition of priming in the absence of rapid response learning would imply abandoning facilitation in perceptual and conceptual networks as interpretation of priming in favour of rapid response learning (see Chapter 5).

2.4 Conclusion

The presence of a stimulus-response effect in Experiments 1 is the first demonstration of rapid response learning in a speeded semantic classification task with stimuli from a domain other than the domain of objects, indicating that rapid response learning is not specific to object recognition but generalizes to person recognition too.

Chapter 3

Experiment 1 presented the first evidence of rapid response learning in person recognition. This finding contrasts with the lack of any evidence of facilitation in processes beyond perceptual and conceptual networks for person recognition. A similar new outcome could be justified by the presence in Experiment 1 of some experimental factors unusual to most designs used to study facilitation in perceptual and conceptual networks in person recognition. Three design issues were identified: 1) a task that requires computation of a classification, 2) contiguity of study and test phases, 3) multiple presentations of stimuli at study. In three experiments the relevance of these experimental factors was investigated by cumulatively subtracting them from the design used in Experiment 1. Experiment 2 employed a conventional conceptual task in order to evaluate the relevance of computational processes involved by the task; Experiment 3 employed a conventional study-study-test design to address the relevance of contiguity of study and test phases; in Experiment 4 stimuli were presented only once at study to investigate the importance of multiple study presentations. Results showed that the stimulus-response effect was abolished when stimuli were presented only once at study and when contiguity of study and test phases with identical categorical cues was interrupted by the intrusion of a study phase with reversed categorical cue. These results indicated that contiguity of study and test phases and multiple presentation of stimuli at study are necessary for the creation of stimulus-response binding, and consequently, for rapid response learning in person recognition.

Which experimental factor gives rise to rapid response learning in person recognition?

3.1 Introduction

Inversion of the categorical cue allows modulation of the stimulus-response effect without affecting perceptual and conceptual processing. This experimental factor is generally embodied in a design made up of multiple study-test cycles, where stimuli at study are presented three times in a size judgement task - a similar design is often used in the literature of repetition priming in object recognition and was used in Experiment 1. Three design factors distinguish this design from repetition priming design in person recognition, like the one used by Boehm & Sommer (2012): 1) the task, 2) arrangement of study and test phases, and 3) number of stimulus repetitions at study. In regular repetition priming designs in person recognition a conventional task (occupation judgement) is used, all the study phases precede a single test phase and stimuli at study are presented only once.

3.1.1 Task that requires further computation

Rapid response learning in object recognition is generally studied in so-called “shoebox tasks” (Dobbins et al., 2004; Horner & Henson, 2009; Schnyer et al., 2007; Schnyer et al., 2006); Experiment 1 employed a similar size judgement task. Size is not a discrete but a continuous variable; consequently any categorical judgement should be computed online according to a reference size. Rapid response learning can be, therefore, the consequence of active utilization of semantic information in tasks that require further computations to be carried out (Bruce et al., 2000). The cognitive system could encode the output of *ad hoc* time-consuming computation (either classification or response) and retrieve its content when the stimulus is presented again, involving rapid response

learning. On the other hand, similar encoding and retrieval processes could be limited when the utilization of pre-existent semantic information is sufficient to carry out a more regular categorical task (like occupation judgement), without the need of computations; in this case the stimulus-response effect should be absent because stimulus-response binding is not encoded as it is not necessary for the task. A significant stimulus-response effect in other classification tasks in object recognition, like natural/manmade (Horner & Henson, 2009, Experiment 2), seems to indicate that stimulus-response binding is created even in classical categorical tasks. However, Bruce et al. (2000) showed high dependency of repetition priming in object recognition on the semantic task; therefore, it is still possible that stimulus-response binding in person recognition might need further computations to generate a classification code.

3.1.2 Contiguity of phases with identical question

Rapid response learning was first studied in a design made up of a single study phase followed by two test phases (Dobbins et al., 2004; Schnyer et al., 2007; Schnyer et al., 2006 Experiment 1). Schnyer et al. (2006) showed that breaking contiguity of study and test phase with identical categorical cue by intrusion of a test phase with reversed categorical cue had a significant impact on stimulus-response effect. The role of contiguity in the utilization of a stimulus-response binding has not been investigated further, but it has been neglected and circumvented by the use of designs in which test phases immediately follow the corresponding study phases (Horner & Henson, 2008, 2009, 2011a, 2011b, 2012; Schnyer et al., 2007; Wig et al., 2009); similarly, Experiment 1 used a design made up of study-test cycles. Contiguity of study and test phases makes evident the relationship between task instructions in the two consecutive phases and could promote the use of episodic memory strategies. For example, participants could retrieve the previously

given response for the identical categorical cues or retrieve and invert the previously given response for the reversed categorical cue. Dew and Giovanello (2010a) showed that this is not the case. Awareness that some stimuli were repeated at test and use of memory strategies did not influence associative priming, ruling out this interpretation. On the other hand, contiguity of phases with identical categorical cue could be necessary for utilization of a stimulus-response binding, a particular kind of associative priming. In conclusion, rapid response learning could be favoured by designs in which the relationship between categorical cue at study and test is clear because of contiguity of the two phases but blocked when this relationship is less clear.

3.1.3 Number of stimulus repetitions at study

The need for multiple stimulus presentations to obtain rapid response learning has been an extremely controversial topic. Most consistent and reliable stimulus-response effects have been obtained after two (Wig et al., 2009) or three presentations of stimuli at study (Horner & Henson, 2011b, 2012; Race et al., 2010; Race et al., 2009) but reversing the categorical cue can decrease facilitation even after a single study presentation when stimuli were primed alone (Experiment 1 in Dew & Giovanello, 2010b; Soldan et al., 2012) and for pairs of stimuli (Dennis et al., 2010; Dennis & Schmidt, 2003). However, a significant stimulus-response effect after a single presentation of individual stimuli at study was obtained for long exposure times (Experiment 1 in Dew & Giovanello, 2010b) but not after short presentation times (Experiment 1 in Horner & Henson, 2011a). In addition, studies that presented stimuli one or three times at study, showed that the general trend of rapid response learning was similar in the two repetition conditions but more robust after three repetitions (Dobbins et al., 2004; Horner & Henson, 2009; Schnyer et al., 2007; Schnyer et al., 2006). In conclusion, stimulus-response binding might need multiple

presentations of stimuli at study to acquire sufficient strength to become behaviourally relevant.

These three experimental factors can offer the solution to the question why rapid response learning in person recognition was significant in Experiment 1 but not in other studies on priming for person recognition, like Boehm & Sommer (2012).

3.1.2 Present experiments

The aim of the present series of experiments was to cut as much as possible the distance between experimental design used in Experiment 1, in which stimulus-response effect was significant, and experimental designs generally used to investigate repetition priming in person recognition, in which stimulus-response effect was not significant.

	Task	Design	Number of repetitions	Inversion of categorical cue	Stimulus-response effect
Experiment 1	Size judgement	S-T-S-T	3	Yes	Significant
Experiment 2	Occupation judgement	S-T-S-T	3	Yes	?
Experiment 3	Occupation judgement	S-S-T	3	Yes	?
Experiment 4	Occupation judgement	S-S-T	1	Yes	?
Boehm & Sommer, 2012	Occupation judgement	S-S-T	1	No	Not significant

Figure 4 Representation of factors subtracted step by step from a design (red) that showed significant stimulus-response effect and a design (black) in which stimulus-response effect was not significant. In design column: S = study phase, T = test phase.

Rapid response learning in person recognition was tested directly in three experiments to identify the design factors that give rise to stimulus-response effect. A subtractive procedure was conducted (see Figure 4); starting and ending points of this process were respectively Experiment 1 and Boehm & Sommer (2012). Experiment 1 was

designed to be as similar as possible to experiments carried out to study stimulus-response binding in object recognition (Horner & Henson, 2008, 2009), with the main exception that faces of famous people were used instead of objects. In Experiments 2-4, design factors were cumulatively subtracted. In Experiment 2, instead of size judgement, a judgement that does not require computation of a response (Bruce et al., 2000; see also Barsalou, 1983), like occupation judgement, was used. In Experiment 3 contiguity of study and test phases was interrupted by employing a design in which all the study phases were separated from a single test phase by a distractor task. As the last subtraction, in Experiment 4 the number of stimulus repetitions was reduced from three to one. In conclusion, Experiment 4 was identical to experiments carried out to test repetition priming in person recognition (the only difference was the use of identical and reversed task instructions), in which no evidence of stimulus-response effects have ever been reported (Boehm & Sommer, 2012).

Experiments 2-4 investigated which experimental factor determines the transition from facilitation in perceptual and conceptual networks to rapid response learning: such a transition would be evident as disappearance of any significant difference in facilitation for repeated stimuli due to prime history (identical and reversed categorical cue), the so-called stimulus-response effect.

3.2 Experiment 2

In Experiment 2, rapid response learning in person recognition was tested in an occupation judgement task. Occupation judgement is a canonical task to study repetition priming in person recognition and it is based on a piece of semantic information that is crucial for famous people: celebrities are familiar to most of the people because of their occupation. Moreover, the occupation task relies directly on a semantic entry and, unlike

height judgement, no further computations are required to express an answer.

Different directions of the categorization were accomplished by the use of a negation in the question: the two categorical questions were ‘Is the celebrity an actor/actress?’ and ‘Is the celebrity a non-actor/non-actress?’.

3.2.1 Materials and Methods

The experimental design of Experiment 2 was identical to that of Experiment 1, with the following exceptions.

3.2.1.1 Participants

Forty-three adults took part in the experiment. The data from three participants were discarded because overall accuracy was below 60% (chance performance is 50%). The mean age of the remaining participants (25 females) was 21 years (range 18-37). By self-report three participants were left-handed.

3.2.1.2 Stimuli

Stimuli consisted of 208 grey-scale facial images of celebrities. The set was made up of 52 actors, 52 actresses, 52 non-actors, 52 non-actresses. Non-actors/non-actresses were mostly singers, politicians, television presenters and athletes. The stimulus set was identical to that used by Boehm and Sommer (2012), except that four stimuli were added.

A set of 20 pictures of famous people, resembling the characteristics of the experimental stimulus set, was used for practice runs.

3.2.1.3 Procedure

The experiment consisted of two cycles of consecutive study-test phases. The experimental task was occupation judgement; task instructions were ‘Is the celebrity an actor/actress?’ and ‘Is the celebrity a non-actor/non-actress?’. Questions in study and test phases were identical in one cycle and reversed in one cycle. The order of cycles was counterbalanced across participants. Half of the participants performed ‘actor’ judgments in test phases, half performed ‘non-actor’ judgments in test phases.

In study phases 52 faces (13 faces for each sub-set: actor, non-actor, actress, and non-actress) were presented in semi-random order three times. In test phases, 104 faces were presented in random order; half of them were repeated from the preceding study phase (primed), half were novel stimuli, never presented before in the experiment (unprimed).

Stimuli were presented at a size of 11.1x13.5 deg for 600 ms, separated by a fixation cross for 2400 ms in study phases and for 1900 ms in test phases.

Participants first practiced to categorize stimuli according to the two occupation questions in two short runs (10 stimuli each).

3.2.2 Results

Missing and early responses (response times < 200 ms) accounted for 0.4% of trials. Repetition of a stimulus determined a significant improvement in accuracy, both when questions in the cycle were identical, $z = 4.54$, $p < .001$, and when questions in the cycles were reversed, $z = 3.25$, $p = .001$ (see Table 3). Facilitation in accuracy was significantly larger for stimuli primed in the identical-question condition compared to those primed in the reversed-question condition, $z = 2.12$, $p = .034$.

Table 3
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 2.

Accuracy %	Identical		Reversed	
Unprimed	74.0 (1.8)		75.1 (1.4)	
Primed	83.0 (1.3)		79.9 (1.7)	
Priming	9.0 (1.5)	***	4.8 (1.4)	**

Note: ** $p < .01$; *** $p < .001$.

Further 22.3% of the primed trials were excluded because of wrong responses at study. Responses to primed stimuli were significantly faster than responses to unprimed stimuli both for the identical-question condition, $t(39) = 13.30$, $p < .001$, and the reversed-question condition, $t(39) = 11.44$, $p < .001$ (see Table 4).

Table 4
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 2.

Response Times	Identical		Reversed	
Unprimed	952 (31)		961 (33)	
Primed	722 (25)		766 (29)	
Priming	230 (17)	***	195 (17)	***

Note: *** $p < .001$

The stimulus-response effect, assessed as difference between amounts of priming in the two cycles, was significant, $t(39) = 2.13$, $p < .039$ (see Figure 5).

The between-subjects factors, order of the cycles and task instruction at test, did not interact with stimulus-response effect in response times analysis, $F_s(1,36) < 2.33$, $ps > .632$.

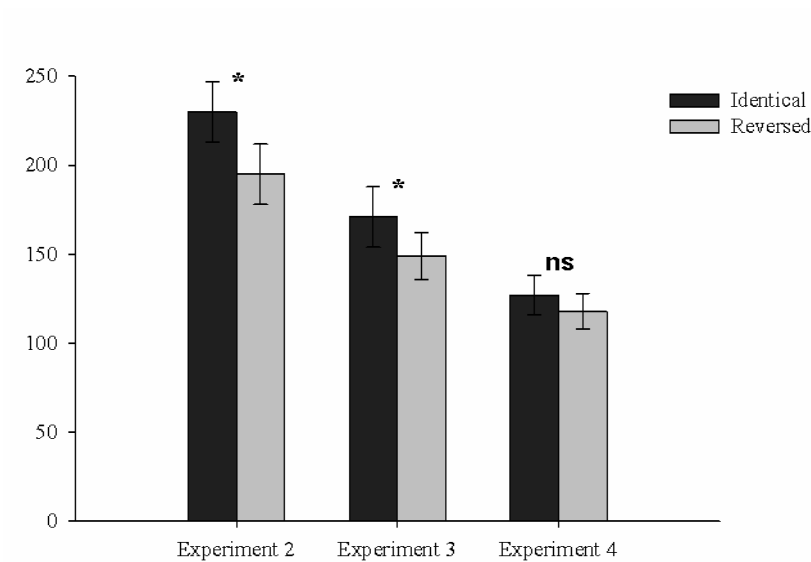


Figure 5 Mean priming in the two question conditions in Experiments 2-3-4
Note: * $p < .05$ and ns $p > .05$.

3.2.4 Discussion

Having answered a reversed question in the study phase significantly affects priming both for accuracy and response times compared to having answered the identical question at study: accuracy gain and response times benefit due to stimulus repetition were smaller in the reversed-question condition compared to the identical-question condition. This outcome, a replication of the results of Experiment 1, demonstrates that a stimulus-response effect for faces can be obtained even in more conventional tasks where accuracy is higher and no further computations are required.

Priming in the reversed-question condition was significant both for response times and accuracy; this facilitation could be either the effect of stimulus-classification binding or facilitation in perceptual and conceptual networks.

The significant stimulus-response effect in Experiment 2 rules out task requirements from the list of the design factors that determine the involvement of rapid response learning in person recognition.

3.3 Experiment 3

In Experiment 3 rapid response learning in person recognition was tested with a design in which, instead of having study-test cycles, two study phases were performed consecutively at the beginning of the experiment, followed by a distractor task, and a single test phase. A similar design was used by Dennis et al. (2010) in Experiment 1, with the exception that a distractor phase between study phases and test phase was employed in the present experiment. In this design it is quite unlikely that participants realize the memory nature of the experiment, therefore explicit encoding is reduced. In addition, contiguity between phases with identical question is interrupted by distractor task.

3.3.1 Materials and Methods

The experimental design of Experiment 3 was identical to that of Experiment 2, with the following exceptions.

3.3.1.1 Participants

From forty-seven adults participating in the experiment, the data of seven participants were discarded because the overall accuracy was below 60% (chance performance is 50%) or a failure to answer the correct question in one of the study phases. Mean age of the remaining 40 participants (27 females) was 21 years (range 18 - 43). Three participants were left-handed by self-report.

3.3.1.2 Stimuli

Only 204 stimuli (identical stimulus set used by Boehm and Sommer, 2012) from the set of 208 stimuli used in Experiment 2 were used for the experiment proper. An additional

150 colour pictures of common objects on a white background were used for the distractor phase; half of the objects were presented upright and the other half were presented upside-down. 10 objects were randomly selected for practice with the distractor task; the remaining 140 objects were used for the experimental distractor phase.

3.3.1.3 Procedure

Participants first practiced the two categorizations for celebrities ('actor/actress' and 'non-actor/non-actress') and the categorization for objects ('correctly orientated' or 'not correctly orientated') in three short practice runs (10 stimuli each).

The experiment consisted of two study phases, followed by distractor phase and test phase. Different questions were answered in the two study phases. At test a stimulus could be presented for the first time (unprimed) or could have been presented before under identical (primed identical-question) or reversed (primed reversed-question) question. The order of the two study phases was counterbalanced across participants. Task instructions for the distractor phase were for half the participants 'Is the object correctly orientated?' and for the other half 'Is the object not correctly orientated?'.

In study phases, 68 faces (17 faces for each category: male actor, male non-actor, female actor, and female non-actor) were presented in random order three times, while avoiding immediate repetitions. At test, all the 204 stimuli were presented: 1/3 of the stimuli were repeated from the study phase with identical question, 1/3 of the stimuli were repeated from the study phase with reversed question and 1/3 were stimuli not presented before.

Between the two study phases and the test phase, a distractor phase was conducted, presenting pictures of objects in random order with size of 13.1*13.1 deg for 600 ms and separated by a black fixation cross on white background for 2400 ms.

3.3.1.4 Data Analysis

Priming in the two conditions was assessed by contrasting unprimed stimuli against stimuli presented before in one of the two study phases separately (priming identical-question = unprimed – primed identical-question; priming reversed-question = unprimed – primed reversed-question).

Data from the distractor phase was not considered in data analysis.

3.3.2 Results

Missing and early responses (response times < 200 ms) accounted for 0.8% of trials. Accuracy for unprimed stimuli was significantly lower than accuracy for stimuli presented in a study phase with identical question to that at test, $z = 4.36, p < .001$, or with reversed question, $z = 3.39, p = .001$ (see Table 5). The 1.1% ($SE = 0.9\%$) difference in accuracy gain between question conditions, signature of stimulus-response effect, was not significant, $z = 1.13, p = .258$.

Table 5
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 3.

Accuracy %	Identical	Reversed
Unprimed		72.9 (1.6)
Primed	79.0 (1.5)	77.9 (1.3)
Priming	6.1 (1.0) ***	5.0 (1.2) **

Note: ** $p < .01$; *** $p < .001$.

Inconsistent responses accounted for 23.2% of correct primed trials. Priming resulted in significant faster responses for both identical-question, $t(39) = 10.24, p < .001$, and reversed-question condition, $t(39) = 11.42, p < .001$ (see Table 6).

Table 6
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 3.

Response Times	Identical	Reversed
Unprimed		906 (30)
Primed	736 (23)	758 (24)
Priming	171 (17) ***	149 (13) ***

Note: *** $p < .001$.

Facilitation was significantly reduced when the question was reversed, ($M = 22$, $SE = 9$), $t(39) = 2.57$, $p = .014$, indicating a stimulus-response effect (see Figure 5).

Interestingly, the size of the stimulus-response effect was larger when the second study phase and the test phase had identical questions (for example: first study phase - ‘actor/actress?’; second study phase – ‘non-actor/non-actress?’ – test phase ‘non-actor/non-actress?’) ($M = 40$ ms, $SE = 10$) compared to when question in test phase was reversed compared to question at second study (for example: first study phase - ‘non-actor/non-actress?’; second study phase – ‘actor/actress?’ – test phase ‘non-actor/non-actress?’) ($M = 3$ ms, $SE = 13$), $F(1,36) = 5.20$, $p = .029$. The significant stimulus-response effect was obtained only when the second study and test phases had identical questions (priming identical-question: $M = 187$ ms, $SE = 24$; priming reversed-question: $M = 147$ ms, $SE = 20$), $t(19) = 4.07$, $p = .001$, but not when questions in these two phases were reversed (priming identical-question: $M = 155$ ms, $SE = 22$; priming reversed-question: $M = 151$ ms, $SE = 17$), $t(19) = 0.26$, $p = .795$.

The second between-subjects factor, question at test, did not interact with stimulus-response effect, $F(1,36) = 1.41$, $p = .243$.

3.3.3 Discussion

The results showed that rapid response learning in person recognition was present in a design that minimizes, as much as possible, the influence of episodic memory and the association between a primed stimulus and a specific priming history condition. Facilitation in response times, but not in accuracy, at test was significantly larger for stimuli primed in a study phase with the identical question than that for stimuli primed in a study phase with the reversed question.

Again, priming in the reversed-question condition was significant both for response times and accuracy.

Interestingly the stimulus-response effect was not abolished by the intrusion of a distractor phase between the two study phases and the single test phase, indicating that the contiguity of identical question is not necessary for rapid response learning. On the contrary, modulation of stimulus-response effect by the arrangement of study phases seems to indicate otherwise: the stimulus-response effect was significant when the second study phase had identical question but not when the second study phase had reversed question. This effect could be due to the fact that stimulus-response binding does not survive long lags or, alternatively, that stimulus-response binding requires contiguity of identical questions between the test phase and the preceding study phase, even if separated by a classification task for object recognition.

The overall significant stimulus-response effect in Experiment 3 seems to rule out the necessity of study-test cycles to obtain rapid response learning in person recognition. The order effect, on the contrary, suggests that either contiguity of study and test phases with identical questions, even if interrupted by a distractor task, is necessary for the retrieval of stimulus-response binding, or, alternatively, the binding is short-lived.

3.4 Experiment 4

In the study of repetition priming in person recognition stimuli were generally primed by a single presentation at study. In Experiment 4 rapid response learning in person recognition was investigated when primed stimuli were presented only once at study. The design of Experiment 4 resembles designs reported in the literature of priming in person recognition with the only difference that in study phases different questions were presented.

3.4.1 Materials and Methods

The experimental design of Experiment 4 was identical to that of Experiment 3, with the following exceptions.

3.4.1.1 Participants

From forty-five adults participating in the experiment, the data of five participants were discarded because the overall accuracy was below 60% (chance performance is 50%). The mean age of the remaining forty participants (26 female) was 23 years (range 19-53). All the participants were right-handed by self-report.

3.4.1.2 Procedure

The procedure was identical to that of Experiment 3, with the exception that stimuli in the two study phases were presented only once.

3.4.2 Results

Missing and early responses (response times < 200 ms) accounted for 0.4% of trials.

When question was identical in study and test phases, the accuracy for primed stimuli was significantly larger than accuracy for unprimed stimuli, $z = 4.22$, $p < .001$, indicating improved accuracy as a result of priming. Repetition of a stimulus improved accuracy even when questions were reversed, $z = 3.61$, $p < .001$. Accuracy gains for primed stimuli did not differ significantly, $z = 1.30$, $p = .19$ (see Table 7).

Table 7
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 4.

Accuracy %	Identical		Reversed	
Unprimed			80.2 (1.4)	
Primed	85.2 (1.1)		84.4 (1.1)	
Priming	5.0 (0.8)	***	4.2 (1.0)	***

Note: *** $p < .001$.

Inconsistent responses accounted for 10.8% of correct primed trials. Response times for primed stimuli were significantly faster than unprimed stimuli regardless of the question at study phase, $t(39) > 11.90$, $ps < .001$ (see table 8).

Table 8
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 4.

Response Times	Identical		Reversed	
Unprimed			1019 (24)	
Primed	891 (24)		900 (26)	
Priming	127 (11)	***	118 (10)	***

Note: *** $p < .001$.

The stimulus-response effect in reaction times was not significant, $t(39) > 1.11$, $p <$

.276 (see Figure 5).

None of the between-subjects factors interacted with the stimulus-response effect: order of the study phases, $F(1,36) = 0.51$, $p = .480$, task instruction at test, $F(1,36) = 1.36$, $p = .251$.

3.4.3 Discussion

Facilitation for stimuli primed by a single presentation at study did not differ significantly according to the question at study. This result suggests that a stimulus must necessarily be presented more than one time in order to induce the stimulus-response binding, fundamental for rapid response learning. The absence of a stimulus-response effect when stimuli were presented only once at study is in line with most of the studies of repetition priming in person recognition.

No matter the absence of rapid response learning, priming for repeated stimuli was significant both in accuracy and response times.

A non significant stimulus-response effect in Experiment 4 suggests that multiple stimulus repetitions at study is the experimental factor x - the experimental factor that determines the involvement of rapid response learning in repetition priming in person recognition.

3.5 General Discussion

The present series of experiments was conducted in an attempt to identify the design factor, or design factors, that gives rise to a stimulus-response effect. Rapid response learning in person recognition was extensively studied in three experiments and three design factors were cumulatively subtracted to evaluate which one is necessary for

the expression of rapid response learning in person recognition. Reversing the direction of categorization significantly reduced priming in response times when stimuli were repeated three times (Experiments 2-3) but not when stimuli were presented only one time at study (Experiment 4). In addition, the order effect in Experiment 3 suggests that retrieval of a stimulus-response binding can be modulated by arrangement of the study phases or the delay between study and test phases. These results indicate that stimulus-response binding requires multiple study presentations to be created, and it can either be short-lived or depend on contiguity of phases with identical task instruction.

Throughout the three experiments, facilitation was significant in response times analyses and numerically positive in accuracy analyses not only for primed identical-question but for primed reversed-question as well. Residual priming after inversion of task instruction could result from stimulus-classification binding or from facilitation in perceptual and conceptual networks, but the use of a task that does not require additional computation theoretically excludes stimulus-classification binding. Classifying a stimulus as taller or as shorter than a reference size, as in Experiment 1, could be useful because a response cannot be generated immediately from semantic information, height of the person, but it requires further computations. On the contrary, an occupation judgement task, the classification code coincides with the semantic entry: a celebrity is already categorized as an actor, and therefore there is no reason for any task-specific classification. Therefore imposing a classification code even for pre-existent categorization is an excessive twist; it would be easier to state that, even if perceptual and semantic networks are by-passed by stimulus-response association, they are tuned, and some facilitation can be generated in these networks, when the retrieval of a stimulus-response binding is no more efficient. Chapter 5 presents unquestionable empirical data in favour of tuning of perceptual and conceptual networks beside the creation of a stimulus-response binding.

3.4.1 Task that requires further computation

The presence of a significant stimulus-response effect in Experiment 2 means that rapid response learning is not a consequence of the task (height judgment vs. occupation judgement). Rapid response learning was significant both in a task like height judgement (Experiment 1) that requires creation of an *ad hoc* answer to be solved, and in a task like occupation judgement (Experiment 2) that can be solved by the usage of pre-existing information. Surprisingly, the stimulus-response effect in accuracy analysis was significant in the occupation judgement but not in the height judgement: the opposite would be expected because if stimulus-response binding is the consequence of encoding the output of computational processes to avoid re-engaging in these computations again, then the stimulus-response effect should be significant in Experiment 1 but not in Experiment 2. Interestingly, the magnitude of both the stimulus-response effect and priming in response times between Experiment 1 and Experiment 2 was numerically similar, indicating a general homogeneity of the involved facilitations in these two different judgements. This homogeneity suggests that other secondary experimental differences between Experiment 1 and Experiment 2 like presentation times (600 ms in Experiment 2 and 2000 ms in Experiment 1), and consequently different ISI, and number of stimuli at study (52 in Experiment 2 and 34 in Experiment 1), do not have any significant influence on the stimulus-response effect. It is important to highlight at this point that such homogeneity of results between Experiment 1 and Experiment 2 suggests that task, and item difficulty, does not affect significantly priming and rapid response learning results. Even though participants are less sure in judging the height than the occupation of a celebrity and might be, therefore, more prone in creating an *ad hoc* classification to give consistent responses to difficult items, the stimulus-response effect had a similar magnitude in these two experiments. On the other hand, when consistently incorrect responses are considered in

average response times in Experiment 1 (see Appendix), the stimulus-response effect became stronger, indicating a possible influence of ad hoc classifications on rapid response learning.

The occupation judgement was selected because it is a natural categorization that does not require online computation, but it could be argued that the use of a non-actor category as task instruction implies computation and perhaps the creation of a classification code. The semantic system is probably not organized between actors and non-actors, but across actors, singers, politicians, and so on, therefore the need of an *ad hoc* classification for non-actors could be plausible. The use of two close categories (for example actors and singers) is recommended (see Chapter 5, Experiment 7).

3.4.2 Contiguity of phases with identical question

The results of Experiment 3 are less definitive in determining whether rapid response learning depends on contiguity of study and test phases. Although an overall significant stimulus-response effect indicates that contiguity of study and test phases is not a prerequisite for rapid response learning, the significant effect of arrangement of the study phases argues the opposite. The stimulus-response effect was significant (and its magnitude was surprisingly similar to that in Experiment 1 and Experiment 2) only when study and test phases with identical question were contiguous, even if separated by a distractor phase, but the stimulus-response effect was abolished when the contiguous study and test phases had reversed questions. The order effect opens two important possibilities: 1) contiguity of study and test phases with identical question is a design factor x for rapid response learning or 2) stimulus-response binding is short-lived. Before discussing the details of these two alternatives, it is worthwhile underlining that a similar effect must be considered cautiously and further investigations are preferable, particularly within-

participant, given the low statistical power of the analysis in Experiment 3 (see Chapter 4, Experiment 6; and for within-participant analysis Chapter 6).

An interaction of the arrangement of questions in the study phases with a stimulus-response effect is not a new finding in the literature of rapid response learning in object recognition. The first design used to test rapid response learning employed a single study phase and two test phases: ‘switch’, reversed question condition, and ‘return’, identical question condition. Dobbins et al. (2004) reported that after a switch phase, neural and behavioural priming did not show any recovery: in other words, performing a test phase in which task instruction was reversed abolished neural and behavioural signatures of rapid response learning. Schnyer et al. (2006) analysed behaviourally this effect and obtained similar results: when the test phase with the identical question was performed after the test phase with the reversed question, the stimulus-response effect was significantly smaller compared to when the test phase with the identical question followed immediately the study phase. Schnyer et al. (2006) interpreted this result as neglect in retrieving stimulus-response binding when a categorization state is interrupted (see Chapter 6 and Chapter 7).

An alternative interpretation is the lag-effect: stimulus-response binding is short-lived and disappears when a stimulus is not tested immediately after its study phase. Contrary to the design with multiple test phases, in Experiment 3 two study phases were conducted before a single test phase, and these different phases were separated by a distractor task. Consequently, there are different delays between the moment a stimulus is studied in the two conditions and the moment it is tested, determining differences in lag. Although this experiment was not design to test lag-effect, it can give us some interesting insights about the nature of stimulus-response binding. The delay between phases imposed by the distractor task would create lags similar, or even longer, to the ones for the second test phase in Schnyer et al. (2006), hence, any stimulus-response effect should be

abolished no matter the arrangement of questions in the study phases in Experiment 3. On the other hand, the stimulus-response effect survived lag when the reversed question was answered during the first study phase and the identical question during the second study phase and its magnitude resembled that obtained in Experiment 1 and Experiment 2, when no lag was involved. Although these findings seem to indicate that the stimulus-response effect is not short-lived direct investigation is required (see Chapter 4, Experiment 6).

3.7.3 Number of stimulus repetitions at study

The absence of a significant stimulus-response effect in Experiment 4 indicates that a single stimulus repetition at study is not sufficient to induce binding between stimulus and response - binding that is essential for the expression of rapid response learning. The lack of a significant stimulus-response effect in Experiment 4, which employed a setup closest to conventional repetition priming studies, is in line with more than twenty years of research in priming in person recognition, suggesting that rapid response learning may contribute very little to conventional person recognition when stimuli are presented just once at study.

However, Experiment 4 is the end point of a subtractive process, therefore the absence of a significant stimulus-response effect could be determined by the combination of the three subtracted factors (task, design structure, number of repetitions) and not by the number of stimuli presentations at study per se. The numerical decrease of both priming and stimulus-response effect (if order effect is not taken into account) in Experiment 3 suggests that design structure could have had an influence on facilitation. Besides, the stimulus-response effect in object recognition was previously shown significant even after a single presentation (Dew & Giovanello, 2010b). Therefore the statement that rapid response learning in person recognition requires multiple presentations of stimuli at study

needs to be corroborated by an experiment with a regular rapid response learning design (study-test cycles) and a single stimulus repetition at study (see Chapter 4, Experiment 5).

3.8 Conclusion

Stimulus-response binding requires multiple stimulus presentations at study to be behaviourally relevant, and its effect is abolished when the contiguity between study and test phases with identical questions is interrupted by another study phase with reversed questions. These two potential x factors need, tough, further corroboration.

Chapter 4

Chapter 3 shows that rapid response learning in person recognition is absent when stimuli are presented only one time at study or when the study phase with identical task instruction does not immediately precede the test phase. Both these two outcomes need further investigation to exclude confounding factors or to obtain a better understanding of the reason behind the specific effect. Two experiments were carried out. Experiment 5 employed a design identical to that of Experiment 2 with the exception that stimuli were presented only once at study to address the necessity of multiple presentation of stimuli for stimulus-response binding. Experiment 6 employed a design identical to that of Experiment 4 with the exception that the duration of the distractor phase was extended to investigate any lag effect for stimulus-response effect. The results showed that the stimulus-response effect was absent after a single repetition even in a design made up of study-test cycles but was significant both for short and long delays. Surprisingly, the order effect was not replicated in Experiment 6. These two experiments clearly indicate that rapid response learning in person recognition occurs only in designs in which stimuli are repeated more than once, and that it survives delays longer than half an hour between study and test. In addition, the contiguity of study and test phases does not seem to have a reliable/strong impact on rapid response learning.

a) Are multiple stimulus repetitions at study necessary for rapid response learning in person recognition?

4.a.1 Introduction

Priming in person recognition benefits marginally from multiple presentations at study (Lander, Bruce, Smith, & Hancock, 2009; Lewis & Ellis, 1999). Priming is generally significant even after a single presentation (e.g. Rugg et al., 1998). Consequently, priming has been studied mostly by presenting stimuli only once in study phases.

On the other hand, rapid response learning for objects has been mainly tested with stimuli primed by single (low primed) or triple presentation (high primed) during the same study phase (Dennis & Perfect, 2012; Dobbins et al., 2004; Horner & Henson, 2009; Schnyer et al., 2007; Schnyer et al., 2006). In general, the stimulus-response effect is robust and consistently significant across experiments only in the high primed condition; low primed condition generally presents smaller and less reliable stimulus-response effect (but see Schnyer et al., 2006). In fact, most recent rapid response learning experiments have preferred triple or double presentation of stimuli at study (Horner & Henson, 2012; Race et al., 2009; Race et al., 2008; Wig et al., 2009); but significant rapid response learning has been reported even after a single study presentation (Dew & Giovanello, 2010b; but see Experiment 1 in Horner & Henson, 2011a).

Chapter 3 shows that after a single study presentation, like in Experiment 4, the stimulus-response effect is not significant. This result is in line with Experiment 1 in Horner & Henson (2011a) but contrasts with significant effect of stimulus-response binding in Dew & Giovanello (2010b). This last contradiction is difficult to accommodate because similarly to Experiment 4, but contrary to Horner & Henson (2011a), Dew & Giovanello (2010b) presented the same stimulus at study and test. However, an important

difference between Experiment 4 and Experiment 1 in Dew & Giovanello (2010b), which could account for this conflict, is the arrangement of study and test phases: respectively study-study-test and study-test-study-test. In fact, the cumulative subtraction of experimental factors from Experiment 2 to Experiment 4 leaves the possibility that the single presentation of stimuli in study phases is not sufficient to abolish any contribution from stimulus-response binding, but the absence of a stimulus-response effect in Experiment 4 is determined by the combined effect of single stimulus repetition at study and arrangement of study and test phases (see Figure 6).

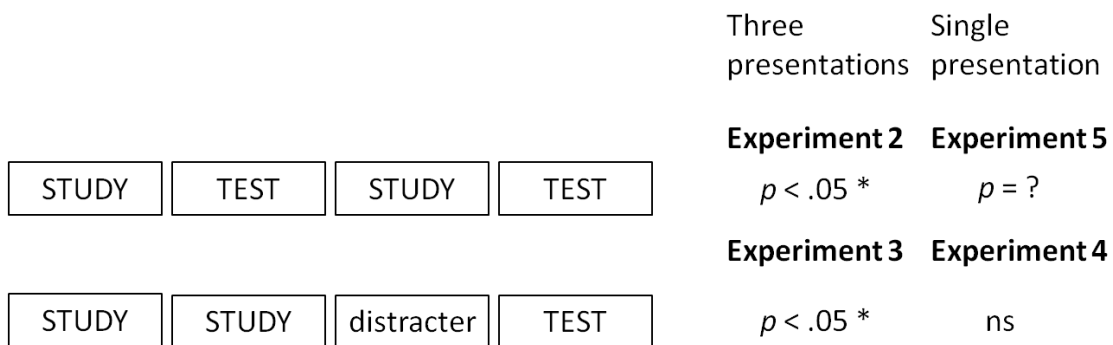


Figure 6 Schematic representation of design factors. On the left hand side designs used in Experiment 2 (study-test cycles) and Experiment 3 and Experiment 4 (study-study-distracter-test) are represented; on the right hand side the experiments are arranged according to the number of stimulus presentations at study (triple or single). A summary of the results of Chapter 2 is reported. The missing point to get the complete picture of the results is Experiment 5.

Experiment 5 tested whether a single repetition is sufficient to elicit stimulus-response binding in person recognition when a design that emphasizes contiguity between study and test phases is used, as in Dew & Giovanello (2010b). No significant difference between amounts of priming would support the claim that stimulus-response binding in person recognition depends on multiple stimulus repetitions, regardless of the arrangement of study and test phases; on the other hand, significant results would indicate that single presentation of stimuli is not sufficient to abolish stimulus-response effect if the contiguity

of study and test phases is maintained.

4.a.2 Experiment 5

Experiment 5 investigated whether the stimulus-response effect is not significant after a single presentation of stimuli even when study-test cycles are used. Experiment 5 employed a design identical to that of Experiment 2 with the exception that stimuli were presented only once at study.

4.a.2.1 Materials and Methods

The experimental design of Experiment 5 was identical to that of Experiment 2, with the following exceptions.

4.a.2.1.1 Participants

From forty-five adults participating in the experiment, the data of five participants were discarded because overall accuracy was below 60% (chance performance is 50 %). The mean age of the remaining 40 participants (28 females, 5 left-handed) was 21 years (range 18-36).

4.a.2.1.2 Procedure

The procedure was identical to that of Experiment 2, with the exception that stimuli in study phases were presented only once.

4.a.2.2 Results

Missing and early responses accounted for 0.4% of trials. When questions in study and test phases were identical, accuracy for primed stimuli was significantly higher than accuracy for unprimed stimuli, $z = 3.41, p = .001$; when questions were reversed, accuracy for primed stimuli was not significantly different from accuracy for unprimed stimuli, $z = 1.42, p = .157$ (see Table 9). The larger accuracy gain of 3.7% for the identical-question condition compared to the reversed-question condition was not significant, $z = 1.45, p = .146$.

Table 9
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 5.

Accuracy %	Identical	Reversed
Unprimed	81.1 (1.4)	79.2 (1.5)
Primed	75.4 (1.9)	77.2 (1.4)
Priming	5.7 (1.5) **	2.0 (1.3)

Note: ** $p < .01$.

A further 12.8% of correct primed trials were discarded because of incorrect responses at study. Priming in response times was assessed by comparing response times of correct and consistent primed trials against correct unprimed trials in the two question conditions. Repetition of a stimulus resulted in significant faster responses for both the identical-question condition, $t(39) = 10.47, p < .001$, and the reversed-question condition, $t(39) = 9.80, p < .001$ (see Table 10).

Table 10
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 5.

Response Times	Identical		Reversed	
Unprimed	961 (33)		967 (31)	
Primed	847 (27)		863 (29)	
Priming	114 (11)	***	102 (10)	***

*Note: *** $p < .001$.*

The stimulus-response effect was assessed by comparing the two amounts of priming; reversing the categorizations did not significantly slow down responses ($M = 12$ ms, $SE = 13$), $t(39) = 0.92$, $p = .365$, indicating a lack of significant rapid response learning.

Neither the question in test phases nor the order of the cycles interacted with the stimulus-response effect, $F_s(1,36) < 0.73$, $ps > .398$.

4.a.2.3 Discussion

Results of Experiment 5 showed that the stimulus-response effect was not significant after a single study presentation even when a design that highlights the association between a repeated stimulus and its study context was employed. This result contrasted with significant priming in both question conditions (identical and reversed).

The present experiment further supports the conclusion that rapid response learning does not play a significant role in person recognition when stimuli are presented only once at study.

4.a.3 General discussion

The present experiment was conducted to investigate whether single presentation of stimuli at study did not involve facilitation produced by retrieval of stimulus-response binding even when the arrangement of study and test phases emphasised the association of a primed stimulus to a specific priming context. The absence of a significant stimulus-response effect in Experiment 5 indicates that the number of stimulus repetitions at study is a factor x behind the expression of rapid response learning: when stimuli are presented only once, facilitation for repeated stimuli does not change according to the question at study.

The results of Experiment 5 replicate the outcomes of Experiment 4: the stimulus-response effect is not significant after a single presentation. In addition, any concurrent influence of arrangement of study and test phases on results of Experiment 4 is ruled out. This result, together with the similar result in Experiment 4, is in line with most studies of priming in person recognition: response processes (decision and action) occurring beyond perceptual and conceptual networks do not play a significant role in regular priming experiments when stimuli are presented only once at study. In the domain of objects, instead, Dew & Giovanello (2010b) reported the only direct evidence of rapid response learning after a single presentation but this could be consequence of long presentation time (6 sec) of stimuli at study. Indeed, in Experiment 1, Horner & Henson (2011b), using a shorter presentation time (2 sec) did not find a significant stimulus-response effect. The effect of trial duration on rapid response learning has never been considered, but it could allow more elaborated processing and, consequently, the strengthening of the link between a stimulus and a response, even after a single presentation.

On the other hand, results from experiments that used low and high primed stimuli within the same study phase, should be considered cautiously, because such design could

favour retrieval of stimulus-response binding even when the binding is weak, as for stimuli primed only once at study. In addition, these experiments present a methodological limitation. In an ANOVA, a non significant interaction between question conditions (identical vs. reversed) and priming conditions (low vs. high) could be driven by a similar trend in the stimulus-response effect but, without follow-up test, it is impossible to conclude that the stimulus-response effect is significant even for low primed stimuli. As a matter of fact, in the present experiment and Experiment 4, a numerical trend was observed (priming in the identical-question condition was numerically larger than priming in the reversed-question condition) but the difference was not significant. An interesting follow-up investigation would be to test rapid response learning in person recognition using low primed and high primed stimuli within the same study phase.

It is important to note that after a single repetition the stimulus-response effect is not significant, but that priming is significant for all repeated stimuli. As suggested before, this could be evidence for stimulus-classification binding, but it sounds quite overblown that an association between a stimulus and a classification code requires only one repetition while an association between a stimulus and decision or action codes would need multiple repetitions. Therefore, an interpretation of similar priming as facilitation in perceptual and conceptual networks seems more plausible (for direct evidence, see Chapter 5).

4.a.4 Conclusion

Multiple presentations of stimuli are an essential requirement for the creation and utilization of stimulus-response binding and for the observation of a robust stimulus-response effect.

b) Is stimulus-response binding short-lived? Or does it require contiguity of phases with identical task instruction to be expressed?

4.b.1 Introduction

Rapid response learning in object recognition has generally been studied with designs in which test phases proceed immediately after the respective study phase (Dew & Giovanello, 2010b; Horner & Henson, 2009), but the first design used to study rapid response learning had a single study phase and two test phases with opposite questions (Dobbins et al., 2004). Schnyer et al. (2006) suggested for the first time to abandon Dobbins et al. (2004) design in favour of a design made up of study-test cycles, because of the potential confounding experimental issues of lag. In fact, the effect of arrangement of the test phases, interpreted as blocked reactivation of any stimulus-response binding by responding to different questions, could be the result of decay of stimulus-response binding if not tested within a short period of time.

Experiment 3 presented a similar experimental issue. Stimuli were primed at two different points in time, creating delays that could have an impact on rapid response learning due to lag. In Experiment 3, delays between presentations of a stimulus at study and test were defined mostly by the length of the distractor task and by the order of the study phases. If we consider d (7 min) the duration of the distractor task and s (10 min) the duration of each individual study phase; the minimum lag for stimuli presented in the first study phase was equal to $d+s$ (a mean lag* of 25 min) while the lag for stimuli presented in the second study phase was equal to d (a mean lag of 15 min).

*Mean lag is calculated by adjusting minimum lag, a situation in which a stimulus is last in the study phase and first at test, by adding 50% of the duration of the test phase (5min) and 86% of the duration of the study phase (around 8min)

These temporal differences (d vs. $d+s$) could have an effect if stimulus-response binding is short-lived and, in this case, the lag could be the cause of the significant order effect in Experiment 3 (see also Dobbins et al., 2004; Schnyer et al., 2006). Given that the stimulus-response effect in Experiment 3 was significant for identical question in the second study phase but not in first study phase, s seems to be a temporal delay sufficient to disrupt or block the utilization of stimulus-response binding.

In Experiment 6, lag effects on rapid response learning were directly investigated. The number of stimuli in the distractor phase was increased and, consequently, the duration of the distractor phase was longer: $d+d'$ (where $d' = s$; 17min) (see Figure 7). In Experiment 6 the delay between study phases and test phase was $d+d'$ (a mean lag of around 25min) for the second study phase and $d+d'+s$ for the first study phase (a mean lag of around 35min) (or, if d' is substituted with s : $d+s$ for the second study phase and $d+s+s$ for the first study phase).

Experiment 3



Experiment 6

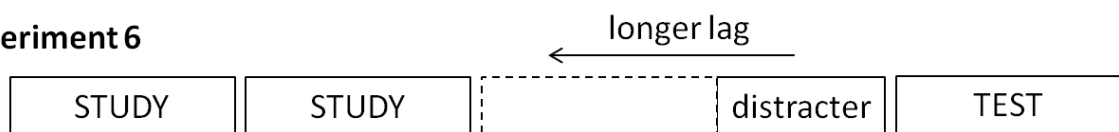


Figure 7 Schematic representation of the designs used in Experiment 3 and Experiment 6. The only difference is that the duration of the distractor task in Experiment 5 is expanded in such a way that the delay between second study phase and test phase in Experiment 6 match the delay between first study phase and test phase in Experiment 3.

The aim of Experiment 6 was to test whether stimulus-response binding survives long lag between study and test phases. If stimulus-response binding does not survive a 25 min delay, as in Experiment 3, no stimulus-response effect is expected in the present experiment, no matter the arrangement of the questions at study. An overall significant

stimulus-response effect would instead rule out any lag effect, and support an interpretation of the order effect as contiguity.

4.b.2 Experiment 6

In Experiment 6 rapid response learning was investigated after a long distractor phase. Compared to Experiment 3, the number of stimuli in the distractor phase was increased from 140 to 340, increasing the duration of the distractor phase to 17 min.

4.b.2.1 Materials and Methods

Experiment 6 was identical to Experiment 3 with the following exceptions.

4.b.2.1.1 Participants

From forty-three adults participating in the experiment, the data of three participants were discarded because the overall accuracy was below 60% (chance performance is 50%) or the wrong task instruction was answered in one of the study phases. The mean age of the remaining 40 participants (28 females, 3 left-handed) was 19 years (range 18-29).

4.b.2.1.2 Stimuli

A further 200 pictures of objects (100 objects represented in their canonical position, 100 objects represented upside-down) were used in the distractor task.

4.b.2.1.3 Procedure

During the distractor task 340 pictures of objects were randomly displayed instead of 140.

4.b.2.2 Results

Missing and early responses accounted for 1.5% of trials. When the question at test was identical to the question at study, accuracy was significantly higher for primed compared to unprimed stimuli, $z = 4.23, p < .001$, but not when the question was reversed, $z = 0.92, p = .357$ (see Table 11). The larger accuracy gain of 5.5 % for the identical-question condition compared to the reversed-question condition was strongly significant, $z = 4.39, p < .001$.

Table 11
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 6.

Accuracy %	Identical		Reversed
Unprimed		75.8 (1.6)	
Primed	83.0 (1.2)		77.5 (1.2)
Priming	7.2 (1.4)	***	1.7 (1.4)

*Note: *** $p < .001$.*

A further 22.6% of correct primed trials were discarded because of incorrect responses at study. Priming in response times was assessed by comparing response times of correct and consistent primed trials for the two question conditions against the unprimed trials. Priming resulted in significantly faster responses for both the identical-question condition, $t(39) = 14.39, p < .001$, and the reversed-question condition, $t(39) = 12.07, p < .001$ (see Table 12).

Table 12
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 6.

Response Times	Identical	Reversed
Unprimed		928 (26)
Primed	752 (21)	780 (23)
Priming	176 (12) ***	149 (12) ***

*Note: *** $p < .001$.*

Rapid response learning was assessed by comparing response times between the two question conditions; the reversed-question condition presented significantly slower mean response times than mean response times in the identical-question condition ($M = 28$ ms, $SE = 8$), $t(39) = 3.35$, $p = .002$, indicating a stimulus-response effect.

The size of the stimulus-response effect was numerically larger, but not significantly larger, when the second study phase and the test phase had identical questions ($M = 34$ ms, $SE = 13$) compared to when questions in the second study phase and the test phase were reversed ($M = 21$ ms, $SE = 11$), $F(1,36) = 0.57$, $p = .454$. A significant stimulus-response effect was only obtained when the second study and test phases had identical questions (priming identical-question: $M = 183$ ms, $SE = 20$; priming reversed-question: $M = 149$ ms, $SE = 17$), $t(19) = 2.69$, $p = .014$, but not when questions of the second study and the test phase were reversed (priming identical-question: $M = 169$ ms, $SE = 14$; priming reversed-question: $M = 148$ ms, $SE = 18$), $t(19) = 1.97$, $p = .063$.

The second between-subjects factor, task at test, did not interact with the stimulus-response effect, $F(1,36) = 0.46$, $p = .501$.

4.b.2.3 Discussion

Experiment 6 tested rapid response learning after long delays between the time at

which a stimulus is presented at study and presented again at test. The presence of an overall significant stimulus-response effect in accuracy and response times analysis suggested that stimulus-response binding is not short-lived: it lasted for at least 30 min. This result was further supported by between-subject statistics when the order of study blocks was taken into account: the stimulus-response effect was significant both for short delays between study and test phases with identical questions and nearly significant for long delays between study and test phases with identical questions. If considered together, these two pieces of evidence rule out the possibility that rapid response learning is short-lived.

Surprisingly, we found no order effect. Although the stimulus-response effect was numerically larger when the identical question was answered in the second study phase than in the first study phase, the difference was not significant. Although the general trend is in line with contiguity, given that lag effect is ruled out, the present results indicate that a similar effect is not reliable in the expression of rapid response learning. In fact the stimulus-response effect was nearly significant even when contiguity of phases with identical questions was blocked by a phase with reversed task instruction.

4.b.3 General discussion

Experiment 6 investigated whether stimulus-response binding is short-lived, and, in that case, whether this property can explain the order effect in a study-study-test design. Results are against an account of stimulus-response effect as a short-lived priming effect. In fact, the stimulus-response effect in the present experiment survived delays of around 40 min between the last presentation of a stimulus at study and its presentation at test. Similar delay is the longest ever used in the study of rapid response learning. This outcome is in line with what was suggested by Schnyer et al. (2004): arrangement of the phases has

an effect not because of the different delays between study and test phases but because of the presence, in some condition, of a phase that disrupts contiguity between phases with identical questions.

Surprisingly, although these results rule out an explanation of the order effect, as in Experiment 3, in term of lag, they undermine the reliability of the order effect in general. About this point, despite the similar trend of rapid response learning in the two order conditions, there are two main differences between results in Experiment 3 and Experiment 6: the order effect was significant in the first but not the second and the stimulus-response effect when identical question were performed in the first study phase was not significant in the first but nearly significant in the second. Considering that the two experiments were identical except for the duration of the distractor task, and since the lag effect does not abolish the stimulus-response effect, similar mismatches are difficult to explain. Such a mismatch could indicate high elusivity of this effect (see also Chapter 6 and Chapter 7).

4.b.4 Conclusion

Stimulus-response binding is not a short-lived effect. Although the lag does not account for the order effects, like the ones reported in the literature and obtained in Experiment 3, the present experiment does not fully support the alternative interpretation - contiguity - because the order effect was not significant and the stimulus-response effect was present even in the non-contiguity condition.

Chapter 5

An open question at this point is whether facilitation in perceptual and conceptual networks is overpowered by rapid response learning when stimuli are presented more than one time at study, preventing it from becoming behaviourally relevant. Chapter 5 aims to isolate data-driven and conceptually driven priming (facilitation in perceptual and conceptual networks), to prove the presence of facilitation other than rapid response learning in designs that promote stimulus-response binding. Orthogonal tasks were used in two experiments to detect the incontrovertible presence of networks facilitation when stimulus-response and stimulus-classification bindings cannot produce facilitation, as in the case of incongruent responses. Results showed that priming was significant even in the absence of any possible facilitation from the retrieval of bindings created by rapid response learning. This is clear evidence of data-driven and conceptually driven priming. Other modulations of priming were obtained and interpreted as conceptually driven priming and stimulus-response effect. For the first time in this series of experiments, evidence for interference caused by rapid response learning was also obtained. These findings indicate that facilitation in perceptual and conceptual networks is not obliterated by the creation and utilization of stimulus-response binding, and perhaps stimulus-classification binding, but that it co-occurs with rapid response learning to produce repetition priming. In other words, rapid response learning and facilitation in perceptual and conceptual networks are complementary rather than competing aspects of priming.

Is facilitation in perceptual and conceptual networks obliterated by rapid response learning?

5.1 Introduction

In Chapter 4 faster and more accurate responses to primed than unprimed stimuli in the reversed-question condition were interpreted outside the framework of rapid response learning; facilitation in perceptual and conceptual networks for face perception and categorization was suggested instead. In fact, when the same stimulus is repeated in study and test phases and task instructions require accessing the same semantic information, as in Experiments 1-6, data-driven and conceptually driven priming should be involved.

Although a similar interpretation of priming in the reversed-question condition is supported by more than 20 years of research on priming for person recognition, the alternative explanation, retrieval of a stimulus-classification binding, cannot definitely be ruled out yet. Priming in the reversed-question condition could still result from the reactivation of a classification code bound to the stimulus, which, by-passing perceptual and conceptual networks, allows the generation of a response without the need for full stimulus re-processing (Horner & Henson, 2009).

In Chapter 3, and Chapter 4, stimulus-classification binding was criticized on theoretical grounds, but, still, using priming in the reversed-question condition as evidence of networks facilitation is potentially questionable if this alternative explanation is not demonstrated to be empirically plausible. In fact there is no reason to call upon networks facilitation to explain an ambiguous effect if it is not demonstrated first that data-driven and conceptually driven priming are still effective even in the presence of rapid response learning. Therefore, Experiment 7 and Experiment 8 aimed to bring up empirical evidence about the existence of facilitation that cannot be explained by rapid response learning, even as stimulus-classification binding. Similar priming will be interpreted in terms of

facilitation in perceptual and conceptual networks.

The best way to find pure facilitation in perceptual and conceptual networks is by experimentally limiting any contribution of rapid response learning to priming. Orthogonal tasks offer a possible condition in which facilitation from stimulus-classification binding, and, at the same time, facilitation from stimulus-response binding are abolished, for half of the stimuli. To be clearer about this crucial point: two tasks are considered orthogonal if they depend on two different pieces of semantic information (i.e., size vs. natural-manmade), but responses to the two tasks are identical for half of the stimuli (congruent: yes-yes, no-no) and different for half of the stimuli (incongruent: yes-no, no-yes). In a similar condition, classifying a stimulus at study as 'bigger', does not allow any facilitation at test if the judgement is natural-manmade, excluding any contribution from retrieval of a stimulus-classification binding. Moreover, facilitation due to retrieval of stimulus-response binding is blocked for stimuli that required different responses in the two tasks. For example, if the questions at study and test are respectively 'Is the object smaller than a shoebox?' and 'Is the object manmade?', at study the stimulus 'chair' is classified as 'bigger' and response codes (decision and action) are 'no' and 'right button press' while at test all retrieved codes are wrong: 'manmade', 'yes', 'left button press'. On the other hand, the stimulus 'mug' is classified differently in the two tasks ('smaller' and 'manmade') but the same response codes are required ('yes' and 'left button press'). Responses to 'chair' are incongruent while responses to 'mug' are congruent.

In summary, the use of orthogonal tasks allows a condition in which facilitation due to rapid response learning is ruled out both at response and classification level. Therefore, any facilitation in such condition would imply that rapid response learning is not the exclusive generator of priming and that other forms of facilitation should be considered. In addition, larger priming for congruent than incongruent responses (congruency effect), a

signature of stimulus-response binding, would indicate that facilitation due to the retrieval of a stimulus-response binding co-exists with facilitation in conceptual and perceptual networks. It is important to highlight here a terminological aspect: effect of retrieval of a stimulus-response binding in orthogonal tasks is generally called a congruency effect, instead of a stimulus-response effect, but the source of the two effects is probably identical (stimulus-response binding).

In the literature of repetition priming in person recognition orthogonal tasks have been already used. Significant facilitation has been obtained after a single presentation of stimuli at study even when responses are incongruent (Burton, Kelly & Bruce, 1998; Johnston & Barry, 2006). Significant across-task priming for faces (orthogonal tasks condition) for incongruent responses is an outcome incompatible with rapid response learning, but predicted by facilitation in perceptual and conceptual networks. However, the picture that emerges from the study of orthogonal tasks in object recognition is opposite. Across-task priming for incongruent responses is not significant: both after single (Bruce et al., 2000; Vriezen, et al., 1995) and triple presentation of stimuli at study (Horner & Henson, 2009; Race et al., 2010). The absence of across-task priming in object recognition for incongruent responses is an outcome incompatible with facilitation in perceptual and conceptual networks, but predicted by rapid response learning.

Regarding the retrieval of stimulus-response binding across tasks, a congruency effect was significant when stimuli (objects) were presented three times at study (Horner & Henson, 2009; Race et al., 2010) but not after single presentation (faces: Johnston & Barry, 2006; object: Vriezen et al., 1995). A similar picture is in line with an interpretation of rapid response learning as facilitation that occurs only after multiple presentations of a stimulus at study (see Chapter 3 and Chapter 4). Whether similar generalization takes place in the domain of faces when stimuli are presented three times has never been tested

before.

In conclusion, the literature of across-task priming suggests that networks facilitation seems the best explanation of priming in person recognition while rapid response learning accommodates priming in object recognition, particularly when stimuli are repeated more than once at study. This contradiction is investigated in the present experiments by testing across-task priming for faces after multiple presentations of stimuli at study: a condition in which stimulus-response binding is strong enough to allow the involvement of rapid response learning in the generation of facilitation.

5.1.1 Within-task priming vs. across-task priming

Orthogonal tasks offer the possibility of testing whether priming within tasks is larger than priming across tasks. According to Burton's (1998) model of person recognition, activation of a PIN determines the activation of all the linked SIUs. The consequent prediction is that priming across tasks is equal to priming within tasks because all the links between PIN and SIUs are strengthened regardless of task demands. In fact, Burton et al. (1998) obtained significant priming from names to facial pictures of celebrities (no data-driven priming) at test even in a new categorical task (dead/alive at study, nationality at test). A similar point was supported by non significant difference in the amounts of priming within tasks and across tasks (Experiment 2, Johnston & Berry, 2006) when names of celebrities were used to primed facial pictures of celebrities. On the other hand, priming was significantly larger within tasks than across tasks when stimuli at study and test were identical (Experiment 1, Johnston & Berry, 2006). Significant priming even in the absence of data-driven priming was interpreted as conceptually driven priming, a form of facilitation resulting from previous engagement in a semantic task; but whether conceptually driven priming is modulated by the identity of tasks at study and test is an

aspect that needs further investigations.

In object recognition, Horner and Henson (2009) and Race et al. (2010) found significantly smaller priming in the orthogonal-question compared to the identical-question condition when stimuli were primed three times at study (for single presentation see Vriezen et al., 1995). These results were, however, less clear if congruency was taken into account. In fact, identical-question and reversed-question conditions (within-task conditions) imply congruent and incongruent responses respectively, therefore orthogonal tasks (across-task condition) with congruent responses must be considered the across-task counterpart of the identical-question condition and, similarly, orthogonal tasks with incongruent responses for the reversed-question condition (See Fig 8). Interestingly, Race et al. (2010) did not find any significant difference between facilitations within tasks and across tasks for congruent responses. On the other hand, although Horner & Henson (2009) did not carry out direct statistics between within-task and across-task conditions by taking response congruency into consideration (identical-question condition vs. orthogonal-question condition with congruent responses; reversed-question condition vs. orthogonal-question condition with incongruent responses), priming was always numerically larger within tasks compared to across tasks, both for congruent and incongruent responses.

It is important to underline that, in the two reported studies of object recognition, differences between within-task and across-task priming can be the effect of stimulus-classification binding retrieval. In fact, rapid response learning is significant when stimuli are repeated three times at study (see Chapter 4). Considering the two reported studies in person recognition, it sounds reasonable to speak about pure conceptually driven priming, because Chapters 2-3 show that rapid response learning does not affect significantly behaviour after a single presentation.

In summary, an additional investigation of the present experiments was to contrast amounts of priming within tasks against across tasks by taking congruency of responses into account to explore whether performing the same task at study and test produces larger facilitation than performing two different tasks. Results will be discussed according to both conceptually driven priming and stimulus-classification binding.

5.1.2 Occupation judgement vs. nationality judgement

An open debate in the literature of person recognition is whether the semantic system for people is organized in categories, and, in that case, what they are. To investigate this point many different approaches have been used [category matching in a double decision task (Johnston & Bruce, 1990); release from proactive interference (Darling & Valentine, 2005); masked categorical priming (Stone & Valentine, 2007); and categorical priming (Bruce, 1983)]. Outcomes from different approaches converge on the point that occupation, but not nationality or dead/alive, is a core category in the semantic system for people (Johnston & Bruce, 1990). Contrary to this point, Johnston & Barry (2006) found that participants were faster in responding to nationality than occupation of celebrities: the opposite would be expected if occupation, but not nationality, was a form of categorical information. Along the same lines, Barry, Johnston and Scanlan (1998) showed that the semantic representation of people, contrary to that of objects, is not encapsulated in categories.

The representational status of occupation and nationality in the semantic system is an extremely relevant piece of knowledge for the present studies because stimulus-classification binding could have a different influence on priming according to whether a task relies directly on categorical semantic information or on a property (Hampton, 1984). Creation and utilization of a classification code is reasonable for properties of a stimulus,

because of the absence of pre-existent information, but not for a categorical semantic entry.

The present experiments explored whether responses are faster in one judgement than the other, and whether this difference has an impact on priming. Such a difference would be interpreted as retrieval of a stimulus-classification binding.

5.1.3 The present experiments

The main focus of Experiment 7 and Experiment 8 was the isolation of a form of facilitation in person recognition that can exclusively be explained as facilitation in perceptual and conceptual networks. If a similar facilitation is obtained, its co-existence with retrieval of a stimulus-response binding was investigated. Data were also further analysed to investigate the influences of performing same or different tasks at study and test or performing occupation or nationality judgement on networks facilitation and rapid response learning.

Experiment 7 and Experiment 8 could be considered together as part of a perfectly counterbalanced experiment but are presented separately because of potential differences in the nature of the categorical judgement at test (Johnston & Bruce, 1990). If nationality and occupation play different roles in the organization of the semantic system, effects on accuracy and response times are expected. This possibility and its implication for rapid response learning are investigated directly in the Interexperimental Analysis section.

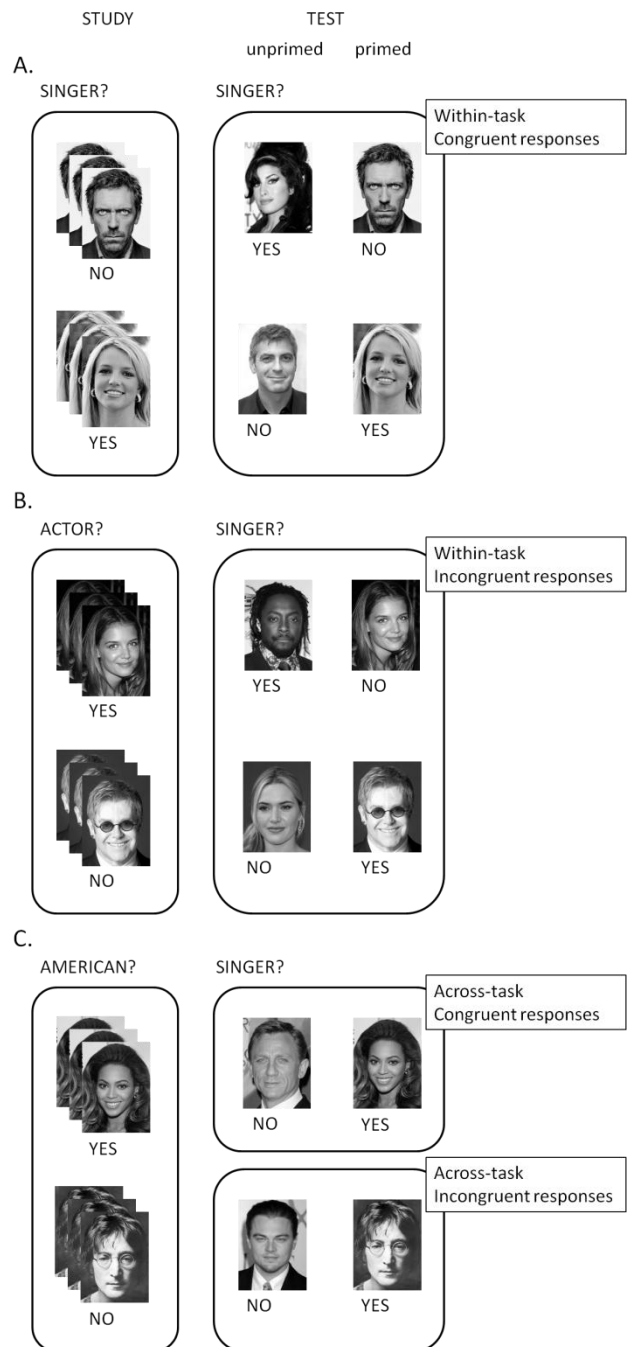
5.2 Experiment 7

In the present experiment, the influence of facilitation in perceptual and conceptual networks in person recognition was explored in a design that enhances the impact of rapid response learning. The principal aim of Experiment 7 was the isolation of a form of facilitation that cannot be explained otherwise than via networks facilitation. The condition

in which pure data-driven and conceptually driven priming were expected to occur was when orthogonal tasks were used and responses were incongruent.

The selected design was identical to that used by Experiments 1-3 in Horner and Henson (2009) with the main exceptions that stimuli at study were presented always three times and faces were used as stimuli.

Figure 8 Example of the experimental design of Experiment 7 and Experiment 8. Three study-test cycles were employed: A identical-question condition, B reversed-question condition, C orthogonal-question condition. The responses at study and test for primed stimuli were the same for stimuli in A and half of the stimuli in C. and different for stimuli in B and half of the stimuli in C. Stimuli at study (left-hand side boxes) were repeated three times under a categorical task; while, at test (right-hand side boxes) primed stimuli were repeated again intermixed with unprimed stimuli. Throughout the three cycles, the same categorical question was required at test. According to the relationship between the task at study and the task at test priming condition could be within-task congruent responses (singer?-singer? cycle A) or within-task incongruent responses (actor?-singer? cycle B) or across-task congruent responses and across-task incongruent response (American?-singer? cycle C). Orthogonal categorizations resulted in two different congruency conditions. Congruency applied to unprimed stimuli as well, considering the supposed response at study.



Three study-test cycles were employed. Questions at test were always the same (for example: ‘singer?’) while the question at study could be identical (within-task, congruent responses: ‘singer?’, see Figure 8A), reversed (within-task, incongruent responses: ‘actor/actress?’, see Figure 8B), or orthogonal (across-task, 50% incongruent responses and 50% congruent responses: ‘American?’, see Figure 8C). In the orthogonal cycle, half of the stimuli required the same responses at study and test (across-task, congruent responses) and half required different responses (across-task, incongruent responses). It is important to underline that responses could be expressed or not: to unprimed stimuli no response was given at study, nevertheless these stimuli could have required a congruent or incongruent response in the two phases of the orthogonal cycle. For example if the question at study was ‘American?’ and the question at test was ‘singer?’, Daniel Craig would be considered a congruent trial (‘no’-‘no’, he is a British actor) while John Lennon would be considered an incongruent trial (‘yes’-‘no’, he is a British singer) regardless of having been presented at study or not (see Figure 8C).

We expected to find significant priming in the orthogonal cycle like Burton et al. (1998) and Experiment 2 in Johnston & Barry (2006). Contrary to Johnston & Barry (2006), significant congruency effect in the orthogonal cycle should be obtained in the present design, as a consequence of the acquired strength of stimulus-response binding due to multiple stimulus repetitions at study (see Chapter 3).

In addition, this design allows us to study directly whether inversion of the direction of the categorical task is treated differently compared to a complete change of categorical task. In other words, when response conditions are equal, is there a benefit of re-engaging in the same semantic task compared to carrying out a completely different semantic task? As explained before, congruent and incongruent trials in the orthogonal cycle could be considered the across-task conditions of identical and reversed cycles; therefore any

difference would be an effect of facilitation in conceptual networks, which should be present only in the within-task conditions but not in the across-task conditions.

Experiment 7 employed three study-test cycles with occupation judgement as test task. Occupation is considered a categorical semantic node (Johnston & Bruce, 1990; Bruce, 1983; but see also Barry et al., 1998) therefore facilitation due to retrieval of stimulus-classification was not expected.

5.2.1 Materials and Methods

5.2.1.1 Participants

Fifty young British adults (mostly Bangor University undergraduate students) took part in Experiment 7 in return of course and printer credits. Data of two participants were discarded because the wrong task instruction was answered in one of the study or test phases. The mean age of the remaining forty-eight participants (13 male, 35 female) was 20 years (range 18-38). All the participants had normal or corrected-to-normal vision and three participants were left-handed, by self report.

The study was approved by the research ethics committee of Bangor University. Prior to the experiment, all the participants gave written informed consent.

5.2.1.2 Stimuli

Black and white facial pictures of British and American celebrities were used as stimuli. 204 stimuli were used in the experiment: ¼ British singers, ¼ American singers, ¼ British actors/actresses, ¼ American actors/actresses. Each nationality/occupation subset had 30 male celebrities and 21 female celebrities. Celebrities whose occupation or nationality was not clear (for example the singer and actor Russell Brand) were not

included in the stimuli set.

An additional set of 36 stimuli, resembling the characteristics of the main stimulus set, was used for practice runs.

5.2.1.3 Procedure

Three consecutive study-test cycles constituted the main experiment. Occupation judgement was always required at test. According to the relationship with questions at test (for example ‘singer?’), the question at study could be identical (singer?), reversed (actor/actress?) or orthogonal (British? or American?). Each phase started with the presentation of the task instruction that had to be performed on each individual stimulus (‘Is the celebrity x?’ where x could be ‘a singer’, ‘an actor/actress’, ‘British’ or ‘American’). Participants were instructed to use four pieces of paper, reporting each the crucial piece of information of the task instruction (x), as reminders: Every time a task instruction was displayed participants had to place the correspondent reminder next to the keyboard. Order of the cycles, the question at test (singer? or actor/actress?) and the question at study in the orthogonal cycle (British? or American?) were counterbalanced across participants.

Stimuli were divided into six sets of 34: three sets were used as primed stimuli (shown both at study and test) and three sets as unprimed stimuli (presented only at test). In each 34 stimuli set (20 male celebrities) occupations and nationalities were equally represented in such a way that for all questions half of the stimuli required a positive response; crucially, in the orthogonal cycle an equal number of primed and unprimed stimuli required congruent or incongruent responses to questions at study and test. During each study phase, the 34 stimuli of a set were all presented randomly three times, avoiding consecutive presentations. At test, stimuli from the precedent study phase (primed) were

presented again randomly intermixed with stimuli from a different set (unprimed).

In each phase stimuli were presented for 600 ms followed by a fixation cross, displayed for 2400 ms at study and 1900 ms at test. Responses were recorded throughout the whole duration of the trial (stimulus + fixation cross). Participants were instructed to be as fast and accurate as possible in pressing with their left and right index finger F and J keys, on computer keyboard, to express respectively 'Yes' and 'No' answers. Stimuli had a size of 8.6*11.6 deg (width*height) and were displayed on a black background.

5.2.1.4 Data analysis

Only data from the test phases are reported (see Appendix 2 for data analysis of accuracy and response times in the study phases). Trials were considered correct when the correct response occurred between 200 ms after face onset and before the next face presentation. Accuracy was analyzed with Wilcoxon-signed-rank tests because the data did not show a normal distribution.

Response times for unprimed faces were analysed from correct trials while response times for primed faces were analyzed only when correct responses within the defined time window were given in the test as well as in the study phases. In this way, trials for primed faces with correct responses at test were excluded from the calculation of mean response times when one or more incorrect responses were given in the study phase. A 3 x 2 ANOVA was performed on mean response times; the following factors were considered: question condition (identical vs. reversed vs. orthogonal) and priming condition (primed vs. unprimed). Follow-up comparisons between mean response times were made with paired-sample two-tailed *t*-tests.

Data in the orthogonal cycle were split according to congruency of the response required at study and the response required at test; the response could be expressed, as for

primed stimuli, or not, as for unprimed stimuli. In accuracy analysis priming for congruent and incongruent response was analyzed with Wilcoxon-signed-rank tests as differences between mean accuracies for primed and unprimed stimuli; the congruency effect was analyzed as the difference in accuracy gains due to priming for congruent and incongruent stimuli.

A 2 x 2 ANOVA with response congruency (congruent vs. incongruent) and priming condition (unprimed vs. primed) as factors was performed on response times data to investigate main effects of response congruency and priming, and their interaction. Independent-sample one-tailed *t*-tests were performed to investigate priming in the two congruency conditions.

The difference between within-task and across-task priming in response times was assessed in a 2 x 2 ANOVA with task (within-task vs. across-task) and congruency (congruent vs. incongruent) as factors: dependent variables were priming in the cycle with identical questions, priming in the cycle with reversed questions, priming in the orthogonal cycles for stimuli that required congruent responses and priming in the orthogonal cycle for stimuli that required incongruent responses.

The significance level was set at $\alpha=.05$ for all comparisons of accuracy and response times.

5.2.2 Results

After excluding 0.3% of trials because of missing or early responses (response time faster than 200 ms), mean accuracy at test was 87.2%. Accuracy at test was significantly larger for primed than unprimed stimuli when questions were identical, $z = 4.56, p < .001$, but not for reversed or orthogonal question at study, $z_s < 0.61, p_s > .541$ (see Table 13).

Table 13
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 7.

Accuracy %	Identical	Reversed	Orthogonal
Unprimed	85.5 (1.2)	86.9 (1.1)	86.5 (1.2)
Primed	91.8 (0.8)	86.0 (1.3)	86.0 (1.4)
Priming	6.3 (1.1) ***	-0.9 (1.1)	-0.4 (1.2)

Note: *** $p < .001$.

Accuracy gain of around 5.4% for the identical-question condition was significantly larger than accuracy gains in the reversed-question and the orthogonal-question conditions, $z_s < 3.87$, $ps < .001$; but not between the two latter conditions, $z = 0.31$, $p < .759$. Figure 9 displays mean accuracy values for primed and unprimed stimuli in the three conditions.

Further 18.7 % of primed trials were discarded from response times analysis because of at least one wrong response at study. A 3 x 2 ANOVA was performed on mean response times; both the main effects were significant: question at study, $F(2,46) = 19.07$, $p < .001$, and priming condition, $F(1,47) = 218.82$, $p < .001$. The interaction between variables was significant too, $F(2,46) = 18.38$, $p < .001$. Priming was strongly significant in all the three question conditions, $ts(47) > 9.49$, $ps < .001$ (see Table 14).

Table 14
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 7.

Response Times	Identical	Reversed	Orthogonal
Unprimed	906 (29)	940 (23)	929 (23)
Primed	717 (26)	813 (24)	832 (23)
Priming	188 (15) ***	127 (11) ***	98 (10) ***

Note: *** $p < .001$.

The stimulus-response effect, assessed as the difference between amounts of priming in the identical-question and the reversed-question condition, was significant, $t(47) = 4.35$, $p < .001$. Moreover, facilitation was significantly larger for stimuli primed at study by occupation judgement (no matter the question, identical or reversed, within-task conditions) compared to stimuli primed at study by nationality judgement (across-task condition), $ts(47) > 2.50$, $ps < .016$. (see Figure 10).

When responses were congruent, participants were more accurate with primed than unprimed stimuli: larger accuracy was supported by a trend toward significance, $z = 1.80$, $p = .072$. On the contrary, participants were significantly less accurate for primed than unprimed stimuli when decisions were incongruent, $z = 2.11$, $p = .035$ (see Table 15).

Table 15
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Congruency Conditions in Experiment 7.

Accuracy %	Congruent	Incongruent
Unprimed	87.0 (1.4)	86.0 (1.6)
Primed	90.0 (1.3)	82.1 (1.8)
Priming	3.0 (1.5)	-3.8 (1.7) *

Note: * $p < .05$.

Giving the same response at study and test in the orthogonal cycle allowed participants to be more accurate in responding to primed stimuli, $z = 3.00$, $p = .003$ (see Figure 11).

Mean response times in the orthogonal task were analysed by taking congruency of responses in consideration. A 2 x 2 ANOVA showed significant main effects of congruency, $F(1,47) = 5.56$, $p = .023$, and priming condition, $F(1,47) = 67.62$, $p < .001$:

response times were faster for stimuli that required the same responses compared to those requiring different responses in study and test phase in orthogonal cycle (respectively $M = 871$, $SE = 23$ and $M = 895$, $SE = 24$); moreover, facilitation was larger for primed ($M = 832$, $SE = 23$) than unprimed stimuli ($M = 929$, $SE = 23$). Priming in the two congruency conditions was significant: participants had a benefit in responding to repeated stimuli no matter the response given at study: congruent, $t(47) = 7.63$, $p < .001$, incongruent $t(47) = 4.91$, $p < .001$ (see Table 16).

Table 16
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Congruency Conditions in Experiment 7.

Response Times	Congruent	Incongruent
Unprimed	925 (24)	934 (24)
Primed	817 (26)	856 (26)
Priming	109 (14) ***	78 (16) ***

*Note: *** $p < .001$.*

The interaction between factors was not significant, $F(1,47) = 2.41$, $p = .127$, indicating that, despite the numerical difference, facilitation in congruent responses condition was not significantly larger than facilitation in incongruent responses condition (see Figure 12).

The difference between within-task and across-task priming was assessed in a 2 x 2 ANOVA. Main effect of task was significant, $F(1,47) = 27.35$, $p < .001$: priming was larger within tasks than across tasks.

5.2.3 Discussion

The results of Experiment 7 showed that responses to primed stimuli in orthogonal tasks when responses were incongruent were significantly faster than responses to unprimed stimuli. This finding in response times analysis is in line with facilitation in perceptual and conceptual networks. In orthogonal tasks, despite the numerical difference, priming for congruent trials was not significantly larger than priming for incongruent trials, indicating that stimulus-response effect had only a marginal effect across tasks, in contrast to its significant influence within tasks.

The significant difference between facilitation in the identical-question condition and the reversed-question condition was the signature of involvement of rapid response learning in the present experiment. Presenting stimuli three times appears to boost a stimulus-response binding that affects priming within tasks.

In orthogonal tasks, facilitation in response times for primed stimuli that required an incongruent response and the absence of a congruency effect in the orthogonal cycles were a replication of the results of Johnston and Barry (2006) and could indicate that rapid response learning only has a marginal effect on priming for person recognition across tasks, even after three stimulus repetitions at study. However, accuracy analysis suggested otherwise: accuracy gain due to priming was significantly larger for congruent trials than incongruent trials, suggesting that a stimulus-response effect generalized from one task to the other. A similar generalization of stimulus-response binding was not restricted to congruent trials but extended to incongruent trials too and determined interference, evident from lower accuracy in this condition.

Smaller facilitation across tasks than within tasks when congruency was taken into account could be a signature of either modulation of conceptually driven priming or stimulus-classification binding. Given that multiple streams of research consider

occupation a categorical node in the semantic system for people, an interpretation of a similar effect as modulation of conceptually driven priming sounds more reasonable.

Residual facilitation in the across-task condition for incongruent responses is unquestionable evidence of a form of facilitation not explicable according to rapid response learning. Similar facilitation is in line with data-driven and conceptually driven priming. Although, accuracy analysis presented effects ascribable to rapid response learning in the orthogonal cycle as well; the main evidence was a decrease in accuracy for incongruent trials.

In addition, priming in response times within tasks was larger than priming across tasks. Given the categorical nature of the semantic information, this effect could be evidence of modulation of conceptually driven priming.

5.3 Experiment 8

Experiment 8 investigated priming and rapid response learning across tasks using a task that relies on non-categorical semantic information (Johnston & Bruce, 1990) at test.

5.3.1 Materials and Methods

Experiment 8 was identical to Experiment 7 except that nationality judgement was the main judgement (in test phases) while occupation judgement was used only in the study phase of the orthogonal cycle.

5.3.1.1 Participants

Fifty British students of Bangor University took part in the Experiment in return for

course and printer credits. Data of two participants were not considered in the data analysis because the wrong question was answered at study. The mean age of the remaining 48 participants (7 male, 41 female; 5 left-handed) was 20 years (range 18-42).

5.3.2 Results

After excluding 0.8% of trials because of missing or outlier responses (response time < 200 ms), accuracy was 77.4%. Participants were more accurate in responding to primed stimuli when tasks at study and test phases were both nationality: benefit in accuracy was strongly significant, $z = 0.42$, $p < .001$, when questions were identical but even for reversed questions accuracy for primed stimuli was significantly larger than accuracy for unprimed stimuli, $z = 2.19$, $p < .028$. In the orthogonal-question condition responses at test were not significantly more accurate to stimuli presented previously at study than responses to stimuli presented for the first time at test, $z = 1.48$, $p = .139$ (see Table 17).

Table 17
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 8.

Accuracy %	Identical	Reversed	Orthogonal
Unprimed	76.9 (1.8)	74.6 (1.6)	74.5 (1.8)
Primed	82.9 (1.4)	78.1 (1.5)	77.1 (1.5)
Priming	6.0 (1.3) ***	3.5 (1.4) *	2.5 (1.6)

*Note: * $p < .05$; *** $p < .001$.*

Accuracy gains due to priming in the three question conditions were not significantly different, $z_s < 1.62$, $p_s > .105$ (see Figure 9).

Further 19.6% of primed stimuli were discarded because of at least a wrong response at study. A 3 x 2 repeated-measurements ANOVA showed that both main effects were

strongly significant: question at study, $F(1,46) = 25.19, p < .001$, and priming condition, $F(1,47) = 223.70, p < .001$. Responses were faster in the cycle with identical question compared to responses in the other cycles, $t_s(47) > 5.16, p_s < .001$. Responses to primed stimuli were significantly faster than responses to unprimed stimuli in all the three question conditions, $t_s(47) > 4.63, p_s < .001$ (see Table 18). Interaction between the two factors was significant, $F(1,46) = 29.53, p < .001$.

Table 18
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Conditions in Experiment 8.

Response Times	Identical	Reversed	Orthogonal
Unprimed	978 (32)	1003 (33)	1001 (33)
Primed	747 (23)	840 (24)	902 (32)
Priming	232 (17) ***	163 (16) ***	99 (14) ***

Note: *** $p < .001$.

The stimulus-response effect, assessed as difference between amounts of priming in the identical-question and the reversed-question condition, was significant, $t(47) = 4.25, p < .001$; priming in the orthogonal-question condition was significantly smaller than priming in the identical-question condition, $t(47) = 7.19, p < .001$, and priming in the reversed-question condition, $t(47) = 2.49, p = .006$ (see Figure 10).

The effect of congruency of responses in study and test phases of the orthogonal cycle was analysed. When responses were congruent, participants were significantly more accurate for primed than unprimed stimuli, $z = 4.68, p < .001$; contrariwise, a trend toward less accuracy for primed than unprimed stimuli was obtained for incongruent responses, $z = 1.86, p = .063$ (see Table 19).

Congruency had a strongly significant effect on accuracy, $z = 3.80$, $p < .001$ (see Figure 11).

Table 19
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Congruency Conditions in Experiment 8.

Accuracy %	Congruent	Incongruent
Unprimed	75.4 (2.0)	73.7 (2.4)
Primed	85.0 (1.7)	69.1 (2.3)
Priming	9.5 (1.6) ***	-4.5 (2.6)

Note: *** $p < .001$.

A 2 x 2 ANOVA on response times showed significant main effects of response congruency, $F(1,47) = 27.90$, $p < .001$, and priming condition, $F(1,47) = 38.94$, $p < .001$: response times were faster for stimuli that required same responses compared to different responses in study and test phase (respectively $M = 983$, $SE = 34$ and $M = 927$, $SE = 29$) and for primed than unprimed stimuli (respectively $M = 902$, $SE = 32$ and $M = 1001$, $SE = 33$). Priming in the two congruency conditions was significant; participants had a benefit in responding to repeated stimuli no matter the response given at study: congruent, $t(47) = 5.69$, $p < .001$, incongruent $t(47) = 3.24$, $p = .002$ (see Table 20).

Table 20
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Congruency Conditions in Experiment 8.

Response Times	Congruent	Incongruent
Unprimed	987 (33)	1014 (34)
Primed	868 (29)	951 (37)
Priming	119 (21) ***	62 (19) **

Note: ** $p < .01$; *** $p < .001$.

The interaction between factors was significant, $F(1,47) = 4.09, p = .049$, indicating that priming for congruent condition was significantly larger than priming for incongruent condition (see Figure 12).

The difference between within-task and across-task priming was significant, $F(1,47) = 29.88, p < .001$: priming was larger within tasks than across tasks.

5.3.3 Discussion

Experiment 8 replicated most of the outcomes of Experiment 7.

Results in Experiment 8 showed significant priming for primed stimuli across tasks when responses were incongruent, evidence of facilitation in perceptual and conceptual networks in person recognition. Contrary to Experiment 7, the congruency effect on response times was significant. Experiment 8 reported for the first time a significant congruency effect on response times across tasks, when faces were used as stimuli.

The stimulus-response effect was clearly evident in within-task conditions. Participants were faster, but not more accurate, in responding to repeated stimuli when questions at study and test were identical compared to reversed questions.

Results of accuracy analysis in Experiment 8 were less clear than those in Experiment 7. In the orthogonal cycle, repetition of a stimulus when responses were incongruent had a negative effect on accuracy, but the decrement was only marginally significant. The congruency effect for accuracy was strongly significant.

Larger facilitation within tasks than across tasks is hard to be interpreted unambiguously as conceptually driven priming because stimulus-classification binding could account for it also. In fact, nationality is considered property information in the semantic system for people, therefore the creation of a classification code seems likely.

Whether nationality judgement is treated differently than occupation judgement and

the possible consequences on priming and rapid response learning are investigated in the Interexperimental Analysis.

Experiment 8 found evidences of both facilitation in perceptual and conceptual networks and interference cause by rapid response learning in the across-task incongruent responses condition. Congruency effect in the orthogonal cycle was significant both for accuracy and response times analyses, suggesting that stimulus-response binding is not restricted to within-task conditions.

Priming in response times within tasks was larger than priming across tasks: given the not-categorical nature of the semantic information a similar result could be evidence of stimulus-classification binding, or conceptually driven priming, or a combination of the two.

5.4 Interexperimental Analyses

5.4.1 Results

Overall, mean accuracy was significantly higher in Experiment 7 than Experiment 8, $z = 5.10, p < .001$, but mean response times were not significantly different in Experiment 7 ($M = 865, SE = 23$) than Experiment 8 ($M = 912, SE = 27$), $t(94) = 1.57, p = .119$. The significant difference between mean accuracy but not between mean response times in Experiment 7 and Experiment 8 held even when means were restricted to unprimed stimuli, to exclude any possible confounding effect of priming, $z = 5.01, p < .001$ and $t(94) = 1.78, p = .078$.

Gains in accuracy due to priming were not significantly different between experiments in the identical-question condition and the orthogonal-question condition, $z <$

1.46, $p > .145$; in the reversed-question condition gain in accuracy in Experiment 8 ($M = 3.5\%$, $SE = 1.4\%$) was significantly larger than that in Experiment 7 ($M = 0.9\%$, $SE = 1.1\%$), $z = 2.09$, $p = .037$. Despite this last difference, there was only a trend toward a significant difference between the stimulus-response effects in the two experiments, $z = 1.79$, $p = .073$ (see Figure 9).

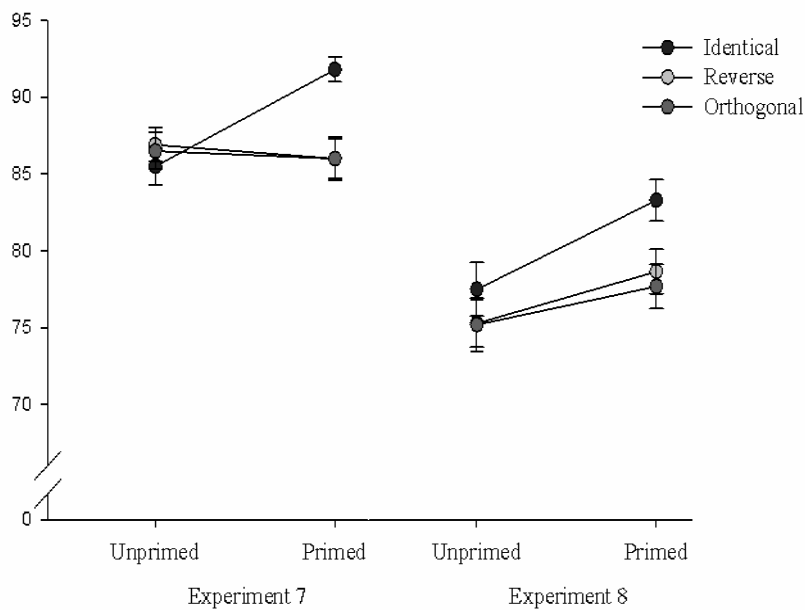


Figure 9 Mean accuracy across question (identical, reversed and orthogonal) and priming (unprimed, primed) conditions in Experiment 7 and Experiment 8. Error bars represent standard error. No statistical analyses are displayed.

A repeated measurement 3 x 2 ANOVA with question at study (identical vs. reversed vs. orthogonal) and priming conditions (primed vs. unprimed) as within-subject factors and experiments (Experiment 7 vs. Experiment 8) as between-subjects factor showed a trend toward a significant interaction between the priming condition and experiments, $F(1,94) = 3.45$, $p = .066$; the interaction was significant when only the within-task conditions were considered, $F(1,94) = 4.90$, $p = .029$. Priming was nearly significantly larger in Experiment 8 than Experiment 7 in the within-task cycles, both for the identical questions, $t(94) = 1.93$, $p = .057$, and for reversed questions, $t(94) = 1.87$, $p = .065$, but not for orthogonal

questions, $t(94) = 0.64, p = .949$ (see Figure 10).

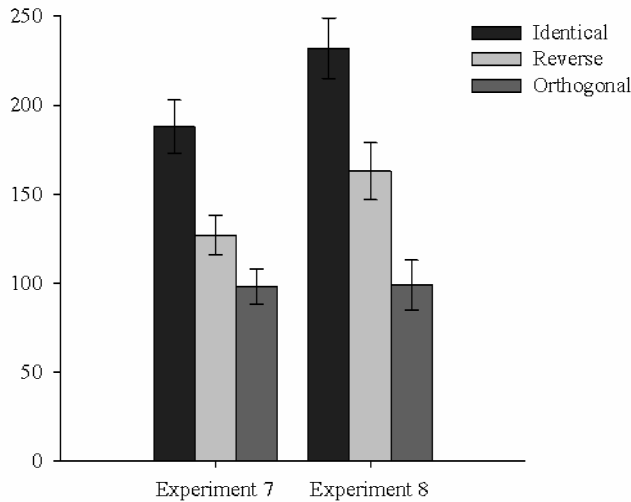


Figure 10 Priming in reaction times across question conditions (identical, reversed and orthogonal) in Experiment 7 and Experiment 8. Error bars represent standard error. No statistical analyses are displayed.

In the orthogonal cycle, the stimulus-response effect (congruency effect), assessed as difference between accuracy gains due to priming in the two congruency conditions, was nearly significantly larger in Experiment 8 compared to Experiment 7, $z = 1.73, p = .084$ (see Figure 11).

Such a trend of larger congruency effect in Experiment 8 than Experiment 7 was absent in response times analysis, $t(94) = 0.75, p < .456$ (see Figure 12).

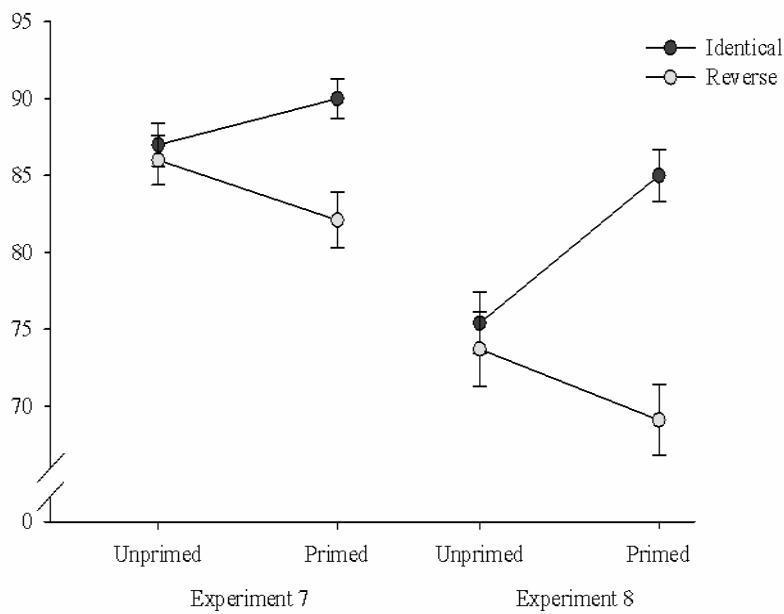


Figure 11 Mean percentages of accuracies across congruency (congruent, incongruent) and priming (unprimed, primed) conditions in Experiment 7 and Experiment 8. Error bars represent standard error. No statistical analyses are displayed

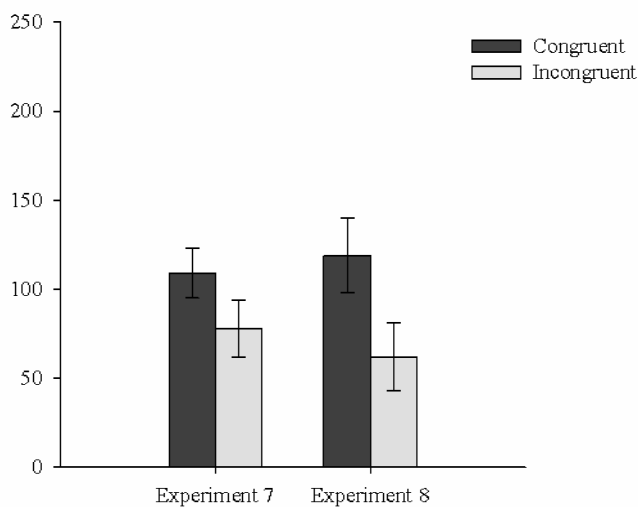


Figure 12 Priming in response times across congruency (congruent, incongruent) conditions in Experiment 7 and Experiment 8. Error bars represent standard error.

5.4.2 Discussion

Participants were more accurate and faster, but not significantly, in occupation than nationality judgement. This difference could be the effect of a different representation of

nationality and occupation in the semantic system, or, alternatively, higher uncertainty in nationality than occupation judgement.

Priming in nationality judgement was significantly larger than priming in occupation judgement, indicating a larger benefit of repetition in this task either due to the fact that nationality judgement involves a larger number of links that can be strengthened by repetition or, alternatively, due to the creation of a stimulus-classification binding that allows faster responses to nationality judgement, but not to occupation judgement because such binding is not created.

The last significant effect found in the Interexperimental Analysis is a trend toward a larger congruency effect across tasks in the nationality judgement compared to the occupation judgement. A similar effect cannot be ascribed to stimulus-classification binding because it has a marginal effect across tasks; data-driven or conceptually driven priming cannot be considered either because they were similar in the two experiments. A possible explanation, but direct investigation is required, could be certainty in the semantic knowledge required by the two orthogonal categorizations. If at test, a participant is unsure about the correct response, stimulus-response binding can favour the selection of the previously given response, resulting in an increase of accuracy when stimulus requires congruent responses and a decrease when stimulus requires incongruent responses. According to uncertainty, a larger congruency effect in Experiment 8 than Experiment 7 would be expected because stimulus-response binding created at study for the occupation judgment (Experiment 8) is stronger than that created at study for nationality judgement (Experiment 7), due to higher certainty. This stimulus-response binding would then compete at test with the output of stimulus processing that is weaker in nationality judgement (Experiment 8) compared to occupation judgement (Experiment 7). Such unbalanced strength could determine a larger bias toward the response of the stimulus-

response binding and consequently a larger congruency effect in Experiment 8.

5.5 General discussion

Experiment 7 and Experiment 8 were conducted to explore whether facilitation in perceptual and conceptual networks plays a role in priming in person recognition when stimuli are presented three times at study, and, therefore, when rapid response learning is involved. A cycle with orthogonal tasks was used to isolate networks facilitation: two other cycles with identical and reversed task instructions were employed to test the magnitude of stimulus-response effect. Results of Experiment 7 and Experiment 8 show that rapid response learning was significant in the within-task condition, indicating that stimulus-response bindings were created in the study phases and utilized at test in the within-task cycles.

In a similar scenario, with evidence of the involvement of rapid response learning by the present design, a form of priming in person recognition not contemplated by rapid response learning was isolated as well. Facilitation for stimuli primed across tasks when responses at study and test were incongruent was significant. Such facilitation cannot be explained according to rapid response learning because of the complete mismatch between response and classification codes retrieved from memory and response and classification codes obtained from reprocessing the stimulus. This facilitation must be accounted for by facilitation in perceptual and conceptual networks, instead, as data-driven priming - facilitation in repeated processing same perceptual information - and conceptually driven priming - facilitation in accessing the semantic system.

This result contrasts with results in Horner & Henson (2009) and Race et al. (2010) in which facilitation in object recognition was abolished when post-semantic processes, critical for rapid response learning, are unusable because their content is incorrect for the

new question context. On the other hand, it is in line with the literature of across-task priming in person recognition when stimuli are repeated only once at study (Burton et al., 1998; Johnston & Barry, 2006). Taken together, these studies indicate a different impact of data-driven and conceptually driven priming in object recognition and person recognition. Presenting a face but not presenting an object causes strengthening of the links between structural encoding, recognition unit, identity node and semantic units that allow priming even when response codes cannot generate any facilitation.

Networks facilitation was not the only priming effect evident in the across-task condition. In fact, priming for congruent stimuli was larger than priming for incongruent stimuli; a numerical difference was significant for accuracy in Experiment 7 and for response times in Experiment 8. The congruency effect is clear evidence of stimulus-response binding even across tasks: having given response at study allows being faster and more accurate in giving the same response at test, even when a different task is performed.

This result is in line with Horner & Henson (2010) and Race et al. (2009), but contrasts with Johnston & Berry (2006) and Vriezen et al. (1995), suggesting that stimulus-response binding is an association that needs multiple stimulus repetitions at study to become behaviourally relevant and generalize to different tasks.

How the reactivation of stimulus-response binding acts in a context different from the one in which it was created, is a question that can find an answer in the different trends of accuracy for primed stimuli across tasks, in relation to congruency. Repetition of a stimulus produced an increase in accuracy when responses at study and test were congruent but a decrease in accuracy when responses at study and test were incongruent. Benefit and cost are indication of interaction in response networks that facilitates giving a congruent response but interferes in giving an incongruent response.

Across-task interference was obtained by Race et al. (2010) for response times.

Horner & Henson (2011b, 2012) reported interference after change of the reference size when names of objects were used to prime pictures of objects. The absence of interference in responses times in the present experiments, both across tasks and within tasks (reversed-question condition), could be related to the fact that negative effects caused by incongruency were masked by positive effects due to data-driven and conceptually driven priming across tasks, and additional facilitation due to stimulus-classification binding within tasks. This possibility makes an interpretation of priming in reversed-question condition as pure facilitation in perceptual and conceptual networks plus stimulus-classification binding questionable. Indeed, facilitation in this condition could be reduced by interference caused by stimulus-response binding. However, no evidence of a cost in accuracy for primed stimuli in reversed-question condition seems against a similar possibility, but the absence of a proper baseline condition within tasks does not allow ruling out interference (see Chapter 6).

An important question, at this point, is how the cognitive system manages mismatch responses, determining interference across tasks but not within tasks. A possible factor could be expectation of a mismatch. In reversed-question condition responses bound to a stimulus are always wrong at test while only half of them are wrong at test in orthogonal-questions condition. Therefore, compared to an orthogonal cycle, in reversed cycle executive processes could be more inclined to accept and manage conflicts between response associated with a stimulus (stimulus-response binding) and new response produced by re-processing the stimulus, favouring the second. In effect a similar conflict should happen for all the stimuli associated with a response (primed); otherwise an error in the re-processing would have occurred. On the other hand, in an orthogonal cycle the control system cannot expect a priori response conflicts because responses mismatched only for half of the primed stimuli. Consequently a response cannot be preferential and

interference might be larger in this condition. This interpretation accounts for interference for incongruent stimuli in the across-task but not in the within-task condition, but it is insufficient to explain why in Experiment 3 and Experiment 6 interference was not evident. In a study-study-distractor-test design the cognitive system cannot expect mismatch for all the repeated stimuli a priori, because for half of the repeated stimuli a match between responses happens (identical-question condition) but for half of the repeated stimuli a mismatch between responses occurs (reversed-question condition). To account for a similar discrepancy the cognitive system should be aware of the priming context and use this information to direct expectation.

In summary, priming in person recognition results from both facilitation in perceptual and conceptual networks and rapid response learning. Taken together, these results and those of Johnston & Barry (2006) suggest that networks facilitation operates immediately after a single presentation of stimuli at study, while rapid response learning comes into play after multiple stimulus presentations. These two types of memory interact and, sometimes compete, in the generation of a correct response.

5.5.1 Within-task priming vs. across-task priming

Experiment 7 and Experiment 8 employed two within-task cycles and one across-task cycle. The two within-task cycles differed according to the congruency of responses: congruent responses in one cycle (identical questions) and incongruent responses in one cycle (reversed questions). The across-task cycle incorporated both congruent and incongruent responses within the same cycle. This design allows detecting facilitation related to performing the same task at study and test by contrasting within-task priming against across-task priming, when congruency of responses is taken into account.

Priming was larger within tasks than across tasks, both for occupation judgement and nationality judgement. This result is in line with findings in Horner & Henson (2009) and in Experiment 1 in Johnston & Barry (2006), but contrasts with findings in Race et al. (2010), Burton et al. (1998) and Experiment 2 in Johnston & Barry (2006).

Larger priming within tasks than across tasks could be either indication of a different impact of conceptually driven in within-task conditions than in across-task conditions or indication of stimulus-classification binding. However, both these alternatives require further specification to account for this result. Conceptually driven priming should be reinterpreted to accommodate for this result. In agreement to Burton's (1998) model all the SIUs associated with a PIN are activated in a semantic task and links are strengthened, allowing conceptually driven priming across tasks, but the link to the target task-specific SIU are strengthened more, determining larger conceptually driven priming in the within-task conditions than in the across-task conditions, as in the present experiments. On the other hand, it should be hypothesised that a task-specific classification is created no matter the presence of an identical categorical SIU.

The categorical nature of occupation judgement allows advancing the hypothesis that larger within- than across-task priming in Experiment 7 is pure modulation of conceptually driven priming. On the other hand, this effect in Experiment 8, given the different nature of nationality judgement, could be either evidence of conceptually driven priming, or stimulus-classification binding, or a combination of the two. Differences between Experiment 7 and Experiment 8 were investigated in Interexperimental Analysis, and are discussed in the next section.

The main outcome of the comparison between within- and across-task conditions was significantly larger priming when the same task was performed at study and test

compared to when different tasks were carried out. Whether this result is evidence of modulation of conceptually driven priming or retrieval of a stimulus-classification binding cannot be answered definitively, but Experiment 7, using occupation judgement at test, supports this interpretation.

5.5.2 Occupation judgement vs. nationality judgement

Experiment 7 and Experiment 8 employed two different semantic tasks: occupation and nationality. Responses to occupation judgement were more accurate, and nearly faster, than responses to nationality judgement, indicating higher uncertainty in the second task compared to the first task, possible consequence of a difference in the representation of the two semantic entries. These results are more or less in line with the literature that considers occupation a categorical entry and nationality a property (Johnston et al., 1990); however, the general trend of the results is opposite compared to that in Johnston & Berry (2006).

How priming and the stimulus-response effect are modulated by these two different tasks was investigated. Within-task priming was significantly larger in Experiment 8 compared to Experiment 7. This result could be evidence of further modulation of conceptually driven priming or stimulus-classification binding. According to Johnston & Bruce (1990) occupation is a category while nationality is a property (Hampton, 1984). Consequently, it is possible that accessing property information involves additional processes that are primed by repetition. However, stimulus-classification binding seems to be the best candidate to explain a similar facilitation. This form of facilitation was identified by Horner & Henson (2009, Experiment 7) but its existence in tasks other than size judgement has never been reported yet. Significant difference between within-task priming in Experiment 7 and Experiment 8 could suggest a role of stimulus-classification binding in nationality judgement but not in occupation judgement. Similarly, in Horner &

Henson (2009) priming was numerically larger (no direct statistics were reported, though) for size judgement than natural/manmade decision.

Retrieval of a stimulus-classification binding is a better explanation for another effect evident in the Interexperimental Analysis: participants were more accurate for reversed task instructions in Experiment 8 compared to Experiment 7. This effect could be caused by utilization of a classification code for nationality but not for occupation judgement.

The general picture that emerges from these studies suggests that classification acts when the categorical judgement relies on properties of the stimulus, like nationality of celebrities (size of object), but not when it relies on categorical information, occupation for celebrities (natural/manmade for objects). In any case, further direct investigations are needed.

5.6 Conclusion

To summarize, the results of Experiment 7 and Experiment 8 bring strong evidence about the existence of data-driven and conceptually driven priming in person recognition even in designs that favour the use of rapid response learning. This point undermines rapid response learning status as global interpretation of priming, but at the same time suggests facilitation can be generated in response networks, particularly after multiple stimulus presentations at study.

Chapter 6

Rapid response learning is the product of the reactivation of a stimulus-response binding. How the cognitive system manages a possible conflict between the response retrieved from memory and the response generated by reprocessing the stimulus is a question not fully answered yet. Lateralized readiness potentials (LRPs) and event-related potentials (ERPs) were used to test whether responses are retrieved even when a change of categorical cue makes them incorrect in the new task condition and the consequences of such retrieval on response production. Participants performed nationality judgements on faces of celebrities when electrophysiological signals from their brain were recorded. Two study phases were followed by a single test phase, in which stimuli from the study phases and stimuli not shown before were presented. Questions in the study phases were identical or reversed compared to questions in the test phase. Clear behavioural and electrophysiological effects of the reactivation of stimulus-response binding were obtained. LRPs showed that a response was transmitted to the motor cortex even when the response was incorrect, causing interference. ERP correlates of stimulus repetition not fully explicable as rapid response learning or episodic memory were also found and interpreted as networks facilitation. Findings of the present experiment support a multiple-routes multiple-stages interpretation of priming in person recognition.

Is rapid response learning a benefit of giving the same response again or an effect of interaction between responses?

6.1 Introduction

Rapid response learning is the reactivation of a stimulus-response binding that allows faster and more accurate responses to repeated stimuli when tasks at study and test are identical, and even when tasks are different but responses are congruent. However, for different tasks, repetition results in faster but less accurate performance when responses are incongruent (Chapter 4; see also Denis & Perfect, 2012). Evidence of interference for incongruent responses, in response times instead, were reported in similar experimental paradigms as well (Race et al., 2010; Race et al., 2009), and consistently when names are used to prime pictures of objects and the reference of the size judgement is changed (Horner & Henson, 2011b, 2012). However, interference has never been reported when categorical cues are reversed. In this condition, interference could be overpowered, or masked, by other sources of facilitation, like data-driven or conceptually driven priming or stimulus-classification binding. In fact, a change of task limits the effect of conceptually driven priming or stimulus-classification binding in Race et al. (2009) and Chapter 5, while a change in domain of the stimulus material (names to pictures) obliterates data-driven priming, as in Horner & Henson (2011b, 2012). Therefore, potential interference due to a stimulus being bound to an incorrect response, when categorical cues are reversed at study and test, represents a crucial aspect for the interpretation of rapid response learning. In other words, is rapid response learning a benefit of giving the same response again or an effect of interaction between responses?

The absence of an appropriate baseline condition in studies that investigated rapid response learning has precluded any attempt to experimentally disentangle these two alternatives. A potential baseline condition could be presenting stimuli at study when the

participants are asked to access as much biographical knowledge as possible about the stimulus, without performing any categorical task. Such an experiment has never been carried out; however some insights into the topic is provided by the study of LRPs. LRPs allow the direct investigation of motor response even in the absence of response. LRPs are electrophysiological correlates of pre-motor and motor processes extracted from the EEG signal (Masaki, Wild-Wall, Sangals, & Sommer, 2004). For example, a left hand movement is preceded by activity in the right motor cortex; this activity generates a larger negative potential over central electrodes contralateral to the responding hand as compared to that over homologous locations ipsilateral to the responding hand. The difference between contralateral and ipsilateral potentials results in a negative deflection of the signal before response when ipsilateral activity is subtracted from contralateral activity (Coles, 1989). The deflection is positive, instead, if a movement with the wrong hand is prepared. Crucially for the present study, a positive deflection of the LRP (the so called “dip”) is an index of incorrect motor preparation, even if the motor response is not overtly expressed. In fact, a wrong response can often be automatically activated but blocked before it is performed, in favour of the correct response. Interference between an automatically prepared incorrect response and newly processed correct response, when the correct response is given, manifests as a positive potential (incorrect motor response) that precedes the negative potential (correct response), and delays the onset latency of the main negative deflection.

If rapid response learning facilitates response processes, it should be evident as a significantly faster onset of the main negative deflection for stimuli primed by the identical task instruction compared to stimuli primed by the reversed task instruction. This difference, if significant, could either be determined by reactivation of the previously given response that delays the preparation of the correct incongruent response and favours

the preparation of the correct congruent response, or, alternatively, the higher availability of the correct response could incentivise the preparation of the correct response only in the congruent condition. The presence of a positive dip (interference) in the primed reversed-question condition would support the first account. Horner & Henson (2012) found that stimulus-response binding determined a response-locked modulation of within-domain ERPs around 250 ms before response due to stimulus-response binding: the ERP for primed congruent response was more negative than the ERP to novel stimuli, whereas the ERP for primed incongruent responses was more positive than the ERP to novel stimuli. This different trend was cautiously interpreted as evidence of interference. The described study found a similar trend in activity in the prefrontal cortex: a decrease of neural signal for the primed congruent response condition and an increase of neural signal for the primed incongruent response condition. Interestingly, the ERP, but not the neural, effect of stimulus-response binding was absent across-domain, a condition in which the behavioural congruency effect was smaller. Interpretation of this ERP trend as clear evidence of interference is problematic because it has not previously been shown that interference determines a shift in polarity of the ERPs. Therefore, more research on interference is needed and the study of LRPs represents a possible way to test the topic directly.

In summary, Experiment 9 aims to investigate whether any significant difference due to the priming history of the stimuli can be detected in LRPs, indicating an effect of stimulus-response binding in response preparation. Further, an indication of reactivation of the incorrect response in the reversed-question condition would suggest interference in this process.

In addition to LRP analysis, the EEG signal was further analysed to extract the ERP correlates of rapid response learning and stimulus repetition. Whether a difference in

priming history is identified at an early or a late stage of stimulus processing is an important piece of information that further advances the understanding of the cognitive processes behind rapid response learning. Logan's (1990) instance theory proposed that facilitation is produced only by reactivation of an instance. How reactivation is managed when the response is incorrect and the categorical cue is reversed remains unclear. In fact, simple reactivation of an instance would produce facilitation in response times regardless of the categorical cue, but a high rate of incorrect responses in those conditions in which responses are incongruent. On the other hand, instances might be retrieved only when categorical cues are identical, but not when they are reversed (Dobbins et al., 2004). This last account was supported by Race et al. (2010). An ERP correlate of retrieval of stimulus-response binding was found around 450 ms after stimulus onset. Interestingly the ERP of primed stimuli with congruent responses was significantly more negative than the ERP of unprimed stimuli and the ERP of primed stimuli with an incongruent response, as would be predicted if retrieval of an instance was blocked when incorrect. However, the fact that the ERP in congruent response conditions had a similar trend within tasks, when the correctness of the retrieved response is predictable, and across-task, when predictability is less straightforward, complicates an interpretation of this effect as pure retrieval of an instance when correct.

Race et al. (2010) obtained an ERP correlate of stimulus-classification binding later in stimulus-processing, around 600 ms. Using a similar paradigm, Hsu & Waszak (2012) reported earlier detection, around 200 ms, of differential priming history (a possible index of stimulus-classification binding) but they did not find any ERP modulation due to response congruency. The discrepancy between these two studies - earlier detection of priming history in Hsu & Waszak (2012) compared to Race et al. (2010) - could be justified by the presence of a confounding experimental factor in Race et al. (2010). A task

description for each individual trial (displayed for 500 ms) was presented before the stimulus, but separated from it by an inter-stimuli interval (ISI) of 500 ms in Hsu & Waszak (2012), while in Race et al. (2010) the task instruction immediately preceded the presentation of the stimulus, without any interval (ISI = 0). Therefore, in Race et al. (2010) stimulus processing could be delayed by processing of task instructions. The absence of any ERP correlate of stimulus-response binding in Hsu & Waszak (2012) is difficult to explain, though, it could be due to stimuli being primed only once at study.

An alternative interpretation of repetition priming is the multiple-routes multiple-codes model (Horner & Henson, 2009). According to this model priming is the product of networks facilitation and interaction/competition between the response retrieved from memory and the response generated by re-processing the stimulus. Horner & Henson (2012) found that stimulus-locked ERPs were modulated by stimulus repetition, in agreement with networks facilitation, whereas response-locked ERPs were modulated by response congruency, in agreement with interaction/competition between responses (see also Race et al., 2010).

To summarize, ERP studies of rapid response learning found that priming history modulates stimulus-locked ERPs, even at an early stage, probably perceptual, (Hsu & Waszak, 2012; Race et al., 2010) even though in one instance this modulation was absent in stimulus-locked ERPs but significant in response-locked ERPs (Horner & Henson, 2012). Whether the effect of retrieval of memory trace is time-locked to the stimulus or the response is a crucial question for differentiating between blocking and interaction/competition accounts of rapid response learning.

A secondary goal of the present experiment, therefore, is to determine at which level of processing (i.e., stimulus or response) the cognitive system detects a difference in

priming history.

The EEG signal is further analysed to investigate whether other forms of memory are engaged by the present design, and if so, which ones. ERP correlates of stimulus repetition can either be a signature of priming or episodic memory. In fact, a stimulus at study is generally primed and encoded in episodic memory at the same time. Paller et al. (2003) showed that the ERP of unlikely remembered faces was more negative than that of new faces over frontal electrodes in the time-window 250-400 ms; on the other hand, the ERP of likely remembered faces was more positive over parietal electrodes in the time-window 400-800 ms. Rugg et al. (1998) found a similar negativity for unremembered primed objects (~ 300-500 ms) with a more posterior topography, but two ERP correlates associated with episodic memory were reported instead of the single effect in the domain of faces: a frontal to central positivity around 300-500 ms and a left parietal positivity around 500-800 ms. Other studies replicated the absence of frontal ERP correlates of episodic memory in the domain of faces (MacKenzie & Donaldson, 2007; Yovel & Paller, 2004).

The present experiment does not employ an episodic memory retrieval test. Consequently, the interpretation of the nature of the ERP correlates of stimulus repetition can be based only on the literature. Priming is generally associated with a small potential that varies in time and topography in relation to the stimulus domain and the task demand. On the other hand, the ERP correlates of episodic memory are less variable: frontal Old/New effect - a positivity over fronto-central electrodes in the time-window 300-500 ms -, parietal Old/New effect - a positivity over parietal electrodes in the time-window 500-800 ms -, and late posterior negativity - a long lasting negativity that starts immediately after the parietal Old/New effect. The frontal Old/New effect (generally

absent for faces) is thought to represent familiarity while the parietal Old/New effect would index recollection (Rugg et al., 1998): the late posterior negativity is generally observed in designs that induce high response conflict or in tasks that require source judgement (Johansson & Mecklinger, 2002).

6.2 Experiment 9

The current experiment tested the core properties of rapid response learning by investigating how priming by identical or reversed questions affects LRPs and ERPs of repeated stimuli. Electrophysiological signals were recorded while participants performed nationality judgements on facial pictures of celebrities. Task of the participants was nationality judgement. The different priming conditions were obtained by employing two study phases: one study phase had the identical question to that in test phase, while the other study phase had the reversed question (still nationality but with a different categorical cue). LRPs and ERPs were analysed to investigate whether motor interference can explain rapid response learning, and at which level of stimulus or response processing the cognitive system is aware of the identical or reversed study context of primed stimuli.

6.2.1 Materials and Methods

6.2.1.1 Participants

Twenty-five German university students participated in this experiment in exchange for course credits or in return for a €16/£15 payment (depending on location). The data of one participant was discarded because overall accuracy was below 60% (chance performance is 50%). Mean age of the remaining twenty-four participants (18 women) was 24 years (range 18-42). All the participants had normal or corrected-to-normal vision and,

according to the Edinburgh Handedness Inventory (Oldfield, 1971) all participants were right-handed except for one ambidextrous and one left-handed participant. The study was approved by the ethics committee at the School of Psychology, Bangor University, and all participants gave written informed consent.

Seventeen participants carried out the experiment at the Institute of Psychology, Humboldt University at Berlin, and eight at the School of Psychology, Bangor University.

6.2.1.2 Stimuli

300 black and white facial pictures of celebrities (mostly actors, singers, politicians, athletes and TV presenters) were used as stimuli. The selected celebrities had half German nationality (90 men, 60 women) and the other half American nationality (90 men, 60 women).

140 colored pictures of objects, on a white background, were also used; half of the objects were presented in their canonical position and half were rotated upside-down.

Additional 24 pictures of celebrities and 12 pictures of objects, resembling the characteristics of the experimental stimulus set, were used as practice stimuli.

6.2.1.3 Procedure

Prior to the beginning of the experiment the procedure was explained to the participants and three short practice runs with 12 stimuli each, in which the three experimental task instructions were presented in a random order, were performed.

The experiment consisted of two cycles of two study phases followed by a distractor task and one test phase. In each cycle the two opposite questions (“Is the celebrity German?” or “Is the celebrity American?”) were presented separately in the two study phases and their order was counterbalanced between cycles. The task in distractor phases

was an orientation judgement (“Is the object correctly orientated?”). In the two test phases, the same question was presented. Participants had to express a yes/no judgement and responded using two response buttons with the left and right index finger.

In each study phase 50 randomly selected stimuli (15 German males, 10 German females, 15 American males, and 10 American females) were presented three times. In study phases a stimulus could not be presented for the second time before all the stimuli had been presented once, and similarly for the third presentation; immediate repetition was also excluded. Stimuli presented in study phases (primed) were presented again in the test phase mixed with 50 stimuli not previously shown (unprimed). According to the question at study, the response for primed stimuli presented in the test phase was either the same (identical-question condition) or the reversed (reversed-question condition) response expressed at study. Between the study phases and the test phase a distractor phase made up of 70 stimuli (35 objects in their canonical position, 35 upside-down rotated objects) was performed. The question at test, response buttons' mapping and order of the study phases were counterbalanced across participants.

Throughout the experiment stimuli were presented for 600 ms, followed by a fixation cross displayed for 2400 ms in study phases and distractor phases and for 1900 ms in test phases. Facial stimuli had a size of 8.6*11.6 deg (width*height) and were displayed on a black background while object stimuli had a size of 8.6*8.6 deg (width*height) and were displayed on a white background. Responses were collected during the whole duration of the trial (stimulus + fixation cross).

The experiment was conducted in a dimly lit, sound-attenuated, and electrically shielded chamber at the Institute of Psychology, Humboldt University at Berlin, or in an electrically shielded room at the School of Psychology, Bangor University.

6.2.1.4 EGG recording

The EEG was recorded during the whole duration of the experiment from 27 Ag/AgCl electrodes embedded in an elastic cap. The locations of the electrodes were based on the International 10-20 system and corresponded to the positions: Fp1, Fp2, F7, F3, Fz, F4, F8, FC3, FCz, FC4, T7, C3, Cz, C4, T8, CP3, CPz, CP4, P7, P3, Pz, P4, P8, PO9, PO10, O1, O2. Two electrodes were applied directly on the skin or on the cap over the left and right mastoids, M1 and M2. Initial common reference was M1 (FCz was used, instead, for eight participants) and AFz (Fpz was used, instead, for eight participants) served as ground. Different reference and ground electrodes were used because of specific experimental procedures in the two labs (Biologische Psychologie/ Psychophysiologie, at Institute of Psychology, Humboldt University at Berlin and Boehm's EEG lab at the School of Psychology, Bangor University). EOG was recorded from four electrodes, with two placed below the right and the left eye (VEOG) and two on outer canthi of both eyes (HEOG). All signals were digitized with a frequency of 250Hz and band-pass filtered to include frequencies from 0.05 to 70Hz. Electrodes impedance was kept below 10k Ω for EEG electrodes and below 20k Ω for EOG electrodes.

6.2.1.5 LRP/ERP data processing

Offline, the influence of blinks and eye movements on the EEG signal was corrected via independent component analysis based on 20 calibration trials for each artefact (left, right, up, down, blink) obtained after the experiment proper. A low-pass filter with a cut-off frequency 30 Hz for ERP analysis or 18 Hz for LRP analysis was applied; slope was 48 dB/octave. A 200 ms pre-stimulus interval was used as baseline.

EEG signal was segmented in epochs anchored to the stimulus, for stimulus-locked analyses, or to the response, for response-locked analyses. For ERP analysis, epochs of

1200 ms were generated: in stimulus-locked analysis the whole epoch extended after stimulus onset, while in response-locked analysis the epoch started 700ms before response. For LRP analysis stimulus-locked and response-locked epochs had a duration of 1000ms: for stimulus-locked analysis the epoch started 200 ms before stimulus onset, while for response-locked analysis the epoch started 500 ms before response.

ERPs/LRPs were obtained as grand averages of unprimed stimuli with correct response at test and of primed stimuli with consistently correct responses at study and test. All epochs for primed faces correctly categorized both at study and test were averaged together according to task instruction at study to obtain two priming conditions (primed identical-question, primed reversed-question); all epochs for unprimed faces correctly categorized at test were averaged together (unprimed).

Epochs were automatically and visually inspected to detect artefacts, which were discarded. All potentials were re-referenced to the average reference.

6.2.1.6 Behavioural analysis

Behavioural analysis was identical to that reported in Chapter 3.

6.2.1.7 ERP data analysis

Average waveforms were computed for conditions and subjects in 50 ms time-windows and analysed with repeated-measures ANOVAs. Degrees of freedom were adjusted according to Greenhouse-Geisser correction. In the occurrence of significant contrasts, time-windows were aggregated, if necessary, and two-tailed paired-sample *t*-tests were performed on electrodes with the highest negative or positive potential. For these statistical analyses EOG electrodes were not included. The significance level was set at $\alpha = .05$ for all statistical tests.

Stimulus-response binding was assessed as the difference between the waveforms for the two question conditions (identical vs. reversed); ERPs for unprimed and primed (collapsed between the two question conditions) were contrasted to investigate the ERP correlates of stimulus repetition.

6.2.1.8 LRP data analyses

To extract the LRPs, activity at central electrodes ipsilateral to the responding hand was subtracted from contralateral activity at the homologous electrode. The LRPs for right hand responses were calculated as the subtraction of activity at C4 from activity at C3, while activity at C3 was subtracted from activity at C4 for left hand responses. The LRPs for right and left hand responses were then averaged within each required response hand and successively average across both response hands according to the condition.

To determine LRP onset time a linear regression procedure (Mordkoff & Gianaros, 2000) was used on jackknife averages (Miller, Patterson, & Ulrich, 1998). Starting from the peak of the LRP, regression lines were generated moving step by step backward with the method of least squares. In other words, considering the peak of the LRP as the anchor point $p_e = 0$, a regression was generated between $p_e = 0$ and $p_s = -1$, the first data point before the peak; similarly regression lines were generated between $p_e = 0$ and $p_s = -2$, and so on for all the p data point ranging from the peak to the beginning of the epoch. The goodness of fit was assessed with standard error of measurement, and the starting point of the regression function was the p_s at which the predictive power of the regression starts an asymptotic decline. The onset time of the LRPs was the point at which the regression line crosses the x-axis. ANOVA was performed on the onset time of the jackknife averages for the two priming conditions. F value was corrected according to Ulrich & Miller (2001), $F_c = F/(n-1)^2$.

Average waveforms were also computed for conditions and subjects and 50 ms time–windows before onset of the negative deflection were analysed with two-tailed paired-samples *t*-tests. The significance level was set at $\alpha = .05$ for all statistical tests.

The unprimed condition was not analysed.

6.2.2 Results

6.2.2.1 Behavioural results

The order of the study phases did not significantly interact with the stimulus-response effect in accuracy, $Z = 1.75$, $p = .080$, or in response times analysis, $t(23) = 0.50$, $p = .961$. Therefore, data were collapsed between cycles.

Missing and early responses accounted for 0.7% of trials. Stimulus repetition significantly improved accuracy only when the questions at study and test were identical, $Z = 2.97$, $p = .003$, but not when they were reversed, $Z = 0.68$, $p = .495$ (see Table 21). The larger accuracy gain of 3.6 % for the identical-question condition compared to reversed-question condition was significant, $z = 2.61$, $p = .009$, demonstrating a stimulus-response effect in person recognition in accuracy analysis.

Table 21
Mean (Plus Standard Error) Percentage of Accuracy and Accuracy Priming (Unprimed Minus Primed) across Question Conditions in Experiment 9.

Accuracy %	Identical		Reversed
Unprimed			87.8 (8.6)
Primed	92.4 (4.4)		88.9 (6.5)
Priming	4.6 (1.3)	**	1.1 (1.3)

*Note: ** $p < .01$.*

A further 14.4% of correct primed trials were discarded because of at least one incorrect response at study. Priming, assessed as difference between response times for unprimed and primed stimuli was significant in both priming conditions: $t(23) = 10.81$, $p < .001$, when questions were identical, and $t(23) = 8.85$, $p < .001$ when questions were reversed (see Table 22).

Table 22
Mean (Plus Standard Error) of Response Times and Response Times Priming (Unprimed Minus Primed) across Question Condition for Experiment 9.

Response Times	Identical	Reversed
Unprimed		952 (30)
Primed	779 (28)	819 (29)
Priming	173 (16) ***	133 (15) ***

Note: *** $p < .001$.

The stimulus-response effect, assessed as the difference between priming levels in the two priming conditions ($M = 40$ ms, $SE = 7$) was significant, $t(23) = 5.82$, $p < .001$ (see Figure 13).

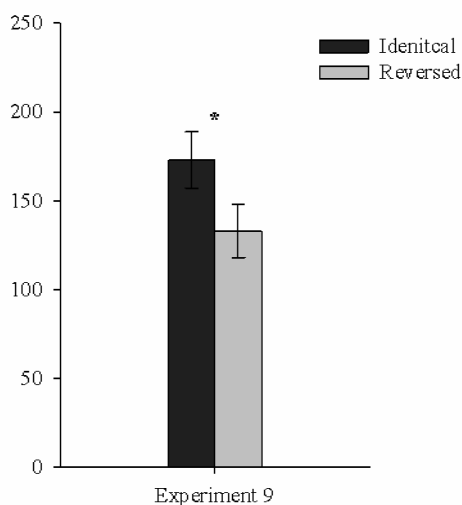


Figure 13 Reaction time priming across priming conditions. Statistically significant contrast was indicated by: * $p < .05$. Error bars represent standard error.

6.2.2.2 ERP results: stimulus-locked

The ERP for primed and the ERP for unprimed stimuli were contrasted to investigate stimulus repetition effect. Stimulus repetition (primed vs. unprimed) significantly modulated ERPs in the time-window 150-250 ms, $F(5.09,117.01) = 3.82, p = .003$: ERPs to primed stimuli were significantly more negative than those to unprimed stimuli over right parieto-occipital locations, peaking at PO10, $t(23) = 2.81, p = .010$ (see Figure 14).

The ERP for repeated stimuli was more positive than the ERP for novel stimuli over parietal electrodes from 450 to 700 ms, $F(3.70,85.05) = 15.94, p < .001$, peaking at Pz, $t(23) = 5.69, p < .001$ (see Figure 15). This parietal correlate of stimulus repetition was immediately followed by a long lasting (until the end of the epoch) left centro-parietal negativity starting at 800 ms, $F(4.42,101.62) = 10.92, p < .001$, peaking at Pz, $t(23) = -5.81, p < .001$ (see Figure 15). In addition, primed stimuli presented more negative ERP over left frontal electrodes from 550 to 1000 ms, $F(5.10,117.32) = -4.16, p = .002$, peaking at Fz, $t(23) = -4.08, p < .001$ (see Figure 16).

The ERP for primed identical-question and the ERP for primed reversed-question were contrasted to investigate stimulus-response effect. These ERPs were significantly different across all electrodes in the time window 300-350 ms, $F(4.22,97.12) = 2.71, p = .032$: the ERP for primed identical-question condition was more negative than the ERP for primed reversed-question condition over fronto-central electrodes, peaking at FCz, $t(23) = -2.63, p = .015$ (see Figure 17), and more negative over left occipito-temporal electrodes, peaking at PO9, $t(23) = 3.26, p = .001$. When contrasted to the unprimed condition, considered as a baseline for the stimulus-response effect, the ERP difference for primed reversed-question was significant, $F(4.87,112.00) = 3.05, p = .014$, but the ERP difference for primed identical-question was not significant, $F(4.44,102.17) = 0.60, p = .679$.

In addition, the ERPs for the two question conditions were significantly different in the time-window 700-1000 ms, $F(5.04,115.94) = 5.06, p < .001$: the ERP for primed identical-question stimuli presented a more positive potential than the ERP for primed reversed-question stimuli over occipito-temporal electrodes, PO10, $t(23) = 3.88, p = .001$, and more negative over centro-parietal electrodes, Cz, $t(23) = 3.22, p = .004$ (see Figure 18).

6.2.2.3 ERP results: response-locked

Stimulus-response binding strongly modulated response-locked ERPs of primed stimuli. An effect starting 500 ms before response, lasting for 400 ms, was strongly significant, $F(4.38,100.78) = 6.09, p < .001$: the ERP for the identical-question condition was more negative than the ERP for reversed-question condition over fronto-central electrodes, peaking at FCz, $t(23) = -2.86, p = .009$ (see Figure 19).

After response, the polarity became more lateralized, the reported negativity moved toward left electrodes and the difference became significant again in the time window 200-300 ms, $F(5.09,117.14) = 3.69, p = .004$.

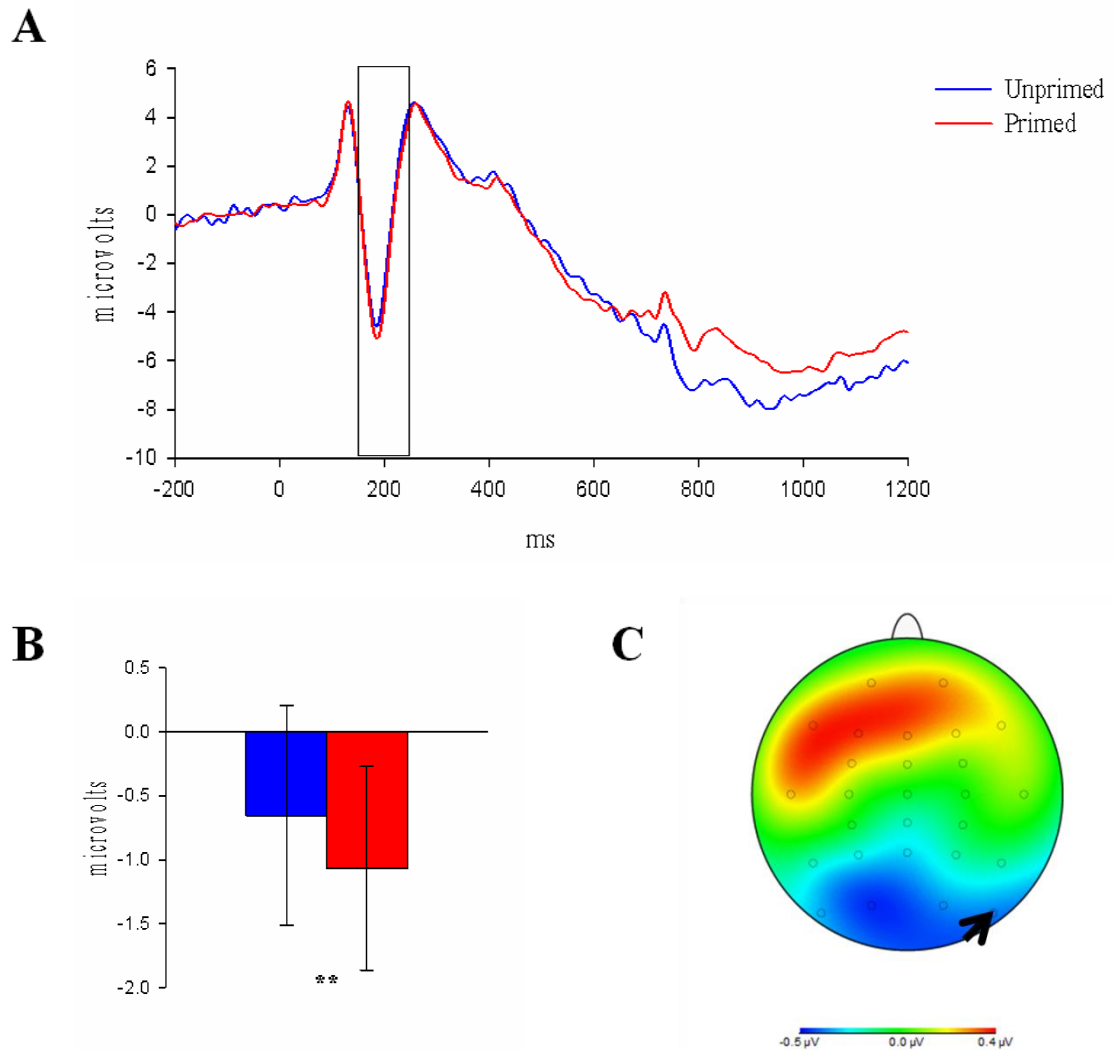


Figure 14 Stimulus-locked ERPs: repetition effect in the time-window 150-250 ms. (A) ERPs for unprimed and primed conditions at electrode PO10. (B) Mean amplitudes of the signal at electrode PO10; significance of the statistical test is also reported. (C) Topographic map of amplitude differences between the ERP for the primed condition and the ERP for the unprimed condition. The arrow points the location of the displayed electrode.

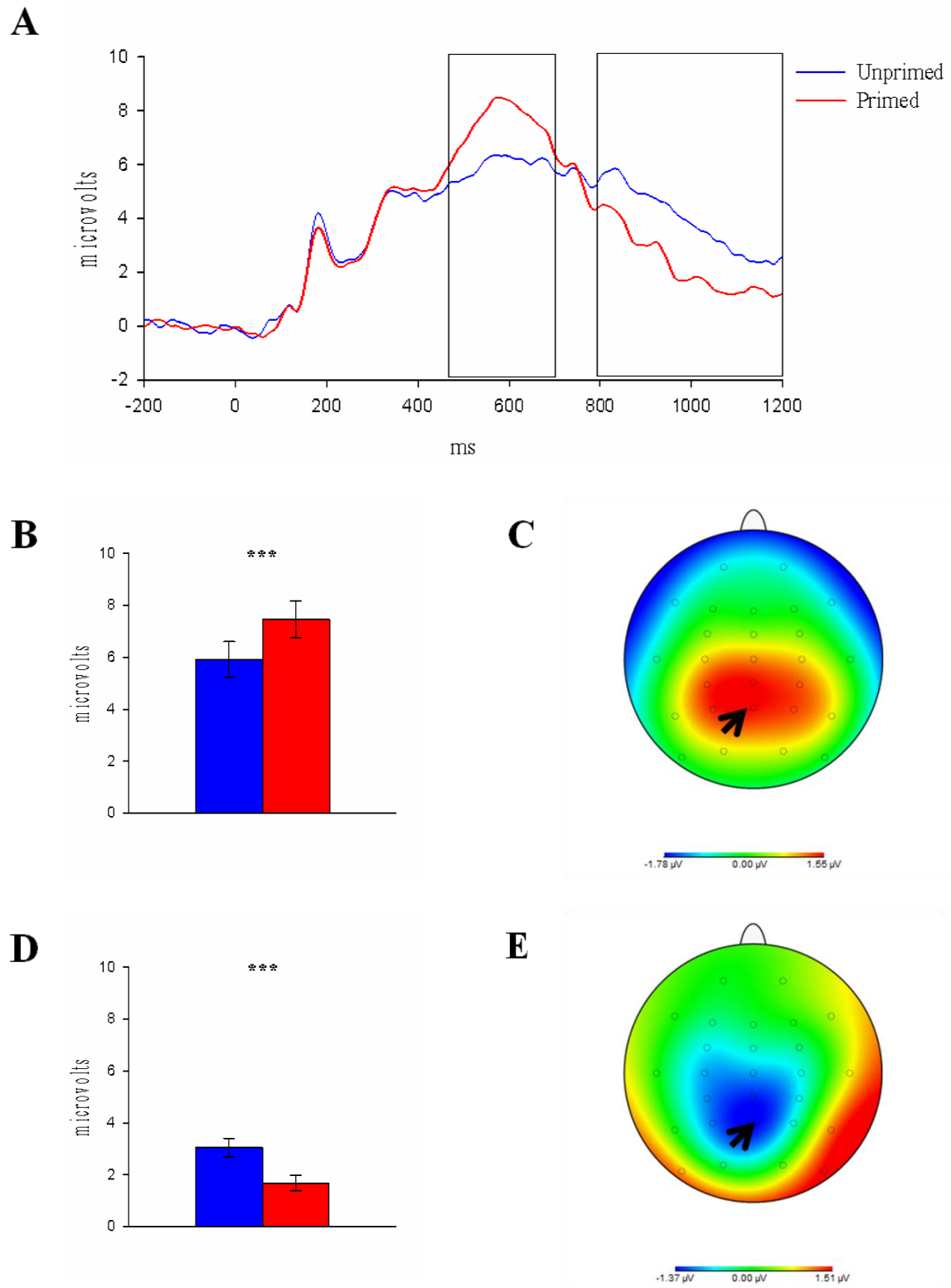


Figure 15 Stimulus-locked ERPs: repetition effects in the time-windows 450-7000 ms and 800-1200 ms. (A) ERPs for unprimed and primed conditions at electrode Pz. (B) and (D) Mean amplitudes of the signal at electrode Pz; significance of the statistical test is also reported. (C) and (E) Topographic map of amplitude differences between the ERP for the primed condition and the ERP for the unprimed condition. The arrow points the location of the displayed electrode.

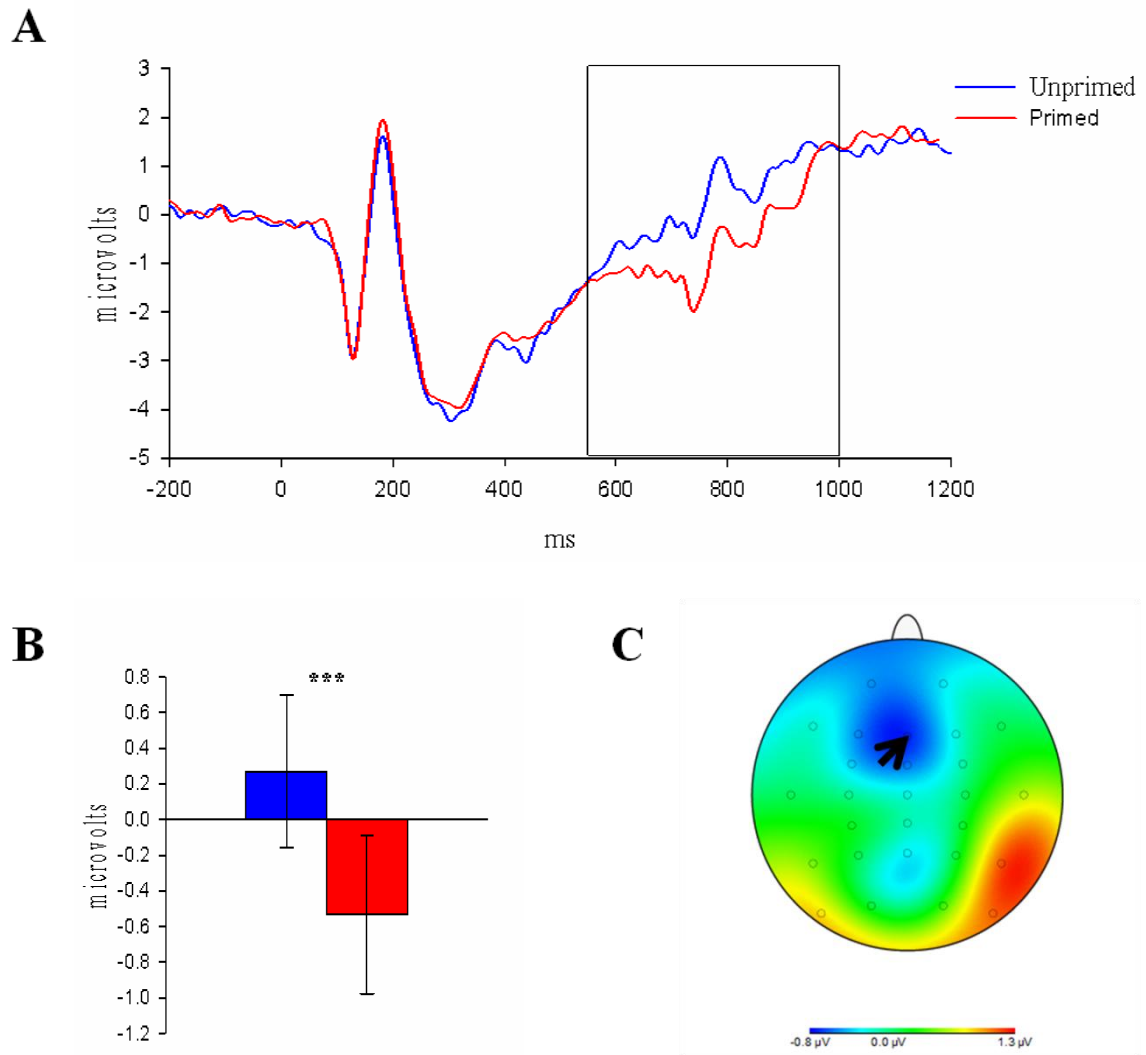


Figure 16 Stimulus-locked ERPs: repetition effect in the time-window 550-1000 ms. (A) ERPs for unprimed and primed conditions at electrode Fz. (B) Mean amplitudes of the signal at electrode Fz; significance of the statistical test is also reported. (C) Topographic map of amplitude differences between the ERP for the primed condition and the ERP for the unprimed condition. The arrow points the location of the displayed electrode.

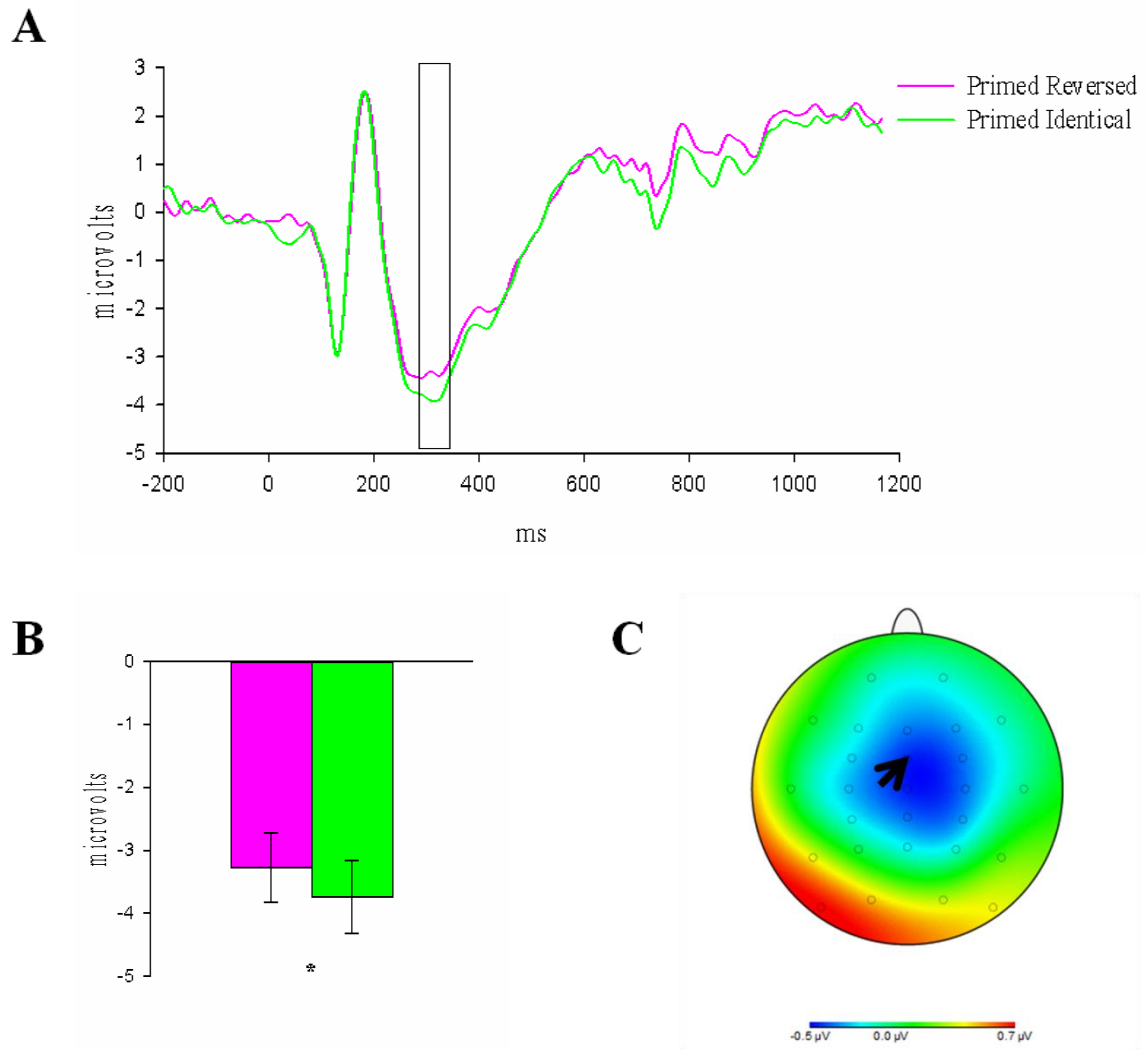


Figure 17 Stimulus-locked ERPs: stimulus-response effect in the time-window 300-350 ms. (A) ERPs for primed identical-question and primed reversed-question conditions at electrode FCz. (B) Mean amplitudes of the signal at electrode FCz; significance of the statistical test is also reported. (C) Topographic map of amplitude differences between the ERP for the primed reversed-question condition and the ERP for the primed identical-question condition. The arrow points the location of the displayed electrode.

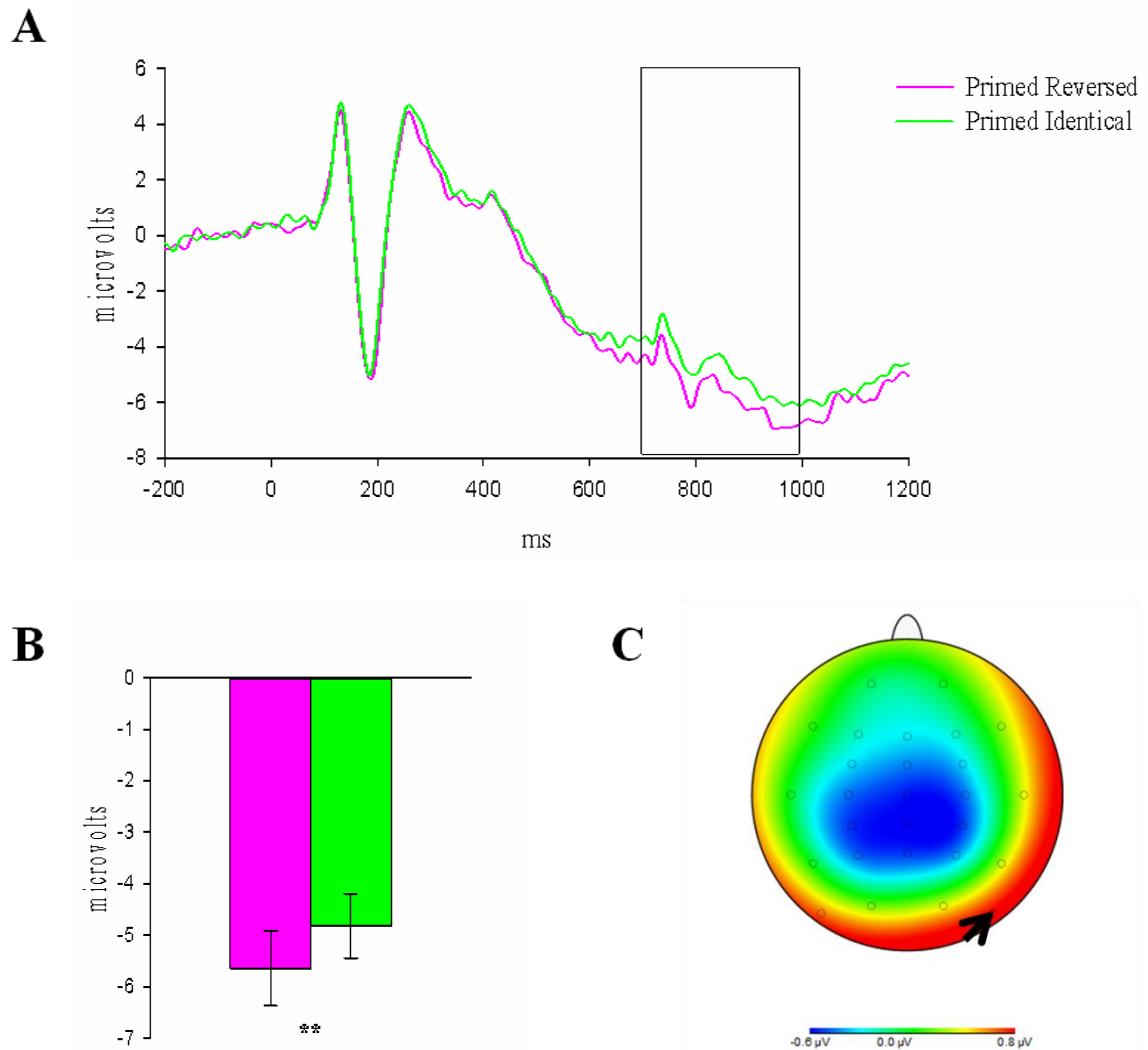


Figure 18 Stimulus-locked ERPs: stimulus-response effect in the time-window 700-1000 ms. (A) ERPs for primed identical-question and primed reversed-question conditions at electrode PO10. (B) Mean amplitudes of the signal at electrode PO10; significance of the statistical test is also reported. (C) Topographic map of amplitude differences between the ERP for the primed reversed-question condition and the ERP for the primed identical-question condition. The arrow points the location of the displayed electrode.

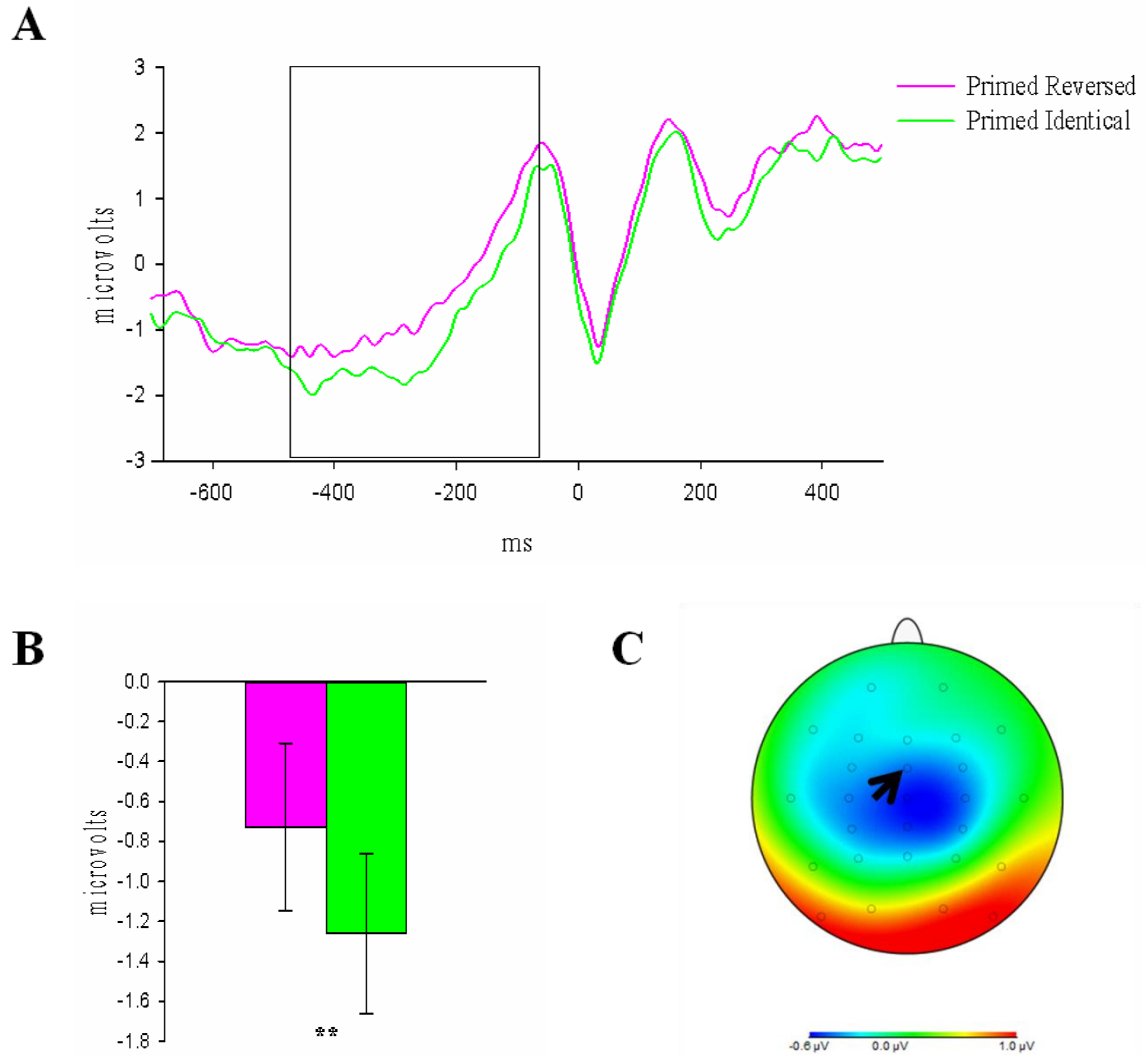


Figure 19 Response-locked ERPs: stimulus-response effect in the time-window -500--100 ms. (A) ERPs for primed identical-question and primed reversed-question conditions at electrode FCz. (B) Mean amplitudes of the signal at electrode FCz; significance of the statistical test is also reported. (C) Topographic map of amplitude differences between the ERP for the primed reversed-question condition and the ERP for the primed identical-question condition. The arrow points the location of the displayed electrode.

6.2.2.4 LRP results: stimulus-locked

Exploratory *t*-test performed on the LRPs in the two question conditions showed a significant difference in the time-window 250-300 ms, $t(23) = 2.40$, $p = .025$. The LRP for the reversed-question condition presented a small positive deflection while the LRP for the identical-question condition presented a small negative deflection (see Figure 20).

Although latencies for the main negative deflection were numerically shorter for the identical-question condition ($M = 324$ ms) than reversed-question condition ($M = 384$ ms), the difference in onset times was not significant, $F_c(1,23) = 1.73$, $p_c = .200$ (see Figure 20). However, this difference was significant when a low-pass filter of 8 was applied and two participants excluded, because no negative deflection was obtained in response-locked analyses, $F_c(1,21) = 4.80$, $p_c = .040$, but smoothing of the signal cancelled the crucial small positive and negative deflections, signatures of interference.

6.2.2.5 LRP results: response-locked

The LRP for the identical-question condition started 235 ms before response, while the LRP for the reversed-question condition started 203 ms before response. This numerical difference between the two onset latencies was not significant, $F_c(1,23) = 2.20$, $p_c = .152$ (see Figure 21)

Visual inspection of the two LRPs excluded the presence of a positive dip. Consequently, no statistical analyses were performed.

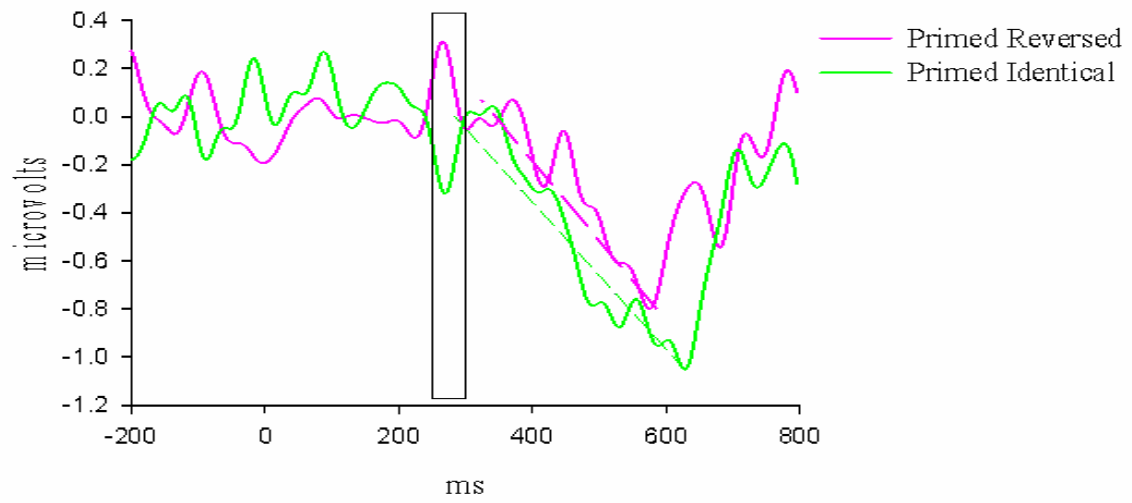


Figure 20 Stimulus-locked LRPs. Significant effect is highlighted in the time window 250-300 ms. Dotted lines represent the regression lines for the two question conditions.

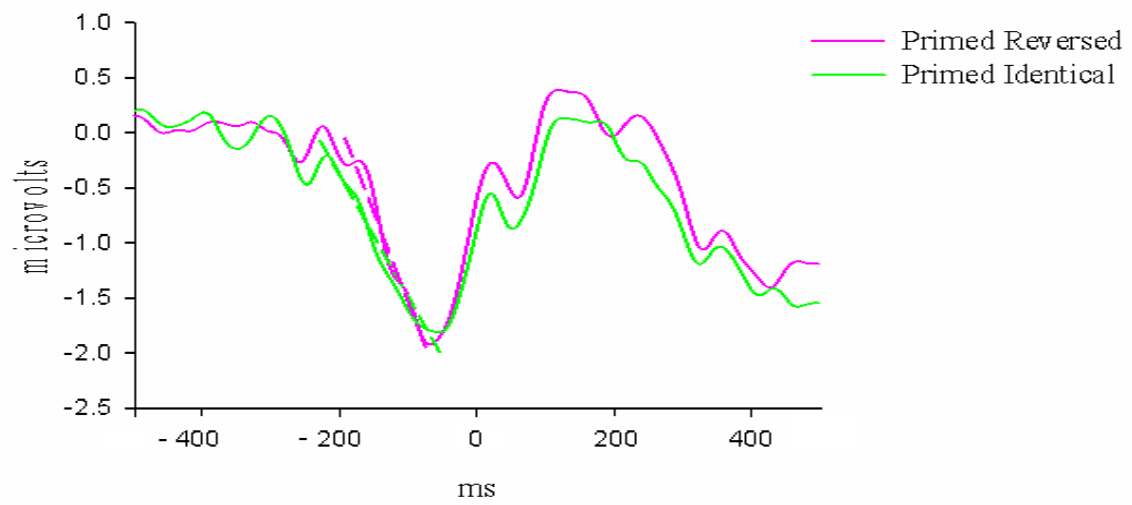


Figure 21 Response-locked LRPs. Dotted lines represent the regression lines for the two question conditions.

6.3 Discussion

The repetition of a stimulus can have a negative impact on performance in the case of a conflict between responses. Behavioural interference has been found across-task or across-reference (Horner & Henson, 2011b, Race et al., 2010) but never within tasks after categorical cue inversion. The current study used LRP and ERP analyses to address interference within tasks for the first time.

Participants were significantly faster in responding to repeated than to novel stimuli, and in turn even faster and more accurate in responding at test to stimuli that had been primed at study by the identical question with respect to the reversed question. This last effect is a clear behavioural evidence of rapid response learning: reactivation of a stimulus-response binding has a significant effect on priming. This finding confirms that the present experiment is suitable to obtain clear rapid response learning that can be further investigated with LRPs and ERPs.

Stimulus-locked LRP analysis showed a numerical difference between latencies of the main negative deflection in the two conditions that was in line with what would be predicted according to rapid response learning: the LRP for the identical-question condition started before the LRP for primed reversed-question condition. However, this difference was not significant. The failure to obtain a significant result could be consequence of the high level of noise in the data: in fact, the difference was significant when a stronger filter was used and two participants, that did not show any response-locked negative deflection, were excluded. Application of a stronger filter reduces noise but it can often mask small effects. Considering that the main focus of the present experiment was the investigation of possible dips whose magnitudes are generally a fraction of the magnitudes of the main negative deflection, the filter was selected in such a way that noise was reduced without having too great an impact on the signal. Response-

locked LRP analysis did not present any significant difference between latencies. This result is expected considering that response-locked LRP are modulated by the motor aspect of the response (Masaki et al., 2003) and in the present experiment responses in the two conditions were identical.

Stimulus-locked LRP analysis showed that stimulus-response binding was reactivated around 250 ms after stimulus onset, both for the identical- and reversed-question conditions. In the 250-300 ms time-window the LRP for the identical-question condition presented a small negative deflection while the LRP for the reversed-question condition presented a small positive deflection. This opposite polarity of the deflections is direct evidence that for the identical-question condition the correct motor response was selected while for reversed-question condition the incorrect motor response was selected, instead. This result demonstrates that stimulus-response binding is activated in the test phase independently of question requirement or the correctness of the output, providing strong support for Horner & Henson's (2009) multiple-routes multiple-stages framework. The finding of activation of both incorrect and correct motor responses is in line with retrieval of stimulus-response binding regardless of its applicability to the new question condition. Therefore, it is reasonable to hypothesise that the output of stimulus-response binding interacts with the output of stimulus reprocessing and produces a benefit when congruent or a cost when incongruent. Without such an interaction, activation of the wrong motor response would lead to a high error rate, but this prediction is not supported by the positive direction, even if not significant, of facilitation in accuracy for primed stimuli when the question was reversed. The absence of negative effects of repetition on accuracy analysis suggests that the outline LRP effect could be larger in designs like the one in Experiment 7 and Experiment 8, where interference was evident in behavioural data as well.

Interference is predicted by the multiple-routes multiple-stages framework (Horner & Henson, 2009) but not by Logan's (1990) instance theory. Further evidence for the good fit of the present data to the Horner & Henson's (2009) framework is the presence of a clear ERP correlate of stimulus repetition whose properties, time-window, topography and magnitude suggest networks facilitation (see also Boehm & Sommer (2005) for a similar early repetition effect). Determining whether this effect represents data-driven or conceptually driven priming is difficult, but its presence is sufficient to rule out the position that perceptual and conceptual processes are completely by-passed by stimulus-response binding. This finding suggests that some facilitation for repeated faces is the product of networks facilitation. On the contrary, Hsu and Waszak (2012) found an effect of stimulus-classification binding in a similar time-window at more anterior right electrodes. Given that inversion of categorical cues does not disable classification code, it is difficult to conclude that the effect in the current study is not a manifestation of classification code. However, further support for an interpretation in terms of networks facilitation comes from the fact that ERP correlates of networks facilitation were found in other studies in the domain of objects and these effects were insensitive to whether the classification code could be applied in the new context (Horner & Henson, 2012; Race et al., 2010). Accounts of rapid response learning underestimate networks facilitation but, although instance theory categorically excludes it, the multiple-routes multiple-stages framework, by incorporating perceptual and conceptual networks, can accommodate this contribution, though it is considered secondary with respect to rapid response learning.

As described in the introduction to this chapter, another important question in the rapid response learning literature is whether ERP correlates of stimulus-response binding are locked to the stimulus or to the response. A similar point allows understanding whether reactivation of a stimulus-response binding impact stimulus processing - as predicted

according to a blocking interpretation of instance theory - or response processing - in agreement with multiple-routes multiple-stages framework. In the present experiment stimulus-response binding was associated with an early stimulus-locked fronto-central negativity around 300-350 ms. The temporal dynamic of this first rapid response learning effect suggested that the cognitive system detected a difference in priming history at quite a late stage of stimulus processing, probably beyond the perceptual networks. The fronto-central negativity of this effect could indicate an involvement of higher cognitive functions, probably response selection. In support to this interpretation, this early effect occurred more or less simultaneously with the onset of a long lasting response-locked stimulus-response effect that had a similar topography: a fronto-central negativity and occipito-temporal positivity. Interestingly, the stimulus-locked ERP for primed reversed-question condition was significantly different from the ERP for unprimed stimuli, but this difference was not significant for the ERP for primed identical-question condition. The opposite would be predicted according to instance theory. What differentiates primed reversed-question from both primed identical-question and unprimed stimuli is the possible presence of interference in this condition, but not in the other two conditions: unprimed stimuli are not associated with any pre-existent response while stimulus-response binding produces a response for primed identical-question condition that does not interfere with the response produced by re-processing the stimulus. Consequently, this early stimulus-locked ERP correlate of rapid response learning seems to be associated more to aspects of response processing, like interference, than stimulus processing.

The two late ERP correlates of stimulus-response binding, stimulus-locked and response-locked, occurred around or after a response is given, and therefore their relevance to repetition priming is probably secondary. In fact, Horner & Henson (2012) found an ERP correlate of rapid response learning around response time but did not discuss it, as

they said it could be related to motor preparation. Response-locked ERP correlates of rapid response learning after response could be evidence of post-response managing of interference (Race et al., 2010).

In summary, ERP and LRP analysis strongly support Horner & Henson's (2009) framework, against Logan's (1990) instance theory. Interference can only occur when the output of stimulus-response binding is compared to the output of stimulus processing: the congruency of outputs allows faster responses than does incongruency of outputs. Considering that the comparison takes place only when the slowest output is produced, facilitation should be related mostly to how fast this output is generated, and, consequently to networks facilitation. Without networks facilitation, response times for primed stimuli should be faster than those for unprimed stimuli when responses are congruent and slower than those for unprimed stimuli when responses are incongruent. In fact, a similar trend of positive and negative priming was found when the benefit of facilitation in perceptual and conceptual networks is limited after a change in domain of the stimuli (Horner & Henson, 2011b, 2012) or a change of task (Race et al., 2010). Facilitation in perceptual and conceptual networks allows raising the bar of priming at a level in which benefit/cost due to rapid response learning is applied. Positive priming in the primed reversed-question condition, even in the presence of interference, supports a similar interpretation.

As an interim summary about the crucial topic of this ERP/LRP investigation, our results support an interpretation of rapid response learning as retrieval of a stimulus-response binding for all repeated stimuli. Reactivation of a response from memory can facilitate or interfere with expression of a correct response. The interaction modulates the magnitude of priming produced by facilitation in perceptual and conceptual networks. In fact, evidence of networks facilitation was also found.

As described earlier in this section the first stimulus repetition effect is likely to represent an electrophysiological correlate of priming because it occurred before well known correlates of episodic memory, its magnitude is quite small (1 η V) and the occipito-temporal topography contrasted with frontal or parietal topography of ERP correlates of episodic memory. On the other hand the later stimulus-locked effects have been widely reported in the literature of episodic memory contamination in priming studies (Paller et al., 2003; Rugg et al., 1998).

The parietal repetition effects, positivity in the time window 450-700 ms and negativity after 800 ms, are both ERP correlates of episodic memory retrieval. In the episodic memory literature they are respectively called the parietal Old/New effect (Rugg et al., 1998) and the late posterior negativity (Johanston & MecKinger, 2006). The absence of any mid-frontal Old/New effect in the present study is in line with other ERP studies of memory retrieval when faces are used as stimuli (MacKenzie & Donaldson, 2007; Yovel & Paller, 2004). The parietal Old/New effect is considered a manifestation of recollection of a qualitatively strong memory generally associated with contextual information (Wilding & Rugg, 1996). Polarity inversion at parietal electrodes occurring after response is an effect often obtained in episodic memory source judgement tasks (Hayama, Johnson & Rugg, 2008, for a review Johansson & Mecklinger, 2003). As in the present experiment, source judgement experiments involve two different study contexts, therefore it is plausible that the participants, even if not instructed to do so, attempted to mentally travel back in time to retrieve the task instruction that was associated with repeated stimuli at study. Less well-documented is the frontal negativity for repeated stimuli. A similar ERP correlate is reported in the literature of memory in aging (Friedman, de Chastelaine, Nessler, & Malcolm, 2010; Nessler, Friedman, Johnson, & Bersick, 2007; Swick, Senkfor, & Van Petten, 2006): older adults present a left frontal negativity starting

at 600 ms after stimulus onset when engaged in source memory retrieval. The interpretation given to this ERP effect is adoption of alternative memory strategies by older adults to recover episodic memory. How a similar ERP correlate of memory in aging fits in a study of rapid response learning when most of the participants were young adults is a question that goes beyond the topic of the present experiment. As a speculation, incidental encoding, similarly to aging, could determine weak source memory and consequently employment of alternative memory strategies.

The parietal Old/New effect, late posterior negativity and left frontal negativity all have something in common: they are all ERP correlates often found in source memory judgement. This finding shows that episodic memory is strongly engaged by the present design, and participants seemed to attempt retrieving the contextual information about the study phase.

6.4 Conclusion

The present experiment showed for the first time evidence of reactivation of stimulus-response binding even when the new task context makes the retrieved response incorrect. The response retrieved from stimulus-response binding interacts with the response obtained from stimulus reprocessing and determines behavioural benefit or cost. Benefits or costs sum up to facilitation in perceptual and conceptual networks to express repetition priming. All these findings are strongly in agreement with a multiple-routes multiple-stages framework of repetition priming in person recognition.

Chapter 7: General Discussion

The main objective of the thesis was to investigate whether rapid response learning applies to the domain of person recognition. It does. Thus, the focus of the thesis moved forward to study the experimental factor (or factors) that favour the creation and utilization of stimulus-response binding in this domain. In addition, this thesis explored how this type of memory acts in comparison to other forms of facilitation, in the specific facilitation in perceptual and conceptual networks. Behavioural and electrophysiological data were recorded to explore this important topic. The results indicated that rapid response learning plays a significant role in priming for person recognition after multiple presentations of stimuli, but the contribution of rapid response learning is marginal compared to that of networks facilitation, with which it interacts at the level of response selection. These findings support a multiple-routes multiple-stages framework of priming for person recognition.

Experiment 1 employed a design that was able to determine the possible contribution of rapid response learning to repeated stimuli in the domain of person recognition. Participants demonstrated different degrees of facilitation according to the type of question answered at study and test: response times were slower to reversed questions than to identical questions. This behavioural effect provides a clear manifestation of rapid response learning in the domain of person recognition.

Experiments 2-4 investigated which experimental factor (or factors) is (are) crucial for the creation and utilization of stimulus-response binding in person recognition. Task, contiguity between study and test phases and number of stimulus repetitions at study were identified as possible experimental factors affecting stimulus-response binding. The cumulative subtraction of these experimental factors from a regular rapid response learning design highlighted the number of stimulus repetitions as the main factor for making

stimulus-response binding behaviourally relevant: priming in the two question conditions was not significantly different after a single stimulus presentation at study, in contrast to a significant difference after three presentations. An effect of contiguity of study and test phases was also found, but its meaning is not clear.

Experiments 5-6 explored further the outcomes of Experiments 2-4 to rule out two experimental confounds present in the reported series of studies. Experiment 5 showed that single stimulus repetition did not involve rapid response learning even when it was the only subtracted factor from a regular rapid response learning design, as opposed to being subtracted concurrently with the other two experimental factors, as in Experiment 4. This result provided strong support for the idea that multiple presentations of stimuli at study are necessary for the creation and utilization of stimulus-response binding. Experiment 6 showed that rapid response learning was resistant to long lags between study and test phases. This result was used to understand the order effect in Experiment 3, but the failure to replicate modulation of stimulus-response effects according to the arrangement of study phases in Experiment 6 indicated a low reliability of this effect, and consequently a secondary role for contiguity in the expression of stimulus-response binding.

Experiments 7-8 incorporated a cycle with orthogonal tasks in a regular rapid response learning design in order to isolate contributions to priming generated by forms of memory other than rapid response learning. Stimuli primed by orthogonal questions presented significant facilitation even in the absence of any possible contribution of stimulus-response and stimulus-classification binding. This result indicates that facilitation in perceptual and conceptual networks is not obliterated by rapid response learning but occurs alongside it. In this series of experiments, evidence of interference due to retrieval of stimulus-response binding was obtained for the first time.

Experiment 9 employed EEG to investigate whether stimulus-response bindings

were retrieved even for reversed task instructions, and how a similar reactivation is managed when the output is wrong in the new task condition. Lateralized readiness potential showed that a signal from stimulus-response binding was transmitted to the motor cortex regardless of its correctness. This signal interacts with the output of stimulus reprocessing and facilitates performance when they match but causes a cost when they mismatch. Event-related potential analysis supported an interpretation in terms of interference.

Considered together, these results provide strong empirical support to the current models of priming in person recognition, but their theoretical impact goes beyond the domain of person recognition. Current theories of repetition priming for person recognition are assessed according to the present findings. A framework that incorporates both perceptual and conceptual networks and stimulus-response binding is proposed.

7.1 Structural model

Facilitation in perceptual and conceptual networks explains repetition priming as the effect of link strengthening between representational units engaged in stimulus processing. Two main types of facilitations are proposed: data-driven and conceptually driven priming. Presenting an identical stimulus at study and test produces full facilitation in perceptual networks (i.e., data-driven priming), whilst performing the same categorical judgement at study and test expresses full facilitation in conceptual networks (i.e., conceptually driven priming). Networks facilitation has been proposed to account for most repetition priming results in person recognition but has some limitations in explaining some findings of the present series of experiments. Firstly, the significant difference in priming between reversed-question condition and identical-question condition represents an outcome not

readily explicable by networks facilitation. This is because networks facilitation predicts similar priming in these two conditions: because perceptual and conceptual processing is identical in these two conditions, the same stimulus is presented at study and test, and identical semantic entry is accessed to express the judgement, equal priming would be expected. In fact, reversing task instruction does not change the semantic entry necessary to express the judgement but how semantic information is utilized, a process that occurs after the semantic entry is activated where no pre-existing link can be strengthened to contribute to conceptually driven priming. A possible interpretation that could account for these results without overturning the core aspect of the theory is that conceptually driven priming is blocked every time the question is changed, no matter if reversed or orthogonal. A similar re-interpretation is supported by the absence of rapid response learning when a study phase with reversed task instruction interrupts contiguity of study and test phases in a study-study-test design, as in Experiment 3. However, the fact that the priming difference was significant when contiguity was interrupted, in Experiment 6 and Experiment 9, and when task was changed, as in Experiments 7-8, undermines such an explanation. The significant congruency effect in the orthogonal cycles in Experiments 7-8 represents an extra challenge for the networks facilitation account. This effect cannot be explained by modulation of data-driven or conceptually driven priming. The congruency effect is unquestionable evidence of facilitation (or cost) induced by response processes. Contrary to a difference between priming for stimuli primed at study by identical or reversed questions, in the orthogonal cycle repeated stimuli were primed and tested under equal conditions, therefore no experimental factor can confuse the real source of the effect. Priming in the orthogonal cycle is unquestionably modulated by congruency or incongruency between responses given at study and response at test. A similar interpretation can be applied to the previously described priming difference between

reversed-question condition and identical-question conditions. The congruency effect cannot be accounted for by a model that does not include a network of response units beyond the semantic networks and a set of links between response units and semantic units that can be strengthened by repetition. Such a model accounts for all the priming effects in this series of experiments: the congruency effect could be explained as faster activation of a response if congruent because re-processed links are tuned compared to activation of a response if incongruent because re-processed links are not tuned. Unfortunately, this interpretation of facilitation in response networks predicts only facilitation, but not cost, such as lower accuracy for primed than unprimed stimuli that required incongruent responses as in Experiments 7-8. An additional distortion to the original interpretation of facilitation in perceptual and conceptual networks, required to account for cost, would be that links to a response that are not strengthened are inhibited. This type of process is not new in models of face learning and recognition. Burton et al., (1990) suggested within-pool competition; however, this competition is short-lived and abolished by presentation of another stimulus: for such competition to be effective in the present design it would have to survive long lags and many intervening stimuli. Alternatively, strengthening of a link to a response favours the selection of that response, sometimes even if incorrect.

An important property of such a response network is that it becomes behaviourally relevant only after multiple stimulus repetitions, in opposition to the immediate significant effect of perceptual and conceptual networks.

In summary, consideration of a response network in which facilitation, but also interference, can arise, in addition to facilitation in perceptual and conceptual networks, could account quite well for present results and most repetition priming results, principally in person recognition. However, evidence of early activation of wrong and correct motor

responses and successive competition in Experiment 9 are more in line with a retrieval account of a stimulus-response binding.

7.2 Episodic model

Instance theory is an interpretation of priming in terms of retrieval of an instance of a previous encounter with a stimulus that allows the by-passing of stimulus processing to generate a response. Retrieving an instance from memory is faster than re-processing the stimulus and, consequently, repetition priming is obtained for primed but not unprimed stimuli. An important aspect of this theory is that priming is exclusively memory-based: no facilitation for repeated algorithmic-based processing is considered. The main predictions of this theory, often contradicted by the literature on priming in person recognition, are significant facilitation for the identical-question condition and absence of facilitation after a change of question. The results of this series of experiments are in accordance with the prediction that priming is always significant when questions are identical at study and test; moreover priming in this condition was always at least numerically larger than priming for the reversed-question condition. However, priming was significant in all priming conditions, even reversed or orthogonal, when retrieval of an instance would favour the production of a wrong response. Significant priming in the reversed-question condition could be accounted for by considering that it is sufficient to reverse the output obtained from instance retrieval to carry out the task without the need of reprocessing the stimulus; consequently, facilitation is reduced for primed reversed-question stimuli because of the additional process of response inversion. A similar explanation is possible for designs in which stimuli from a single study phase are presented again in the following test phase: in this case reversing the categorical cue makes all retrieved responses wrong and the system can automatically apply inversion of the response. However, in study-study-test design,

like the one employed in Experiment 3, 4, 6, 9, and, particularly, in orthogonal cycles, as in Experiments 7-8 such a process cannot operate automatically, otherwise facilitation in response times would be associated with a negative effect of repetition on accuracy. On the contrary, the results of these experiments indicated that repetition allows faster and, sometimes, even more accurate response in primed reversed-question condition. However, an automatic response inversion process in study-study-test design is still possible if the task instruction associated with the stimulus is encoded in memory. Nevertheless, such information cannot guide any automatic response inversion process for some stimuli but not others, as in the case of orthogonal cycles. In conclusion, even if instance theory can be adjusted to accommodate results when categorical cues are reversed, it fails to properly account for significant priming in the orthogonal question condition.

Facilitation in the algorithmic-based processing (in other words facilitation in perceptual and conceptual networks) can accommodate well this result but the pure episodic-based nature of the theory would be lost. However, even considering facilitation in algorithmic-based processing does not solve all the problems. According to instance theory, priming is determined by the process, memory-based or algorithmic-based, that first generates a response. Considering that memory-based processing is faster (since otherwise it could not generate priming for identical-question conditions), memory-based processing is always the winner causing a high error rate in reversed-question condition and orthogonal-question conditions. Alternatively, memory-based processing could be blocked after a change of question, allowing the expression of the slower but facilitated response of the algorithmic-based processing. However, a response congruency effect in the orthogonal cycle could not be accounted for by the exclusive effect of algorithmic-based processing if a response network is not considered, and in this case there would be no need of an independent memory-based processing anymore.

The LRP and ERP results could be interpreted in support of instance theory: the LRP results, by showing that a response is activated regardless of its correctness, suggest that memory-based processing is not disabled for stimuli primed in the study phase with reversed question; in addition, dissimilar ERPs for primed reversed-question compared to primed identical-question and unprimed stimuli could indicate automatic inversion of the response. Nevertheless, this theory fails to accommodate the results in the orthogonal cycle and, particularly, the coexistence of behavioural benefit and cost of stimulus repetition cannot be explained if memory-based processing does not interact with algorithmic-passed processing.

In summary, pure episodic models, like instance theory, successfully, predict results when the questions at study and test are identical but have difficulty explaining significant facilitation for reversed and orthogonal questions. Facilitation in algorithmic-based processing is needed to account for these results, but algorithmic-based processing should interact with memory-based processing to predict facilitation and interference. A similar hybrid model already exists: it is called the multiple-routes multiple-stages framework.

7.3 Hybrid model

The multiple-routes multiple-stages framework is a hybrid model of memory-based and algorithmic-based progressing. Priming is the consequence of the interaction between response codes and classification codes activated by retrieval of a stimulus-response and stimulus-classification binding and obtained from stimulus reprocessing. Greater priming for the identical vs. the reversed question condition is the result from full overlap between response codes in the first but not the second condition. However, significant priming for reversed-question condition requires an additional source of facilitation. According to this

framework, priming in the reversed-question condition is mostly determined by the reactivation of stimulus-classification binding which in turn allows correct responses by-passing perceptual and conceptual networks. However, considering that priming for the identical-question condition and reversed-question condition is significant even in the absence of rapid response learning, as in Experiments 4-5, it must be hypothesized that stimulus-classification binding is created after a single presentation whilst stimulus-response binding needs multiple presentations. Horner & Henson (2009) used a task that rules out such an interpretation. In their study, changing the size of the reference abolished any benefit of by-passing stimulus reprocessing because a correct response cannot be given without semantic reprocessing of the real size of the stimulus, but priming was significant even after a change of reference. In conclusion, stimulus-classification binding cannot be used every time to by-pass algorithmic-based processing, therefore the possibility that data-driven and conceptually driven priming could generate facilitation is still open.

In fact, Experiments 7-8 showed clearly that, in the absence of any possible by-pass, facilitation is significant even when stimulus-response binding determines cost, instead of facilitation. Significant priming across tasks for incongruent responses is unquestionable evidence of facilitation in conceptual and perceptual networks. Such facilitation is modulated by interactions at response stages, resulting in a significant congruency effect. The existence of facilitation in perceptual and conceptual networks across-task suggests that similar facilitation can be effective even within tasks, without the need of any by-pass to be faster. It is important to mention that networks facilitation does not rule out stimulus-classification binding; this binding can still have a significant effect on priming, particularly in some tasks, as an additional interaction stage between the two routes but not as an element of the memory trace that generates priming independently.

In summary, behavioural findings support a multiple-routes multiple-stages framework of repetition priming in person recognition. Contrary to this framework of repetition priming in the domain of objects, larger emphasis is given to algorithmic-based processing, compared to memory-based processing. In fact, rapid response learning represents only a late comparison level that corroborates or inhibits an already facilitated response for repeated stimuli. Given that a comparison can take place only when the to-be-compared elements are both active, the main effect of facilitation can only speed-up the slowest process, in the specific algorithmic-based processing, to allow interaction with the fastest process, in the specific memory-based processing. In such a case the interaction due to rapid response learning can increase or decrease priming due to facilitation in perceptual and conceptual networks. The secondary role of rapid response learning in priming is further supported by the evidence that facilitation in perceptual and conceptual networks occurs even after a single presentation while rapid response learning needs multiple stimulus presentations to be effective. Other experimental factors like task and contiguity of study and test phases seem to be unnecessary for rapid response learning.

This interpretation of the model can account perfectly for all behavioural results of the series of experiments reported in this thesis. Priming is greatest (Experiments 1, 2, 3, 6, 7, 8, 9) for stimuli primed by identical task instruction because of maximum facilitation in perceptual and conceptual networks, and positive effects of interaction at response stages and classification stage. Priming is reduced but still significant (Experiments 1, 2, 3, 6, 7, 8, 9) for stimuli primed by reversed categorical cue because maximum facilitation in perceptual and conceptual networks benefits only from stimulus-classification binding but not from stimulus-response binding, because decision and action retrieved from memory-

based processing mismatch decision and action obtained from algorithmic-based processing. Performing a different task, as in across-task condition, (Experiments 7-8) can cause a reduction of conceptually driven priming and abolishes any facilitation at classification stage, resulting in smaller priming compared to the within-task conditions, but the priming effect is still significant because of data-driven and partial conceptually driven priming. Significant across-task priming is further modulated by comparisons at response stages that enhance or inhibit priming, resulting in a congruency effect.

An important and new aspect of this framework for priming in person recognition is the differential dependency of algorithmic-based and memory-based processing from number of repetitions at study. Memory-based processing, that manifests itself mostly as a stimulus-response effect, requires multiple stimulus presentations at study to be behaviourally relevant; on the other hand, facilitation in perceptual and conceptual networks is significant even after a single presentation (Experiments 4-5). As an aside, it is useful at this point to underline that stimulus-response effects and congruency effects result from the same interaction at response stages, and the use of two different terms to refer to the same effect seems inadvisable; for future studies the term congruency effect is suggested to describe the consequence of interaction at response stages both within and across tasks.

The general picture of priming in accuracy in the present series of experiments is less clear than for response times. Higher noise in accuracy data could be the consequence of not excluding trials with inconsistently correct responses. The use of similar methods in other studies of rapid response learning justified this approach to analysis of accuracy data.

In general repetition of a stimulus leads to greater accuracy in responding to primed than unprimed stimuli in identical task instruction condition, regardless of how many times

the stimulus was presented at study, for both occupation and nationality judgement (Experiments 2-9) but not in height judgement (Experiment 1). In the reversed task instruction condition, although the gain in accuracy is generally positive (except Experiment 7), priming is significant in some experiments (Experiments 2, 3, 4, 8) but not others (Experiments 1, 5, 6, 7, 9). The absence of any regularity makes the interpretation of the different trends of priming results difficult. A similar problem was observed in the stimulus-response effect in accuracy analysis: the stimulus-response effect was significant in some experiments after multiple presentations of stimuli (Experiments 2, 6, 9) but not others (Experiments 1, 3, 5, 8), though never after a single presentation (Experiments 4, 5). This last result further supports the idea that multiple presentations of stimuli at study are necessary for rapid response learning, but not much else can be concluded from within-task analysis of accuracy. More interesting are the negative and positive priming effects on accuracy in the across-task condition due to congruency of responses: this effect is clear evidence of a benefit/cost interaction at response stages. Given that priming was generally positive (but sometimes not significant) in all, except one, of the within-task conditions it can be hypothesised that interference due to response stages is masked by facilitation from conceptually driven priming or stimulus-classification binding; the presence of positive priming after a single presentation of stimuli seems more in line with facilitation in conceptual networks.

LRP and ERP give further support to the multiple-routes multiple-stages framework for person recognition. LRP analysis showed that stimulus-response binding was activated for all repeated stimuli supporting the existence of memory-based processing. ERPs were affected by stimulus repetition, but priming history had an additional impact on ERP for repeated stimuli: these independent effects of repetition on stimulus-response effect were

interpreted as networks facilitation and rapid response learning, respectively. In summary, the electrophysiological results are consistent with multiple-routes multiple-stages framework in which stimulus-response bindings are automatically activated and interact with the output of tuned stimulus processing; evidence for interference, but not benefit, was also obtained.

The multiple-routes multiple-stages framework is nothing more than an expansion of Burton's (1998) model of person recognition. Perceptual and conceptual networks are supported by a route that pre-activates some classification and response codes beyond conceptual networks when stimuli are repeated more than once: such pre-activation can favour or impede preparation of task specific response. It is important to underline that this alternative route is mostly utilized after multiple presentation of stimuli at study, but when a stimulus is presented once only component processing is accessible and no interaction takes place at response stages. Therefore the predictive power of Burton's (1998) model for priming after a single repetition is further enhanced by the incorporation of stimulus-response and stimulus-classification bindings to account for rapid response learning when stimuli are presented more than once at study.

Although the present series of experiments advances consistently our understanding of priming for person recognition, additional studies are needed to directly explore the influence of classification codes on priming, and specifically whether interaction at this level produces only facilitation or also inhibition. This question has important consequences for understanding the often reported absence of data-driven and conceptually driven priming in the domain of objects (see next paragraph). Another point, not investigated in the present thesis is the stage at which stimulus processing retrieval of bindings occurs. According to many studies in the domain of object recognition, the

stimulus-response effect is significant even for different exemplars or for different format of stimulus, indicating that rapid response learning is not specific to a stimulus but generalizes to the identity of the stimulus. In addition, a replication of ERP and LRP results seems necessary to provide further support for the effect found and reduce noise in the signal to increase analysis sensitivity, particularly with regard to LRPs onset latencies. A design that emphasizes interference would be preferable; and the across-task condition seems more suited to such an investigation.

The multiple-routes multiple-stages framework proposed here for person recognition differs from the one proposed by Horner & Henson (2009) for object recognition in two ways: 1) larger emphasis is given to facilitation in perceptual and conceptual networks compared to rapid response learning and 2) rapid response learning seems to be more dependent on the number of stimulus repetition. The absence of net priming across tasks in object recognition requires a re-evaluation of the impact of networks facilitation in object recognition. Presenting the same stimulus at study and test does not produce significant data-driven priming, or, alternatively data-driven priming is masked by interference at the classification stage. The idea that data-driven priming is less important for object recognition than face recognition could be a consequence of the fact that judgements for people are based mostly on the identity of the individual person, while judgements for objects are based mostly on the category, instead of the specific stimulus. Person recognition requires the identification of persons within the category, for example, recognition of a familiar face among other faces. Object recognition usually does not require such individuation of objects; it rather involves identification of the object category, such as chair or house. Testing whether data-driven priming in object recognition is stronger in a task that required individuation of an object within the category is an

interesting investigation for future studies. An example of such task in object recognition could be the classification of cars according to manufactory nationality. On the other hand, some results provide support for facilitation in perceptual and conceptual networks even in object recognition. Amnesic patients did not present rapid response learning but show significant priming regardless of how many times a stimulus is presented at study and regardless of task instruction performed at study (Schnyer et al., 2006): this is a clear indication of a form of facilitation that is not affected by inversion of the task or number of stimulus repetitions: both characteristics are important for rapid response learning but not for networks facilitation. Larger modulation of priming than stimulus-response effect due to change of exemplar or format of a stimulus (Horner & Henson, 2011b) is more plausible according to data-driven priming than rapid response learning. In addition evidence of networks facilitation was found both in fMRI and EEG: BOLD and electrophysiological signals were modulated by repetition of a stimulus regardless of the study context, these effects are contrary to rapid response learning but in agreement with networks facilitation.

The dependency of rapid response learning in object recognition on multiple stimulus presentations at study is a property often suspected but never stated clearly. Although, the stimulus-response effect was significant in some studies (for example see Dew & Giovanello, 2010b) after long presentation times, the influence of rapid response learning after a single study presentation has been always smaller than the influence after multiple presentations, and sometimes the former has not been significant.

7.4 Conclusion: Multiple-routes multiple-stages framework for person recognition

Burton's (1998) model of person recognition, and its precursor by Bruce and Young (1986), has accounted for and predicted repetition priming in person recognition, and its

explanatory power is not under discussion, particularly after single stimulus repetition at study. The present thesis, however, presents strong evidence that a memory-based route should be incorporated into the model to account for repetition effects specific to multiple stimulus presentations. The outputs of memory-based and algorithmic-based processing interact to facilitate production of previous response if correct and to inhibit expression of a previous response if incorrect. It should be noted, however, that repetition priming is not the exclusive product of this interaction but is significantly modulated by it.

Repetition priming in person recognition is mainly the effect of facilitation in perceptual and conceptual networks, but after multiple encounters with a stimulus, this facilitation is modulated by rapid response learning.

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Appendix

Appendix 1

Response times for consistent responses to a primed stimulus across study and test phases, even if consistently incorrect, were analysed. Only 41% of primed trials had consistent responses (the percentage was 31% when only consistently correct responses were considered). Responses to primed stimuli were significantly faster than those for unprimed stimuli regardless of categorical cue at study: for the identical-question condition (RTs for primed stimuli: $M = 830$, $SE = 20$), $t(39) = 12.53$, $p < .001$; for the reversed-question condition (RTs for primed stimuli: $M = 916$, $SE = 20$), $t(39) = 9.35$, $p < .001$.

The stimulus-response effect was strongly significant, $t(39) = 3.01$, $p = .004$: facilitation was 52 ms ($SE = 17$) larger for the identical-question condition compared to the reversed-question condition.

Appendix 2

Experiment 1

Mean accuracy percentages in the study phases were 61.9% ($SE = 0.8$) for the first presentation, 63.7% ($SE = 1.0$) for the second presentation and 63.5% ($SE = 0.9$) for third the presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 2.12$, $ps < .034$; however there was no change in performance between the second and third presentations, $z = 0.10$, $p = .922$.

Mean response times in the study phases were 1066 ms ($SE = 26$) for the first presentation, 909 ms ($SE = 22$) for the second presentation and 833 ms ($SE = 20$) for the

third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 157$ ms, $SE = 15$), $t(39) = 10.55$, $p < .001$; moreover, presenting a stimulus a third time lead to a further significant decrease in response times, compared to the second presentation ($M = 76$ ms, $SE = 11$), $t(39) = 6.69$, $p < .001$.

Experiment 2

Mean accuracy percentages in the study phases were 74.1% ($SE = 1.8$) for the first presentation, 78.4% ($SE = 1.6$) for the second presentation and 80.1% ($SE = 1.5$) for third the presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 3.90$, $ps < .001$; however there was only a trend toward a significant change in performance between the second and third presentations , $z = 1.80$, $p = .071$.

Mean response times in the study phases were 965 ms ($SE = 29$) for the first presentation, 774 ms ($SE = 27$) for the second presentation and 713 ms ($SE = 23$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 192$ ms, $SE = 13$), $t(39) = 13.81$, $p < .001$; moreover, presenting a stimulus a third time lead to a further significant decrease in response times, compared to the second presentation ($M = 61$ ms, $SE = 11$), $t(39) = 5.63$, $p < .001$.

Experiment 3

Mean accuracy percentages in the study phases were 73.7% ($SE = 1.2$) for the first presentation, 77.1% ($SE = 1.1$) for the second presentation and 77.5% ($SE = 1.1$) for third

the presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 3.71, p_s < .001$; however there was no change in performance between the second and third presentations, $z = 0.59, p = .557$.

Mean response times in the study phases were 1023 ms ($SE = 23$) for the first presentation, 802 ms ($SE = 18$) for the second presentation and 737 ms ($SE = 17$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 221$ ms, $SE = 14$), $t(39) = 15.35, p < .001$; moreover, presenting a stimulus a third time lead to a further significant decrease in response times, compared to the second presentation ($M = 65$ ms, $SE = 5$), $t(39) = 11.22, p < .001$.

Experiment 6

Mean accuracy percentages in the study phases were 76.0% ($SE = 1.1$) for the first presentation, 79.3% ($SE = 1.1$) for the second presentation and 80.9% ($SE = 1.1$) for third the presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 4.05, p_s < .001$; gain in accuracy was significantly larger for third than second presentation, $z = 2.73, p = .006$.

Mean response times in the study phases were 962 ms ($SE = 25$) for the first presentation, 765 ms ($SE = 21$) for the second presentation and 720 ms ($SE = 19$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 197$ ms, $SE = 10$), $t(39) = 19.80, p < .001$; moreover, presenting a stimulus a third time lead to a further significant

decrease in response times, compared to the second presentation ($M = 46$ ms, $SE = 8$), $t(39) = 5.60, p < .001$.

Experiment 7

Mean accuracy percentages in the study phases of the within-task conditions were 86.4% ($SE = 1.1$) for the first presentation, 89.4% ($SE = 0.8$) for the second presentation and 89.7% ($SE = 1.0$) for the third presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 3.34, ps < .001$; however there was only a trend toward a significant change in performance between the second and third presentations, $z = 1.23, p = .220$.

Mean response times in the study phases of the within-task conditions were 947 ms ($SE = 24$) for the first presentation, 752 ms ($SE = 22$) for the second presentation and 696 ms ($SE = 23$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 196$ ms, $SE = 12$), $t(47) = 15.51, p < .001$; moreover, presenting a stimulus a third time lead to a further significant decrease in response times, compared to the second presentation ($M = 55$ ms, $SE = 8$), $t(47) = 6.64, p < .001$.

Results had a similar trend in the across-task condition. Mean accuracy percentages in the study phases of the within-task conditions were 80.4% ($SE = 1.4$) for the first presentation, 83.4% ($SE = 1.2$) for the second presentation and 83.7% ($SE = 1.2$) for the third presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 2.70, ps < .007$; however there was only a trend

toward a significant change in performance between the second and third presentations , $z = 0.49, p = .624$.

Mean response times in the study phases of the within-task conditions were 1024 ms ($SE = 27$) for the first presentation, 797 ms ($SE = 24$) for the second presentation and 721 ms ($SE = 22$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 228$ ms, $SE = 14$), $t(47) = 15.92, p < .001$; moreover, presenting a stimulus a third time lead to a further significant decrease in response times, compared to the second presentation ($M = 75$ ms, $SE = 14$), $t(47) = 5.35, p < .001$.

Experiment 8

Mean accuracy percentages in the study phases of the within-task conditions were 76.8% ($SE = 1.6$) for the first presentation, 80.8% ($SE = 1.3$) for the second presentation and 80.6% ($SE = 1.4$) for the third presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 3.83, ps < .001$; however there was only a trend toward a significant change in performance between the second and third presentations , $z = 0.90, p = .928$.

Mean response times in the study phases of the within-task conditions were 1026 ms ($SE = 29$) for the first presentation, 801 ms ($SE = 26$) for the second presentation and 724 ms ($SE = 23$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 225$ ms, $SE = 11$), $t(47) = 19.11, p < .001$; moreover, presenting a stimulus a third time lead to a

further significant decrease in response times, compared to the second presentation ($M = 77$ ms, $SE = 7$), $t(47) = 9.78$, $p < .001$.

Results had a similar trend in the across-task condition. Mean accuracy percentages in the study phases of the within-task conditions were 85.5% ($SE = 1.1$) for the first presentation, 86.7% ($SE = 1.5$) for the second presentation and 87.5% ($SE = 1.4$) for the third presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 1.86$, $ps < .063$; however there was only a trend toward a significant change in performance between the second and third presentations, $z = 1.09$, $p = .274$.

Mean response times in the study phases of the within-task conditions were 973 ms ($SE = 29$) for the first presentation, 772 ms ($SE = 24$) for the second presentation and 697 ms ($SE = 20$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 201$ ms, $SE = 15$), $t(39) = 12.92$, $p < .001$; moreover, presenting a stimulus a third time lead to a further significant decrease in response times, compared to the second presentation ($M = 74$ ms, $SE = 10$), $t(39) = 7.15$, $p < .001$.

Experiment 9

Mean accuracy percentages in the study phases were 87.2% ($SE = 1.4$) for the first presentation, 89.2% ($SE = 1.2$) for the second presentation and 88.9% ($SE = 1.3$) for third the presentation. Performance was significantly higher for second and third presentations compared to the initial presentation $z_s > 2.70$, $ps < .007$; however there was only a trend

toward a significant change in performance between the second and third presentations , $z = 0.05, p = .958$.

Mean response times in the study phases were 1000 ms ($SE = 32$) for the first presentation, 816 ms ($SE = 31$) for the second presentation and 745 ms ($SE = 30$) for the third presentation. Responses to stimuli presented for the second time were significantly faster than responses to stimuli presented for the first time ($M = 184$ ms, $SE = 15$), $t(23) = 12.26, p < .001$; moreover, presenting a stimulus a third time lead to a further significant decrease in response times, compared to the second presentation ($M = 70$ ms, $SE = 8$), $t(23) = 8.17, p < .001$.