DOCTOR OF PHILOSOPHY

The influence of perceived object function on action: time-course and specificity of response activation

Phillips, Julian C.

Award date:
2002

Awarding institution:
University of Wales, Bangor

The Influence of Perceived Object Function on Action: Time-course and Specificity of Response Activation

Julian C. Phillips B.A., M.Sc.

This thesis is submitted in part fulfilment of the requirements for the degree of Doctor of Philosophy. Completed at the Centre for Cognitive Neuroscience, School of Psychology, University of Wales (Bangor)

April 2002

Acknowledgements

This research was sponsored as a CASE studentship, jointly funded by the Economic & Social Research Council, and Unilever (UK)

ESRC CASE Award: S00429837046

Acknowledgement and thanks to my PhD Committee:

Dr. Robert Ward (Supervisor)
Professor Steve Tipper (2nd Supervisor)
Dr. George Houghton (Chair)

Special thanks to Dr. Irene Reppa for helpful comments, discussion, and companionship throughout the course of study.

Table of Contents

Abstract

Recent accounts of visual object affordance suggest that evoked representations for action serve to potentiate motor response components (such as a specific hand) to respond to the most afforded action (Tucker & Ellis, 1998). The present thesis aims to investigate further this hypothesis, and to examine the underlying nature of affordance-generated effects.

Using the stimulus-response compatibility (SRC) paradigm, a set of eleven experiments investigate; a) the conditions under which the effect of affordance may be generated, b) the nature of affordance in terms of response specificity, c) the time course of affordance-based effects.

Initial findings (Chapter 4) show that affordance, operating as a constituent component of corresponding stimulus-response (S-R) mappings, results in facilitation of performance, over non-corresponding mappings, even when the affording object is unrelated to an imperative task. Findings show that an object's affordance does indeed influence action. In addition, effects are shown to build over time. Chapter 5 investigates response specificity and concludes that affordance is probably due to generation of a more abstract spatial code rather than affordance for a specific limb. Chapters 6 and 7 provide evidence relating

to attentional, spatial coding, and frame of reference effects that constrain the investigation of affordance. Finally, experiments in Chapter 8 employ a different method for testing for the effect of affordance on behaviour. Using novel objects as primes, and involving a series of training and testing, the results in Chapter 8 lend support for the idea that attention is a major contributor in achieving correspondence effects through affordance. In addition, results show that the end goal of an action sequence is better afforded, than the means of arriving there.

The findings in this thesis consolidate previous evidence on the role of affordance on action and provide new evidence in relation to the nature of affordance and the conditions in which it can be measured independently of potentially confounding factors.

Chapter 1

1. General Introduction

1.1. Background

The environment in which we function has become increasingly complex, as have the tasks we now routinely perform. The potential load on human cognitive systems has increased dramatically. It is not unusual for many people to operate for long hours, highly complex computerised electro-mechanical systems in situations where speed and accuracy may be vital to lives or fortunes.

Cognitive systems that have taken eons to evolve in the natural world are now under pressure from this ever-increasing complexity of tasks and environments that come with modern technological and industrialised existence. A real consequence of this increased complexity is a higher potential for poor performance and error, accompanied by an equally alarming increase in (potentially) disastrous consequences of that poor performance and error.

In many ways, the effects of complex environments and repetitive operations can be tackled through the improved design of operating routines, methodology, and system interfaces; through better-designed equipment and human-machine compatible environments. However, these procedures may only serve to accommodate tasks that are even more complex. The reality is that any modern industrialised and technological environment is designed around maximising and even stretching resources, one of these resources being the cognitive system of the operator. It is when this cognitive system begins to be stressed that insights can be gained into how certain perceptual mechanisms integrate to produce useful and appropriate action within the environment.

In order for the cognitive system to operate efficiently in complex environments, certain well-practised and routine tasks become automatized and run, for the greater part, in the absence of conscious control. For instance, the initially complex synchronicity required when driving a car becomes quite easily automated with practice. This very automaticity allows us to carry out complex tasks and operate within busy environments. However, it is these well-practised and automated behaviours that may be most susceptible to environmental triggers that may guide or re-route action into automatic action sequences or behaviours, other than those intended. The term environmental trigger is used to describe the way that some aspect of the current environment might serve to catalyse the activation of an associated action sequence, albeit inappropriate to a current task. In most day to day situations, these 'evoked' action sequences will be inhibited where the action is inappropriate, but when an automatic task, such as driving a car is in progress, then automatic inhibition may be lessened or impaired, influencing or even 'hi-jacking' current task behaviour.

The idea that the stimuli within the environment (essentially objects) automatically evoke, within the observer, mental representations for action (action related information), gains support from studies and observations of both neuropsychologically impaired and normal individuals. This evidence is reviewed in Chapter 2.

With respect to cognitive processes, the relationship between an external *stimulus* and an appropriate *response* is of central importance. This relationship has been extensively studied from the platform of the stimulus-response compatibility (SRC) paradigm, more extensively covered in Chapter 3 of this thesis. Traditionally, the SRC paradigm has been used to investigate, under controlled laboratory conditions, the effect of characteristics of the stimulus, such as its spatial location, on fast and accurate generation of response to that stimulus. More recently, investigations into SRC phenomena have been able to elucidate effects of functional, as well as purely spatial aspects of the stimulus on performance; that is, an object not only conveys physical information in terms of what or where, but also information relating to its purpose or function, and that these 'functional' elements of stimulus sets may be evaluated in terms of S-R compatibility or correspondence, in much the same manner as that of the more physical S-R attributes. These functional characteristics of a stimulus, relating to an objects perceived affordance, form the focus of this work. In summary, the general idea is to employ the stimulus-response compatibility paradigm to investigate the link between an object's visual affordance, and the influence of this affordance on current behaviour or goals.

1.2. Perception and Action

Co-ordinated and effective behaviour requires that we perceive and assess the possibilities for action afforded by objects in the environment. To speak of visual affordance is to accept that objects support, invite, or evoke certain types of actions over others; in this sense, the appearance of a handle affords its grasping. Objects and environments therefore, may be seen as offering or *affording* action possibilities to the observer. It then follows, that any object, situation, or environment will evoke different measures of action possibility or affordance, dependant on the observer; the degree of this affordance[1] being dependant upon previously learned associations and experiences with that environment, object, or such similar. In the case of everyday objects, common, learned object-action associations will inevitably exist. Therefore, it may be expected that these everyday objects will evoke similarly common *action representations* within a perceiver.

In general, two broad theoretical frameworks have been formed to conceptualise this relationship between perception and action. On the one hand is the ecological approach where perception-action is seen as single psychological process, in the sense of a perception-action

---

[1] Throughout the experiments in this thesis, the term affordance is used in the sense of 'perceived' affordance, inferring that an object has a causal effect on the action representation system of a perceiver that reflects the objects' best associated action; that is, representation for the action for which an object was designed. This in contrast to the more Gibsonian view in which a novel object may afford action through its more physical attributes, for example, in the way that a log may afford a sitting down action.

feedback loop (e.g. Michaels & Stins, 1997), perception, informing action, with the consequences of that action re-informing perception, ad infinitum.

On the other hand is the information processing perspective of perception-action, which sees the act of *perception* in terms of the processing of retinal images resulting in generation of representations of a situation, environment, or object; and *action* as the result of generation of excitatory representations to muscles. Behind this idea is the view that these two processes can be understood or even analysed separately.

The following two sections briefly outline some of the main notions of the ecological approach to perception-action, as well as some existing evidence from neurologically normal adults. The information-processing view will be reviewed in Chapter 3, in the context of the different theoretical accounts of perception-action compatibility effects.

1.3. Ecological Approach to Perception-Action

The ecological approach to perception-action highlights the more global environmental aspects of the stimulus and action system, positing that facilitation of performance is dependant upon the constituent elements of the whole action system, i.e. the organisation and co-coordinative aspects of any potential or emerging action.

This distinction is made in order to simplify understanding of any experimental manipulations relating to best action possibilities inherent within an object.

This ecological approach does not see perception as a passive process, but one that actively seeks out salient environmental information in order to guide action in a continuous cycle between perceiver and situation. Various studies show that response elements such as hand shape (Michaels & Schilder, 1991) and hand position (Michaels, 1989) significantly influence S-R compatibility effects. Tipper, Lortie & Bayliss (1992) showed that stimulus-response elements, like the position of an effector, and action goals (on reaching movements) determined priming and interference effects. In the same vein, Tucker and Ellis (1998) in a series of choice reaction time tasks, demonstrated that "seen objects automatically potentiate elements of the actions they afford", when they interpreted their S-R compatibility effects as being due to affordance-induced, object-action representations affecting sensori-motor preparedness for an action or response to a particular side of space.

Based on this research, visual affordance as the sole mechanism behind response bias for compatible S-R mappings is questionable. It is one of the purposes of this thesis to investigate the possibility that other phenomena may also contribute to influences on performance as a function of physical affordance, rather than perceived affordance.

1.3.1. Visual Affordance

The concept that the environment offers or 'affords' particular action to a perceiver is central within the ecological framework and more generally to perception-action investigations. J.J Gibson's (1979) belief was that to perceive objects within the environment is to perceive what they afford, thereby implying perception of values and meanings (seemingly) external to the perceiver. Traditionally, the notion of affordance for action has been linked with Gibson's (1979) theory of 'direct' perception. Gibson argued that affordance for action was based on intrinsic perceptual properties of objects, registered directly and without the need for intervening processes such as object recognition.

More recently, and in the same vein, Michaels and Stins (1997) state, "affordance is the possibility for action permitted by virtue of properties of the objects and events taken with respect to action capabilities of animals" (pp. 334). To speak of perception of action possibilities implies the creation of action representations, and if this idea of affordance is accurate, then human sensitivity to this affordance may be interpreted as promoting mental preparedness for object related action. The mere sight of an object should ready the perceiver to envisage, plan, or abort future action. If this is the case, then it is conceivable that this pre-action visualisation might have the effect of automatically priming the sensori-motor system for possible object related action, even prior to any intention on the part of the perceiver to act.

In this light, the working definition of affordance is described as a feature of an object with the power to evoke some form of mental representation for object-related action within a perceiver. This thesis examines whether perception of an object's affordance might automatically elicit or represent action possibilities within the perceiver, and the possible influence on, and implications for, these action representations on current goal related action. Some recent evidence that supports the notion of object affordance is reviewed below.

1.3.2. Action Slips

Action slips are seen as the consequence of the effect of environmental triggers on existing, well practised, but currently inappropriate motor schema, whilst carrying out another task or intention. The 'triggering' effects of the environment on a perceiver can be observed during normal everyday activity in the form of what Norman (1981) termed *action slips*. For example, when meaning to file a document into a filing cabinet, you may inadvertently drop the document into a nearby wastebasket, the wastebasket triggering a similar 'filing' routine. On a day off from work, you might find that instead of driving to the coast, you are indicating to turn into the road that you take daily to get to the office. It seems that the more automatized the behaviour then the more susceptible to action triggers it may be.

Reason (1990), in his account of action slips, stated that we are in the age of the 'organisational accident'. By this, he meant that in the ever-increasing domain of human interaction with mechanical and computer interfaces, the possibility of error due to action inappropriate environmental triggers and constraints (or lack of) has greatly increased, as have the consequences of such error.

In the above context, for action slips to occur, there is probably going to be some degree of overlap between aspects of the current task or intention and aspects of the 'slip' task. What is in effect happening is that correspondences between aspects create a common ground where both the current and the evoked action can exist. If the affordance is powerful, then the evoked task may take over.

Norman (1981) proposed three major types of action slip based upon an "activation–trigger-schema" system (ATS), the schema being defined as a sensori-motor knowledge structure, that under favourable environmental conditions may become either appropriately or inappropriately activated through environmental triggers (affordance). Norman described three classifications of slips as; a) those resulting from indecision or unclear intention, that is, a series of actions is initiated but the goal is not clear; this mental state inviting intrusion from environmental triggers (affordance); b) slips that might result from faulty activation of a schema such as forgetting the intention or skipping or repeating steps (resulting in (a) above), and c) slips that result from faulty triggering of active schemas at an inappropriate time, for example you start to turn left *before* you reach the corner! According to Norman, "Faulty triggering of active schemas can result in spoonerism's blends, premature activation, and insufficient activation". Whatever the classification or conditions for action slip to occur, we are all aware that they do occur, and when we least expect it. The environment affords action and when circumstances are favourable, such as unclear intentions or task instructions; when there is overlap between dimensions of the current task and the triggered action; and when the mind 'wanders', then the possibility of an automated motor sequence (habit) hijacking the current task is high. Recent evidence from brain-damaged adults has helped to further understand the mechanisms underlying these automatic behaviours.

Chapter 2

2. Perception-Action Systems in the Brain

2.1. Introduction

An organism's environment provides a myriad of action possibilities, normally constrained only by the action capability and perhaps will or intention of the perceiver. In order to successfully work with and efficiently operate within any environment, humans have evolved complex cognitive systems that, under normal circumstances, are able to cope with these possibilities for action. Under normal circumstances, organisms are able to select and execute those actions that are either intended or appropriate to achieve a desired goal, whilst suppressing or inhibiting others.

The neural machinery within the human brain responsible for action-related processing is the parietal lobe (e.g. Goodale & Milner, 1992; Milner & Goodale, 1993; 1995). It is composed of cells that are responsive to a variety of stimuli including hand movement, objects within grasping distance, audition, eye movement as well as complex and motivationally significant stimuli (e.g. Mountcastle, Lynch, Georgopoulos, Sakata, & Acuna, 1975; Faugier-Grimaud, Frenois & Stein, 1978; Perenin & Vighetto, 1988; Pierrot-Deseilligny, Rivaud, Gaymard & Agid, 1991). In particular, certain cells in the parietal lobe (area 7) have been described as exerting 'command' functions for action towards an object, whilst their activity ceases when the objects in question is grasped (e.g. Rolls, Perret & Thorpe et al, 1979; c.f. Joseph, 1990). These cells have been described as having the ability to direct visual attention, become excited when certain objects are perceived to be within grasping distance, and motivating and guiding hand movements, including the grasping and manipulation of specific objects (e.g. Hyvarinen & Poranene, c.f. Joseph, 1990; Mountcastle et al., 1975; Lynch, Mountcastle, Talbot, & Yin, 1977). These patterns of excitation are coupled with corresponding patterns of inhibitory control of this parietal psychomotor behaviour, neural substrates of which lie within the frontal lobes (e.g. Denny-Brown, 1956, c.f. Lhermitte, 1983).

Consistent behaviour relies on patterns of excitation and inhibition within the perceptuo-motor (frontoparietal) system, and whilst a healthy 'system' copes well under most circumstances, there may be occasions when either environmental pressures, or internal factors such as brain damage, may result in perceptuo-motor malfunction. Some neuropsychological evidence for such failures is reviewed in the following section.

2.2. Utilization Behaviour

When damage occurs (either unilateral or bilateral) within the frontal lobe region, inhibitory motor processes may become suppressed resulting in what Lhermitte (1983) termed 'utilization behaviour'. Utilization behaviour normally stems from damage to the medial and medial-orbital areas of the frontal lobe (e.g. McNabb, Carroll, & Mastaglia, 1988). Lhermitte (1983) described utilization behaviour (and imitation behaviour) in terms of environmental dependency syndromes resulting in semi purposeful, albeit reflexive motor behaviour. In some cases, patients are described as being 'stimulus bound' and involuntarily respond to, or even compulsively use, objects or stimuli with which they are presented. This utilization behaviour may be elicited by offering patients objects of everyday use and observing that, without instruction (and even with clear instructions not to use them), they will use them appropriately, but often out of context (for example, putting on a second pair of spectacles when one pair is already in place). Various patients also, without instruction, have been shown to imitate an examiner's gestures, no matter how absurd.

According to Joseph (1989, c.f. Joseph, 1990), patients seem to be "reflexively or magnetically directed, solely by external stimuli that trigger involuntary motor reactions" (p.148). It seems the case that even where there is no intention or requirement to act, some kind of *automatic* process selects or reviews candidate motor sequences relating to the observed (affording) object, and under any conditions of damaged inhibitory processes, performs or attempts to perform that object-associated action. The implications are such that, if objects have the power to elicit object-associated action, then each object (or class of object) must not only be mentally represented by its identity, but also by what it can do or be used for, i.e. it's function. In addition, these processes must operate at an unconscious level, each object or situation activating these motor schemas.

However, whilst much of utilization behaviour is reported as being purposeful, there is no reason to believe that it necessarily stems from the effects of uninhibited object affordance on the motor system. Denny-Brown, (1958; c.f. Joseph, 1990) described the type of patient exhibiting utilization behaviour, as being in a "seemingly apathetic and confused condition". When this confused, 'apathetic' person is seated at a desk and presented with a pair of spectacles, what would be more natural than to *use* them, that is, put them on? Does this mean that the object has afforded an action, or is it simply the case that the patient is just doing what he 'thinks' is most appropriate for him to do when presented with an 'inappropriate' object. Has the object afforded the action, or has it simply catalysed the action with which the patient best associates the object, the difference apparently lying in the realms of volition. However, there is a possibility that such behaviour *is* involuntary; in which case, utilization behaviour may result from the effect of object affordance overcoming the damaged or malfunctioning inhibitory 'system'. In this case, the implication is that objects can and do, automatically *afford* action. Further, when cognitive systems become disrupted (or damaged), then this affordance can be said to *evoke* that very action.

2.3. Anarchic (and Alien) Hand Syndrome

In those patients where damage occurs that predominantly destroys the left or right supplementary motor areas or medial frontal cortex, as well as the anterior corpus callosum (Brust, 1986; Goldberg, Mayer, and Toglia, 1981; c.f. Joseph, 1990), then a more specific type of utilization behaviour is seen to occur. This behaviour, termed 'anarchic hand' syndrome (e.g. Della Sala, Marcheti & Spinnler, 1991), which may be confined to one limb, normally involves complex and seemingly purposeful action carried out by that affected limb. In cases where a patient is unaware of the behaviour then, it may be termed 'alien hand' (e.g. Della Sala et al., 1991, 1994).

McNabb et al. (1988) described a case where a female patient's right hand showed an uncontrollable tendency to reach out and take hold of objects, being then unable to release them. McNabb et al. (1988) go on to describe; "At times, the right hand interfered with tasks being performed by the left hand, and she attempted to restrain it by wedging it between her legs or by holding or slapping it with her left hand. The patient would repeatedly express astonishment at these actions." (p.147). They also describe another patient who, whilst attempting to write with her left hand, the right hand would reach over and attempt to take the pencil. The left hand would respond by grasping the right hand to restrain it.

More recently, Riddoch, Edwards, Humphreys, West and Heafield (1998) described patient ES, who was diagnosed with anarchic hand syndrome. On an initial assessment patient ES performed at chance when asked to gesture the use of visually presented objects.

Furthermore, she exhibited involuntary movements by either hand that would interfere with actions carried out by the other (in most cases the left) hand. This case study will be reviewed in more detail later, when the issue of perception-action routes in the brain, is addressed; for now it is only important to note that ES's performance (i.e. pointing towards an object) was significantly affected by the object's affordance. For instance, ES made more errors when asked to respond with her left hand to an object on her left, when the object's handle was oriented to the right, rather than to the left.

The implications (and relevance) of this type of behaviour is that in the event of damage that blocks internal inhibitory (and guidance) processes on motor areas, (releasing them from influences mediated by the opposing hemisphere), then external perceptual activity is preserved resulting in compulsive responding to external stimuli. This behaviour can be seen as evidence that the environment elicits, at the very least, motor representation for behaviour, independent of conscious control, will, or intention. However, whether this behaviour is meaningful is another matter. Certainly most cases of anarchic hand tend to describe behaviour that whilst being purposeful, is normally very inappropriate, and even mischievous, as in the case described earlier by McNabb et al. (1988).

Whilst these studies describe in detail, intriguing cases of anarchic hand, they offer little useful evidence in support of answering the question of why an environment should elicit or afford purposeful mischievous activity in preference to appropriate, helpful, or useful behaviour. Why should an affordance elicit mischief, or do we just interpret it as mischief because it is not appropriate and belongs to action schema that would normally be suppressed. Whether this type of syndrome can be used to support the idea of environmental affordance for action is uncertain. Certainly, in anarchic hand syndrome cases, neither the environment nor the organism constrains the observed action, and without inhibitory control, any possible action may occur based on any number of resident action schema that may (or may not be) loosely semantically related to a current environment or object.

The question of importance here relates to the basis upon which the action takes place. Does the hand simply need to *do* something, solely based on a catalogue of existing motor schema? How and why is the behaviour controlled, for instance why should the hand grasp the other arm rather than the other leg? Only when these questions are answered can we judge whether the behaviour helps to support the idea that the functional affordance of objects in the environment operates automatically, and that, in the absence of the 'will' (through damage) of the organism, the effects of this automaticity may be observed.

2.4. Anatomical Pathways for Vision and Action

To better understand the visual system's underlying perception-action processes, it is necessary to briefly look at the neural substrates involved.

Ungerleider and Mishkin (1982) identified and described two broad 'streams' of visual projections in the macaque monkey brain, a ventral visual processing stream from the occipital lobe to the inferotemporal cortex, and a dorsal visual stream from the occipital to the posterior parietal cortex. Based upon various lesion studies in monkeys (e.g. Pohl, 1973; Ungerleider and Brody, 1977), Ungerleider and Mishkin proposed that the two visual processing pathways, whilst being complementary in visual processing, were also functionally dissociable. More specifically their observations helped form evidence for an occipito-temporal or ventral (what) pathway involved with object recognition, and an occipito-parietal or dorsal (where) pathway involved in object localisation.

An important reconception of the functions subserved by these two visual streams came later from Goodale and Milner (1992). They proposed that both streams can process information about object features and about objects' spatial relations and that the functional difference between the dorsal and ventral visual processing streams was in the *way* that this information was utilised. They suggested that the ventral stream is more involved in representing object characteristics and relations, thus allowing constructions of long-*term perceptual representations*, giving objects functional significance and meaning - the kind of representational information that would, for instance, mediate or catalyse effects of object affordance. On the other hand, the dorsal stream is proposed to be more involved in *on-line operations*, and uses the information about object location and task environment in order to control skilled actions such as pointing, reaching towards, or grasping an object. The anatomical dissociation of the two streams has, therefore, since been theorised in terms of the 'what' and 'how' visual processing systems in the brain (Goodale & Milner, 1992; Milner & Goodale, 1995).

Milner and Goodale, and colleagues have provided evidence not only for the nature of the two visual processing systems, but also for their dissociation, with one being able to operate independently of the other (e.g. Goodale, Milner, Jacobson & Carrey, 1991; Goodale, Jacobson, Milner, Perrett, Benson & Hietanen, 1994; Milner & Goodale, 1995). Specific neuropsychological evidence for these functionally separable visual processing streams comes from cases of *visual agnosia* and *optic ataxia*. For example, patients with damage to the ventral visual system but with intact dorsal system seem unable to perform even the simplest identification tasks when presented with visual objects (optic aphasia). One such patient is DF (reported by Milner, Perret, Johnston, Benson, Jordan, Heeley et al., 1991; Milner & Goodale, 1995) who could perform at chance if for instance, asked to match two rectangles for shape, to report the orientation of straight lines, or to make judgements about the size of an object. By contrast, when DF was asked to perform actions such as inserting a letter into a slot at any orientation or to reach and grasp an object of any size, her performance was as good as that of normal controls.

Conversely, patients with damage to the dorsal visual system but preserved ventral, typically show the opposite pattern of behaviour in the aforementioned tasks. This disorder, known as optic ataxia, is symptomized by the observation that, whilst patients are very accurate in tasks requiring intact perception of identity, they generally have difficulty controlling and guiding their actions towards previously correctly identified objects. Such a performance deficit was exhibited by patient VK reported by Jacobson, Archibald, Carey and Goodale (1991; cf. Goodale, 1993). The characteristic deficit in VK's performance was the inappropriate size of her hand grip when asked to reach out and grasp objects, as well as the abnormally large number of adjustments in her grip once the reaching movement had been initiated. This result, taken with the patient's good performance in pointing movements, gave further support to the notion that the posterior parietal lobes (along the dorsal visual stream) play a role in programming goal-related hand movements.

In the context of the above evidence, the ventral visual system (occipito-temporal stream) seems to process information relating to the identity of visually perceived objects to facilitate the planning of voluntary actions i.e. the ventral stream allows action planning and preparedness. In contrast, the dorsal visual system (occipito-parietal stream) is seen as the neural substrate for processing information about online voluntary actions, such as reaching, grasping, or releasing objects in an appropriate way, without caring for object identity, i.e. the dorsal stream processes information that allows effective on-line control of action.

The two visual processing streams have also been described in terms of the way they code space relative to the object and the viewer. Computational accounts of object recognition have distinguished between two types of visual object representations, that is, *viewer-centred* representations (or descriptions), which, according to Marr (1982), are necessary during the interaction between the viewer and the object without any access to stored knowledge about the object. Marr (1982) distinguished this type of representation from the *object-centred* representations, which are necessary for object recognition[2]. The occipito-temporal (ventral) stream has been shown to code visual information using *object-centred* co-ordinates mediating the process of object recognition. For instance, Perrett, Smith, Potter et al. (1984) showed that certain cells in the region of the superior temporal sulcus (in the ventral stream) fire to specific visual stimuli – more specifically faces – irrespective of the viewpoint or other transformations, such as in size or in lighting (e.g. Perrett, Mistlin & Chitty, 1987; c.f. Milner & Goodale, 1995).

---

[2] There is considerable debate about the nature of representations (also termed as 'descriptions') that mediate visual object recognition. Thus, whilst Marr's model makes object-centred representations of an object necessary for the task of recognition, other theorists propose that recognition can be achieved through viewer-centred descriptions of that object (e.g. Edelman & Bulthoff, 1992; Tarr & Bulthoff, 1993). However, the focus here remains on the argument that the direct route to action is mediated by viewer-centred representations that code for accurate reaching and grasping movements, and not by representations (whether these are object- or viewer-centred) that make semantic properties of objects explicit.

On the other hand, the occipito-superior parietal visual stream (dorsal), codes visual information in 'on-line', *viewer-centred* co-ordinates facilitating accurate reaching and grasping (e.g. Sakata, Taira, Murata & Mine, 1995). Indeed, the most compelling characteristic of neurons along the dorsal steam is the selective activation of certain neurons solely under conditions where the [animal] executes actions towards an object (see Stein, 1991 for review).

However, whilst the aforementioned evidence addresses the anatomical dissociation of the two visual streams there is now increasing confidence in the idea that information coded in both dorsal and ventral processing integrates to produce coherent action (e.g. Duncan, Humphreys and Ward, 1997; also see Duncan, 1999). The integrated competition hypothesis assumes that once an object or event becomes dominant in one part of the sensori-motor network, it subsequently dominates the network as a whole.

2.5. Routes to Action

Neuropsychological evidence further supports the operation of a visual process where the function of a perceived object is represented, thus allowing the organism to visualise, select, and plan appropriate action (e.g. Riddoch & Humphreys, 1987; Rumiati & Humphreys, 1998; Della Sala, Marchetti & Spinnler, 1991). An important concept in action planning is that of 'priming' of the motor system for action; that is, the action-planning process must by definition, produce a state of motor preparedness for that most appropriate action, a readiness to respond. It seems highly probable, that any priming of the motor system at this early a stage of visual processing would be independent of conscious intention. Therefore, the very representation of object-environment action possibilities or action visualisation involves the mental prioritisation of candidate action schema relating to all possible object-actions, independent of observer intention. The action system may thus (at some processing stage) be conceived of as being 'primed' for any action possibility that is most strongly associated with use of the object, under those environmental conditions, by that person.

In support of this suggestion is the previously mentioned study by Riddoch, Edwards, Humphreys, West, and Heafield (1998) who reported the patient ES, who exhibited anarchic hand behaviour in everyday life. In six experiments, Riddoch and colleagues investigated the factors that elicit such involuntary behaviour, in terms of what they referred to as 'manual interference effects' (MIEs). Manual interference refers to the inappropriate response to a stimulus by one hand in situations where the response should be made by the other hand (see Riddoch et al., 1998, p. 648).

A series of experiments were designed in which ES either had to point to, or pick up an object (dependant on task instruction) using either left or right hand, determined by left or right location of the object. The experiments of prime interest here are the grasping and picking up experiments (Riddoch et al., 1998, Experiments 3-5). In these experiments, the object was either a single cup with the handle pointing to left or right, presented to either left or right side of ES, or two cups (simultaneously presented) to left and right with varying combinations of lateral orientation (left or right). The task involved the patient making left-hand responses to left side stimuli and right-hand responses to right side stimuli. MIEs would occur "when one limb takes control of a required response in a way that is contrary to the verbal instructions given in a task" (Riddoch et al., 1998, p.655).

The idea behind the experiments was that observed MIEs could possibly result from, or be a function of, the effects of over-learned stimulus-response associations, i.e. picking up a cup and drinking from it (what this thesis refers to as the foundation for affordance effects). ES had been reported to respond with the right hand to stimuli with which she had previous experience; in this light, expectations were that; a) a familiar object would produce more interference than a unfamiliar object, and b) where the orientation of the object's handle was compatible with a responding hand, that the interference would again increase. The results showed that interference responses by ES could be modulated dependant on stimulus and response context. ES showed interference effect for *both hands*, these effects becoming maximal where a) the object *position* was compatible with responding hand, but incompatible with the handle orientation; b) where the handle's orientation was compatible with a responding hand; and c) where the stimulus object was a *familiar* object (to the respondent) as opposed to a structurally similar non-object, or when the cup was inverted. There was no difference between the numbers of errors made by either hand.

One interpretation of these results is that interference mostly occurred in those task situations where the physical affordance of an object (handle) was spatially compatible with a responding hand, i.e. the MIEs were a function of the strength of the affordance of the object. Where the evoked action was stronger, (due to compatibility between the evoked (afforded) action and the responding hand) then the manual interference effect was at its greatest. In summary, results showed evidence that visual affordance alone (and visual familiarity) could activate motor responses.

A compelling set of patient data with respect to the direct relationship between object affordance and action was recently reported by Humphreys and Riddoch (2001). They reported patient MP, who exhibited unilateral neglect for targets presented on his left side, following damage to the right fronto-parietal region. Interestingly, in visual search tasks, whilst MP had great difficulty finding targets defined by their name or colour, his performance improved when the target was defined in terms of its associated action, i.e. an object from which to drink. In three experiments Humphreys and Riddoch (2001) presented MP and two aged-matched controls with arrays of 10 objects at a time (five on either side of fixation). They compared MP's detection and accuracy scores in finding targets presented on the affected side that were defined by name, by colour or by their associated action. MP's accuracy and speed was significantly better in the latter condition (when targets were defined by their associated action). Of more pertinence are the results from Experiment 5, where MP was presented with a number of everyday objects, their handles oriented either towards or away from him. MP was more accurate and faster to find the target object, when it was defined based on its associated action, *and* when the handle of the target object was oriented towards him. This important result indicates that *intended actions* in conjunction with the *perceptual properties of objects* are encoded and subsequently able to facilitate performance. Most importantly, this finding indicates that action-related performance can be sufficiently cued by the object's affordance, such as handles, that are associated with the intended action. Once more this set of data provide evidence that even when long-term representations of objects are not, or are only partially available during visual search (due to temporal lobe damage), preserved information on how an object is used can still guide search and enable the patient to detect targets on his affected (neglected) side. The results from the above studies (e.g. Riddoch et al., 1998; Humphreys & Riddoch, 2001) are compatible with the conclusions of earlier work by Riddoch and Humphreys (1987), who first proposed the idea of a 'direct route' to action.

Proposals regarding a 'direct route' to action challenge previous proposals that selection of appropriate action or set of actions towards a visually presented object has traditionally been linked with intact stored semantic knowledge of objects (e.g. MacKay, 1985). In these theoretical models, actions associated with the objects are stored in the semantic store, together with other information about the object, i.e. its shape, colour, category, function. However, neuropsychological dissociations have been reported to suggest the existence of not one but two separate processing routes to action associated with an object. The proposal of a 'direct route' to action from a store of visual object knowledge was first put forward and elaborated by Riddoch, Humphreys, and their colleagues (e.g. Riddoch & Humphreys, 1987; Riddoch, Humphreys & Price, 1989; Rumiati & Humphreys, 1998).

Riddoch and Humphreys (1987) reported the case of the optic aphasic patient, JB who, following damage to regions of the temporal lobes, was unable to name or gain access to other semantic information for visually presented objects. This pattern of performance was in contrast with his preserved ability to gesture appropriately to the same, visually presented objects. Riddoch and Humphreys (1987) proposed that this dissociation of performance reflected the operation of two separate visual routes to action (Figure 2.4.1); one 'indirect' route that is dependant on the semantic system and the other, 'direct' route that is independent from this semantic information about the object. In particular, Riddoch and Humphreys noted that gesturing towards visual objects "may often be based on some form of assembled visual description, rather than being based on stored knowledge" (p. 168).

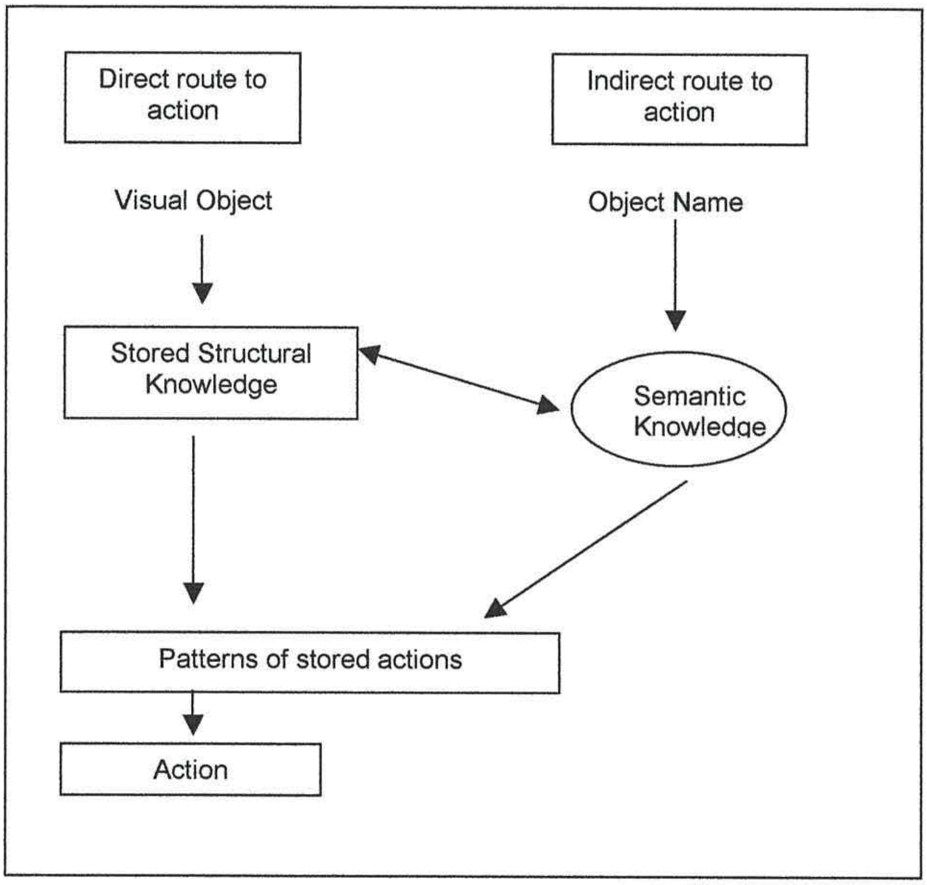


Figure 2.4.1: Schematic illustration of the two routes to action proposed by Riddoch and Humphreys (1987).

Their proposal gains more ground when taken together with the pattern of impairment of the optic apraxic patient, CD, reported by

Riddoch, Humphreys and Price (1989). CD's ability to name and access semantic information for visually presented objects was normal, contrasting with his impairment in gesturing appropriately towards the same objects, when they were visually presented. This result led Riddoch et al. (1989) to suggest that stored visual representations of objects and their associated actions were directly linked, independent from stored semantic information about the object.

More recently, Rumiati and Humphreys (1998) also provided evidence for separate visual and semantic routes to action in neurologically normal adults. They showed that the tasks of naming and gesturing to line drawings of objects are mediated from two separate systems or routes, with naming being mediated by visually accessed semantic representations of the object in hand; gesturing relying more on stored visual information about the object. In agreement with previous evidence from cases of 'utilization behaviour' and 'anarchic hand', they endorsed the idea that stored visual properties of objects, i.e. an object's affordance, are linked directly with the actions associated by that object.

How does the 'dual route-to-action' proposal fit with the long-standing proposal of two visual processing streams in the brain, each with separate but interdependent functions? The neuropsychological and neurophysiological evidence reviewed in section 2.4 (e.g. Milner et al., 1991; Milner & Goodale, 1995) suggests that visual object recognition, and reaching and grasping, are mediated by two anatomically and functionally separate brain regions. The ventral stream codes visual information using object-centred co-ordinates mediating the process of object recognition. On the other hand, the dorsal stream codes visual information in 'on-line', viewer-centred co-ordinates facilitating accurate reaching and grasping. It is, therefore, conceivable that the 'direct', visual route to action is mediated by dorsal stream representations, where objects are represented in viewer-centred co-ordinates (e.g. Goodale et al., 1994) that facilitate action representation. For example, Taira, Mine, Georgopoulos, Murata & Sakata (1990) provided compelling evidence for a specific relationship between action and objects and the representation of this relationship in the dorsal stream. Using single-cell recording technology, they showed that cells in the posterior parietal region fire *only* when a hand action towards a visually presented object is carried out.

On the other hand, the semantic or 'indirect' route to action utilises object-centred representations underpinned by ventral stream visual processing, where objects are coded based on their perceptual features and independently of information relating to a viewer-object spatial relationship. Thus, damage to this ventral region would impair performance relating to the identity and name of the object, leaving the viewer-centred (and action related) information about the object intact (Milner et al., 1991). The opposite pattern of performance would be predicted with damage to the dorsal visual stream.

2.6. Summary

Evidence from studies with brain damaged patients and with neurologically normal adults specifically supports the idea that an object's action-related information (function) may indeed be perceived independently from its identity and the purpose of this functional information is to allow action representation to aid action planning (e.g. Rumiati & Humphreys, 1998; Humphreys & Riddoch, 2001). The distinction between the two routes to action also gains theoretical and empirical support from evidence relating to functions of the ventral and dorsal visual processing systems, each stream processing information about a visual object in different ways and for different purposes. Along the same lines, evidence from cases with anarchic hand syndrome and utilization behaviour suggests that the act of perceiving an object may be enough to automatically elicit an action representation that in some way primes the motor system for action. Where these object-action representations are not suppressed, then object interaction may occur, independent of will.

In normal adults, the degree to which object affordance may operate between sensory and motor systems is best investigated within the paradigm of stimulus-response (S-R) compatibility. This paradigm, reviewed in the following section, allows the study of the effects of S-R interactions on human performance.

Chapter 3

3. Stimulus-Response Compatibility Paradigm

3.1. Introduction to the SRC Paradigm

It has long been accepted that human performance may be considerably affected by the spatial layout, or arrangement of machine controls, displays, or response effectors in relation to the machine's own physical layout or spatial configuration. A typical and often cited example is that of the control layout of the four ring electric cooker. A natural *mapping* would be for each of the ring controls to be located (to mimic) a similar or corresponding spatial layout to that of the rings themselves. These types of natural mapping have been shown to reduce error and generally improve user safety and efficiency.

The question of why such spatial arrangements matter, and why one arrangement can be more efficient or compatible than another has long been the focus of S-R research. One answer must lie in the way we visualise and map potential responses on to what we can physically see. Mapping is made much easier if we can mentally overlay what is being perceived with a response representation template i.e. some kind of logical mapping heuristic. In simple terms, if we need to turn on the back right ring, it is much simpler and intuitively more natural if the control panel displays the on/off switch in a back-right configuration in relation to the other ring controls.

These types of 'natural' mappings may be described in terms of compatibility[3], correspondence, or in the case of Kornblum, Hasbroucq, & Osman (1990), dimensional overlap, between perceived properties or elements of a stimulus set, (stimulus environment), or between those elements of both stimulus and response sets. Therefore, spatial properties and possibly many other object or environmental properties may facilitate, constrain, interfere with, or influence the way we act or respond.

To relate to this compatibility in terms of cognitive structures, the information processing approach utilises the idea of cognitive codes that represent attributes of S-R sets. By definition, perception involves the registration of sensory information (neural excitation) in the brain. In a similar fashion, responsive action requires the generation and transmission of motor information to effector organs. Traditional information-processing accounts of perception-action linkage refer to these patterns of sensory and responsive excitation in terms of either sensory (stimulus) or motor (response) 'codes', and treat both types of code as belonging to independent (sensory or motor) representational domains (e.g. Kornblum et al., 1990; Wallace, 1971). To consider the existence and operation of a stimulus code and a response code, one

---

[3] Various labels are used, to denote situations of compatibility between elements of stimulus-response sets. Throughout this thesis, in order to remain consistent, the mappings of elements of S-R sets will be referred to in terms of correspondence. Where elements do, or do not correspond, and there exists a significant effect attributable to that correspondence, then this effect will be termed a 'correspondence effect'. However, the term compatibility may still be used at the more general level of discussion and when relating past research where authors have used this terminology.

must also consider the process or means, or common element through which these codes communicate or interact with each other.

The paradigm that has been used to investigate the effect of stimulus-response (S-R) properties on human performance is the Stimulus-Response Compatibility (SRC) paradigm (e.g. Fitts & Seeger, 1953; Kornblum et al., 1990). The S-R *compatibility effect,* first coined by Small (1951, cf. Hommel & Prinz, 1997), has been used to refer to the advantage of certain stimulus-response mappings over others. The key notion in the paradigm is the effect that the *interaction* of elements of the S-R or S-S set (such as location, colour etc.) has on performance. This change of focus to take account of the interactive effects of S-R or S-S elements was in contrast to the then traditional view of describing effects as being due to stimulus effects independent of response (or vice-versa).

A multitude of reaction time studies have shown that where a stimulus and a response share certain features such as relative location, then speeded responses to these stimuli are typically faster and more accurate than when there is no sharing of S-R features. This sharing of common characteristics between elements of either S-S or S-R sets is often referred to as *compatibility or correspondence.*

In a classic experiment, Fitts & Seeger (1953) sought to determine whether some stimulus-response (S-R) pairings produced faster response latencies than others. In a choice reaction time task they combined three different sets of spatially arranged stimuli with three different sets of spatially arranged responses, to create nine different stimulus-response combinations (ensembles). Those S-R pairings that shared, for instance the same spatial location or the same direction of movement elicited faster and more accurate performance. These S-R pairings were termed *compatible* (Figure 3.1).

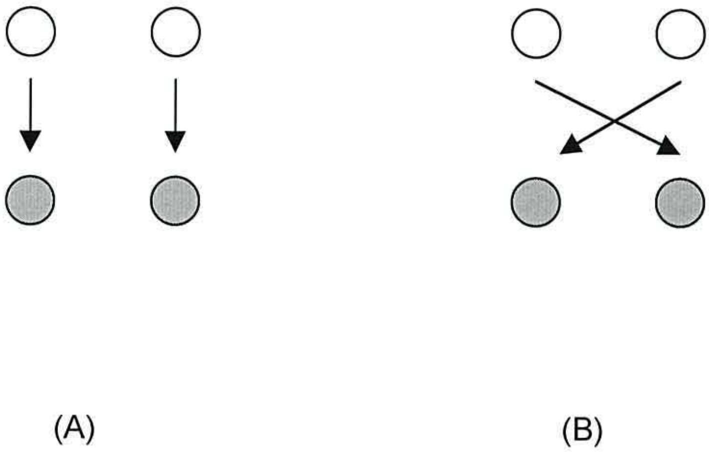


Figure 3.1. Schematic illustration of spatially compatible (A) and incompatible (B) stimulus-response mappings. Reaction times were faster when the stimulus locations (empty circles) corresponded to the assigned response locations (filled circles).

In this experiment subjects showed significantly better performance times and lower error rates for some S-R pairings over others, and generally different average reaction times (RTs) for different sets of S-R pairings. The most compatible (those with the best performance times) were those in which the spatial arrangements of stimuli and responses were most similar. In summary, superior performance was achieved in those situations, where mapping between elements of the stimulus set (object to be interacted with) and elements of the response corresponded. In those situations where performance is positively affected by this correspondence, we have what has traditionally been termed, stimulus-response compatibility (SRC) effects; in essence, the degree to which, what people perceive is consistent with the actions they need to take.

3.1.1. Compatibility on Task Irrelevant Stimulus Dimensions

In the late sixties, an important landmark was reached in research into S-R compatibility phenomena. Simon and Rudell, (1967) showed that even those elements of a stimulus set that were not relevant to the experimental task in hand, also greatly affected response performance, i.e., these task irrelevant elements being processed along with task relevant elements, and affecting performance of the experimental task. This effect of an irrelevant stimulus dimension on performance was termed the Simon effect (Simon, 1969). This irrelevant stimulus information was found to be reliably effective in confounding responses in laboratory controlled S-R tasks. In addition, it was shown that these effects were not tied to absolute S-R spatial mappings but also to relative S-R co-ordinates (see Umilta & Liotti, 1987). The Simon effect will be covered in more detail later, but for now the more important point is that this phenomenon served to greatly promote and encourage more flexible and adaptive accounts of the way in which perceived attributes of the whole stimulus and response environment influences, enhances, or interferes with performance of human response.

Over the past fifty years or so, various theoretical frameworks have been proposed to explain the nature of these perception-action processes, each attempting to account for aspects of SRC phenomena. The most prominent of these approaches, and the one to which this work predominantly relates, is that of 'information processing' (IP). Traditionally, information processing theory simply focussed on the way that information was transmitted between stimulus and response structures, with little thought to the mediating organism, i.e. the architecture of the system receiving and processing it. Later, increasingly cognitively oriented approaches took more account of how information processing might be constrained by cognitive structures, i.e. the human processing system.

3.2. Translation & Controlled Processes

As described earlier, central to information processing interpretations of SRC effects, is the notion of cognitive codes that are generated within a perceiver, upon exposure to an environment. The idea of cognitive coding also pre-supposes the concept or process of 'translation'; the theoretical cognitive process by which one moves from perception (sensory codes) to action (motor codes; for review see Eimer, Hommel & Prinz, 1995), the translation being necessary in order for these two incommensurate (in terms of content) representational domains to 'talk' to each other.

S-R translation is traditionally thought to represent a process, which begins with a 'controlled' intention to act, this intention causing stimulus selection that in turn activates a corresponding response. In a typical reaction time experiment, the translation process would be mediated through, or in the form of, specific task related instructions, given to a participant, and relating to a stimulus response situation or mapping, such as respond left when you see a green light etc.

However, whilst the translation metaphor provided a theoretical structure that might accommodate the idea of simple transitions from perception to action, it could not, on its own, account for the mounting evidence for the interplay of automatic, non-intentional processes within the translation process, resulting in significant effects on task performance. For instance, in a Simon type experiment, instructions may be to respond to the green stimulus using a left side effector, responses are affected by a property of the stimulus, i.e. its location, that is irrelevant to the task in hand and absent from any task instructions.

As far as information processing theory was concerned, these (Simon) effects of irrelevant attributes were difficult to explain. This 'transmitted' stimulus information was to all intents, superfluous to the task and therefore neither anticipated nor required by observer or researcher. Neither was it simple to explain its presence and effect in a framework that was traditionally hypothesised in terms of uncorrupted stimulus and response. Indeed, the translation metaphor, by focussing on the incompatibility of sensory and motor domains, simply bypasses the need for explanation of the processes involved in many typical S-R situations. The mechanics of this type of translation process only account for pure (controlled and intended) linear stimulus-response mapping explanations and neither describe nor accommodate phenomena such as those task-irrelevant relationships between S-R elements (Simon effects). In the same vein, neither does it account for effects of similarly irrelevant semantic S-S associations (Stroop effects).

In the well known 'Stroop' task (Stroop, 1935), those properties of a *stimulus* set that would be termed irrelevant to a required task are, nevertheless, shown to greatly affect or interfere with the actual 'task relevant' aspects of the stimulus, resulting in confusion with response selection when these stimulus attributes conflict. In the Stroop task the effect is thought to result from competing stimulus attributes relating to a task, whereas the Simon effect is mainly associated with the impact of spatial correspondence between the irrelevant location of a target stimulus, and elements of the response set (normally response effector location).

3.3. The Simon Effect

The Simon effect was originally demonstrated using auditory stimuli (high or low tones) presented to either left or right ear (Simon, Hinrichs, & Craft, 1969), where subjects were required to make left or right key-press responses dependant on tone. In those trials with correspondence between response side (left or right hand) and side of stimulus (left or right ear), responses were on average 61 milliseconds faster than in non-corresponding trials. This phenomenon became known as the *Simon effect*. Subsequently, the same effect was also achieved using visual stimuli (e.g. Craft & Simon, 1970); using colour as the relevant stimulus dimension (Hedge & Marsh, 1975) and with various other task relevant visual stimulus dimensions such as geometric shapes (Nicoletti & Umilta, 1989) and letters (Proctor & Lu, 1994). Spatial correspondence was shown to produce very robust facilitation of task performance (e.g. Simon, 1969; Hommel, 1995; Kornblum & Lee, 1995).

Although the Simon effect was originally viewed as a purely spatial function of S-R correspondence, this idea was challenged by Hedge & Marsh (1975). In their first task, subjects were asked to respond to a red or a green stimulus on either left or right of space, using either a red (right hand) or green (left hand) button. Their task was to respond by pressing the button that matched the colour of the stimulus. This task produced the standard Simon effect. Responses were faster in those cases where response side and stimulus side corresponded, as opposed to when they did not. However, in a second task, subjects were asked to respond to the alternate coloured button, so if a stimulus was green, the red button was the response, and vice-versa. In this experiment, the effect was reversed. In trials that did not spatially correspond, responses were significantly faster than in those that did. Response times were faster in those trials where colours corresponded spatially rather than where locations corresponded spatially.

In order to account for this reversed effect, Hedge and Marsh (1975) proposed that a 'reverse mapping' (recoding rule) was not only applied to the (relevant) response button selection; for example, if the stimulus is 'green' then press the 'red' button, but also to the task-irrelevant element of spatial location; for example, if (irrelevant) location of stimulus is 'left' then code for 'right'. In summary, it would work like this; presentation of 'red' stimulus (on left) – mapping rule to select alternate button (green on left – *code left*). Irrelevant (left) stimulus location – mapping artefact codes for alternate location (*code right*), thereby resulting in code conflict; that is, a spatially compatible *left-left scenario* subjected to a reverse mapping rule, being interpreted as a non-corresponding *left-right* trial, resulting in increased response times for non-corresponding over corresponding trials.

In contrast, Hasbroucq and Guiard (1991) proposed the Simon effect to be a function of S-S interaction, that is, stimulus identification processes, and that S-R spatial correspondence in the Simon task confounds the intrinsic congruity between relevant and irrelevant S-S dimensions. They suggested that in the first Hedge and Marsh experiment, the task instruction to respond with 'same colour' button worked in the following fashion; the green button is again on the left and the red is on the right. The colour green is automatically assigned the value 'left' and the red colour to right. On a *spatially* corresponding trial, the red stimulus appears on the right, subject codes right for (relevant) red stimulus, and codes right for (irrelevant) location, thereby producing both S-R correspondence and S-S correspondence, one confounding the other, but resulting in the standard Simon effect.

They accounted for the reversed Simon effect with exactly the same process. This time, subjects were told to respond with the alternate colour button, i.e. press green button for red stimulus and vice-versa. The green button is still on the left and the red on the right. When, in this alternate mapping task, the green (relevant) stimulus is presented, the observer again codes left for green, the stimulus is on the (irrelevant) left so he codes left, and the button he must respond with is on the right (red). So here, we have a spatially non-corresponding S-R mapping but a congruent S-S mapping, thus resulting in dissociation between the spatial correspondence effects and those of S-S congruity. This S-S mapping provides (reverse Simon) facilitation due to S-S congruity, regardless of S-R correspondence. However, the S-S view has failed to gain much ground since it was first proposed. A clue to the inherent problem lay in the fact that in the original Hedge & Marsh task, the reversed Simon effect was over twice as large (55 ms) as the standard effect (23 ms) using the same experimental set-up. This was not predicted by Hasbroucq & Guiard's account. Further research by Lu & Proctor (1994) showed that the magnitude of the Simon effect decreased as a function of time taken to identify the stimulus i.e. longer RTs resulted in reduced effects.

Initial accounts of the Simon effect, proposed that it might be due to an effect of a natural (attentional) orienting of the perceiver towards the point of stimulation (Simon, 1969). However, another more theoretically oriented account was later put forward by Wallace (1971). In order to explain how stimulus and response elements might be cognitively represented, he proposed the idea of response codes and stimulus codes that might represent aspects of the S-R set.

3.4. Translation Account of the Simon Effect

According to Wallace (1971), a translation account of the Simon phenomenon was that, as in translation theory, a stimulus code is translated into a response code, where correspondence between SR codes enhance (or with non-correspondence, presumably interferes with) the normal translation process. However, findings of Eimer et al; 1995 and Hommel (1995) do not lend support for such a pure translation account of the Simon effect. The implications of Wallace's account is that if the irrelevant spatial code is assumed to affect S-R translation, then by shifting the source of the irrelevant spatial code to a later (post translation) period, the effects should be extinguished.

Hommel (1995) devised a method where a subject would be fully informed on each trial, with valid S-R information concerning the following trial, therefore allowing the S-R translation to be prepared in advance. This design precluded the effect of irrelevant stimulus elements, as the response would be prepared prior to presentation of the irrelevant element. In essence, subjects had to withhold a prepared response (one second) until a green go or red no-go signal appeared randomly at either screen left or right; thus if Wallace was correct, then the (irrelevant) location of the go signal should not now matter.

Contrary to Wallace's translation account, responses were much faster in trials with correspondence between the location of the go signal and the response effector. In summary, the design of this experiment negated the need for any translation process of the irrelevant signal location dimension; therefore, it could not possibly interfere with Wallace's proposed single translation process. This evidence supported the case that an irrelevant stimulus dimension need not occur at, or affect the translation stage of task relevant elements and necessarily implied the existence of an alternative or parallel route to the response selection stage.

3.5. Common Coding Approach

In order to account for these 'automatic' effects of irrelevant S-R attributes, Eimer, Hommel, & Prinz (1995) proposed an updated version of the traditional linear translation model. This model further postulates sensory (event) and motor (response) codes that share a common representational domain, thus accommodating the notion of degrees of S-R overlap, The model allows for more direct and automatic S-R processes that may run parallel to, but be independent from, intended or controlled actions, potentially enhancing the existing linear translation process (Figure 3.5.1).

By positing this 'two route' model with less strictly separated domains of event and response codes, this 'common-coding' approach allows both direct activation of codes even when no action is intended, and indirect activation (translation) dependant on task specific contingencies. According to Eimer et al., "This approach holds that there is a functional continuity between perception and action, and that this continuity is relevant for an adequate characterisation of the transition from stimuli to responses" (p. 303). In summary, compatibility effects can be attributed to, and be a function of, the degree of overlap (see Kornblum et al., 1990) between stimulus and response representations.

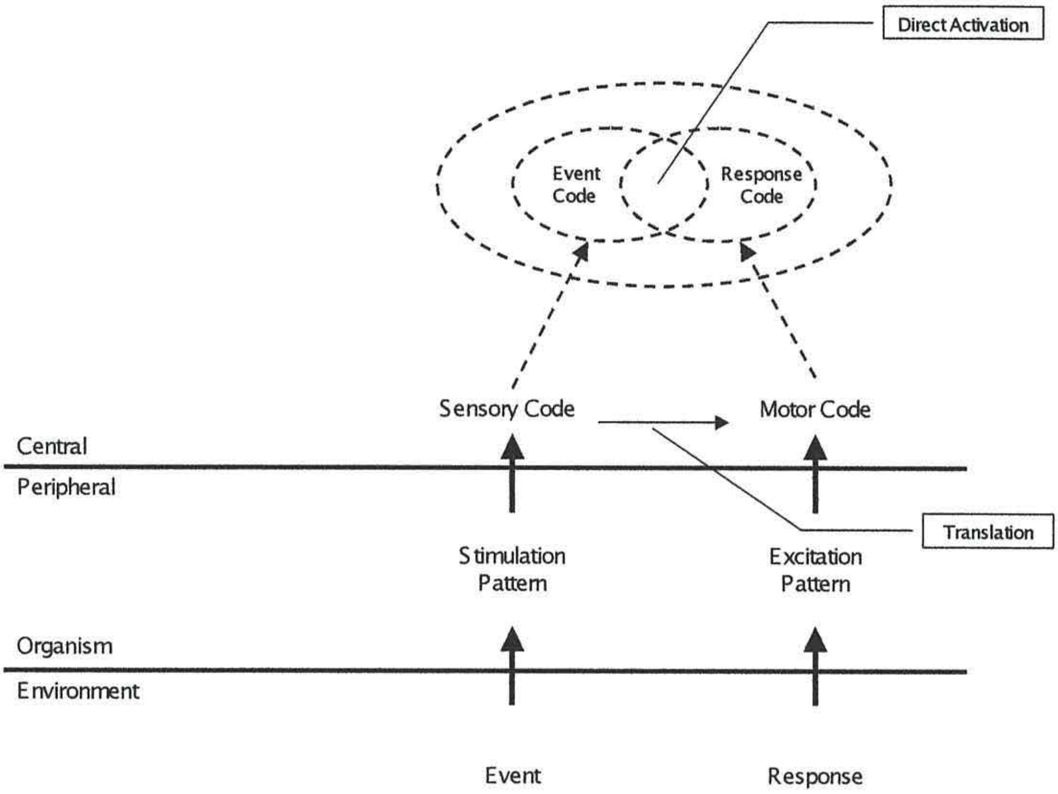


Figure 3.5.1: (Adopted from Eimer et al., 1995). Schematic illustration of the functional components of perception and action. The lower part of the diagram illustrates the separate coding view of perception-action linkage. The upper part of the diagram illustrates the common coding view, where perception (event) and action (response) codes are linked together depending on their representational overlap.

By postulating the generation of event and response codes that share the same representational domain, this model dispenses with the need for translation, any effects of compatibility being determined as a function of the degree to which these codes overlap i.e. the common ground (or degree of similarity between S-R components). Whereas the simple, linear translation model relied on controlled processes dependant on task instruction, the common coding model is seen as also having an automatic route, that is, operating independently from task instruction or intention. The common coding model therefore, is a dual route model with the original translation operating in parallel to the automatic processes; the translation route mediating controlled selection of the correct response, and the automatic route being activated by any effective, irrelevant S-R attributes.

3.6. Relative Spatial Coding Accounts of S-R Compatibility

So far, it has been shown that stimulus location plays a significant role in producing compatibility effects, whether the stimulus location is relevant, or non-relevant, as in the Simon effect. Two of the foremost explanations for the generation of these relative spatial codes are those described by the referential-coding account, (Hommel, 1993a; Umilta & Nicoletti, 1985), and by the attention-shift account, (Nicoletti & Umilta, 1994; Stoffer, 1991; Umilta & Nicoletti, 1992). In essence, these two accounts differ only in the identification of an initial observer reference point. Both accounts usually make identical predictions.

The attention shift account posits the formation of a spatial stimulus code created by a lateral shift in attention from origin, towards the imperative stimulus, be it left or right. In normal experimental circumstances, this attention shift would be from a central fixation point or perhaps a priming object. The imperative stimulus then becomes the new attentional origin for further attention shifts. The idea in the Umilta and Nicoletti (1992, 1994) model is that when the imperative stimulus arrives, a saccadic eye movement is programmed and spatial parameters represented, generating a spatial code, which ultimately, may or may not be congruent with codes generated by other spatial S-R elements.

In contrast, the referential coding account proposes that stimulus spatial code generation is achieved by automatically relating the location of an imperative stimulus to another reference object, or frame within the stimulus environment, and that attention is not functionally involved in the coding of a stimulus location, although, according to Stoffer and Umilta (1997), "the referential coding account does not attempt to specify the processes by which an intentionally defined frame of reference (or object) is actually chosen". There exist various points of view, for and against both accounts, but it is not within the scope of this thesis to delve too deeply into the theoretical arguments. Suffice to state that attention must play a significant part in achieving SRC effects.

3.7. The Dimensional Overlap Model

In an attempt to clarify the theoretical nature of S-R interaction (compatibility) effects, Kornblum, Hasbroucq, & Osman, (1990) presented a dimensional overlap (DO) model of S-S and S-R interactions. Inherent in this model was the idea that "SRC is a direct consequence of the degree to which the stimulus and response sets of a stimulus-response ensemble, are perceptually, conceptually or structurally similar" (Kornblum & Lee, 1995, page 855). Kornblum et al., (1990) presented a taxonomy of eight possible S-S and S-R 'ensembles' that integrates concepts of both dimensional overlap and dimensional relevance. Kornblum and Lee (1995) described a set of five experiments, testing S-S and S-R measures of attribute similarity upon subsequent response times, and provided clear evidence that the model could account for all S-S and S-R contingencies.

The architecture behind the overlap model pre-supposes the existence of dual (parallel) processing routes involved in the inevitable perception-action coupling process. One route is seen as controlled and deliberate, in this case reflecting the task in hand and resulting in production of a 'correct' response code, and the other direct, faster, and automatically activating motor programs.

Essentially, Kornblum and Lee (1995) attribute S-R compatibility effects to a competition between this automatic response activation and controlled S-R translation. That is, a stimulus will automatically elicit a response based on shared stimulus features at the same time (in parallel) as the controlled, intended action translation takes place. If the automatically elicited action representation is appropriate for the intended task, then facilitation is evident in terms of response efficiency. However, if the automatically elicited action representation is not appropriate then the potential action must be suppressed, thus resulting in a form of inhibitory action, in turn, resulting in comparatively slower end responses with a higher potential for error. Kornblum and Lee (1995) subsequently report evidence for faster mean RTs with matching S-R attributes than with unmatched, regardless of attribute relevancy to the response; however with smaller effects where stimulus attributes are irrelevant rather than relevant to the task. They also conclude that faster RTs were due to a facilitative process and the slower RTs to an interference (suppression) process.

3.8. Time Course of the Simon Effect

So far, it has been shown that any explanation of SRC effects, especially those where irrelevant S-R attributes play a role, must incorporate some kind of parallel, dual or multi-route process. Within this process, S-R codes (or dimensions), may either work together in a congruent, overlapping fashion, or conflict, facilitating or interfering with response selection processes. This being the case, the implication is that controlled, automatic processes are inter-dependant and dissociable, and that S-R codes are generated and transmitted along these theoretically different routes, at different times, and for different purposes. Therefore, it is also reasonable to assume that these codes may have differing characteristics, dependant on origin. One characteristic of codes may be in terms of their time course, in terms of optimal temporal conditions for both code generation and its decay process.

In a series of five experiments, Hommel (1993b) manipulated temporal relations between relevant and irrelevant stimulus dimensions, in a simple reaction time task. Based on earlier experimental results, he hypothesised a decrease in the correspondence (Simon) effect would result from increasing the temporal distance between the coding of the relevant stimulus information and the irrelevant stimulus information. In a final and conclusive experiment of the series (visual modality), he attempted to separate out relevant and irrelevant stimulus information. A letter D or a letter U would randomly appear on either left or right of screen and the subject's task was to respond as quickly as possible. The experiment employed an "immediate" condition where stimuli (letters D or U) appeared immediately and a "delayed" condition where the same stimuli were designed to have a gradual onset over 196 milliseconds. In the gradual onset condition, the presentation of the letter would be built up gradually over the period, and the letter 'U' would not be distinguishable from 'D' (and vice-versa) until completion, thus delaying stimulus identification by 196 ms. However, the letters' (irrelevant) location would be immediately perceptible in both conditions. Results showed that the effect of increasing the temporal relationship between the relevant (identity) and irrelevant (location) stimulus attributes, did indeed decrease the Simon effect. In the immediate condition, a standard Simon effect was achieved with a mean difference of 33 milliseconds between corresponding and non-corresponding trials. However, the delayed trials decreased this effect size to a mean difference of just 18 milliseconds.

From this, and other experiments in the series, Hommel proposed a general (and theoretically neutral) temporal-delay hypothesis that assumed that any manipulation that markedly increases the temporal distance between the formation of the relevant stimulus code and the irrelevant stimulus code, leads to a smaller effect of irrelevant spatial correspondence between stimulus and response (Hommel, 1993b). Efforts to actually locate the conflict in S-R processing that causes the Simon effect have produced very general and sometimes conflicting results. On this issue, Hommel concludes that the interaction between corresponding or non-corresponding codes can occur anywhere within the system, as long as these codes exert any influence on S-R processes. He goes on to suggest that "factors affecting quite early processes might interact with the Simon effect, not because they take place at the same stage as the correspondence dependant conflict, but because these factors have an impact on the time-point of formation of the relevant and irrelevant codes" (p.277). Here we have the implication of (potential) indirect effect of early stage processes on subsequent stages.

In summary, Hommel showed that by manipulating the signal quality of a relevant stimulus, he could show a relative decrease in the

Simon effect. In theory, this could be seen as increasing the temporal distance between formation of relevant stimulus code and irrelevant spatial code leading to a relative decrease in interference between conflicting spatial factors affecting early code formation processes.

Similar findings were reported by Kornblum, Stevens, Whipple, & Requin (1999) who further investigated the time course and resulting temporal interactions for S-S and S-R interactions for various S-R ensembles. They also showed that an important criterion for eliciting compatibility effects is that of latency of onset of the imperative stimulus in relation to any other irrelevant stimulus feature that may be presented prior to a task response; this time-lag usually referred to as stimulus onset asynchrony (SOA).

3.9. Functional Aspects of SRC

It has long been understood that task-irrelevant attributes of an S-R set can affect performance on tasks, as evidenced by the Simon and Stroop type effect. However, to postulate the influence of affordance, not to mention irrelevant affordance, on response performance is rather more unusual. Bearing in mind that most stimulus–response research to date has investigated the effects of *spatial* correspondence between stimulus-stimulus and stimulus-response attributes, then the possibility that, *functional* attributes of a stimulus can also significantly affect performance becomes of great interest.

A recent example serving as a major motivation for this present thesis is the work of Tucker and Ellis (1998). Using the stimulus-response compatibility (SRC) paradigm and a choice reaction time task, they showed support for the effect of visual affordance on action by demonstrating that the orientation of common, easily graspable objects could significantly influence task performance when responding towards those objects. They presented various, easily graspable every-day objects at various orientations to an observer, who was required to make simple left or right key-press responses to whether or not the object was inverted. These various orientations of the object effectively resulted in offering (to the observer) a handle to left or right of the observer's space. It was hypothesised that where the handle pointed to a particular side of the observer, then this would preferentially prime an observer response to that side of space. In their experiment, the orientation of the object was always irrelevant to the task of responding to the object's inversion.

Results showed a significant benefit in response performance (faster response times and fewer errors) where the orientation (affordance) and responding hand were compatible, compared to incompatible. Tucker and Ellis interpreted the results in terms of facilitatory effects of affordance, in support of the idea that "intentions to act operate on already existing motor representations of the possible actions in a visual scene" (p. 830). Of course, the interesting aspect to their experiment (described in more detail later) was the interpretation that the (task irrelevant) *affordance* of the object facilitated response performance. The implications of the notion of affordance are that the object's representation also carries object *meaning* relating to it's perceived utility.

One interpretation of the Tucker and Ellis experiment is that the functional component of a stimulus is capable of creating some form of lateralised response code that has the ability to interact with those codes generated by the experimental task. Effects of compatibility of these codes is reviewed in the light of Simon type effects, consistent with the dimensional overlap model (Kornblum et al., 1990), where common (overlapping through similarity) attributes of S-S or S-R sets reduce conflict, thus facilitating performance.

A less theoretical explanation is simply that the perceived affordance of the object has the ability to evoke action representation within the observer when viewed in peri-personal space, thus priming the motor system for the most appropriate response. This explanation was favoured by Tucker and Ellis after observing a null effect for a similar, but unimanual task (in their Experiment 2).

However, this null finding cannot provide sufficient basis for excluding the response code account. Thus, the ambiguity between (and within) the aforementioned accounts for affordance-based effects form the theoretical basis of the current research.

3.10. The Current Research

The aim of this thesis is to examine and assess the effect of object affordance on the human action system. More specifically, it aims to provide converging evidence for affordance-based effects by (a) using differing methodologies from that used by Tucker and Ellis (1998) and (b) by further manipulating the properties of the stimulus and the response sets. The hypothesis examined here is that the effect of the perceived object and its affordance for action is a direct consequence of the observer's prior experience and capabilities.

The reviewed neuropsychological and stimulus-response compatibility literature provides evidence to suggest that objects (that is, their perceived function) may, independently from recognition, elicit some form of mental representation for object-related action, (e.g. Norman, 1981; Michaels and Stins, 1997; Tucker and Ellis, 1998; Reason, 1990; Humphreys & Riddoch, 2001, amongst many others), even in the absence of any intention to act. However, what remains vague, is the way that an affordance might operate. Is affordance for a particular limb or a more general action goal related response; how important is object salience or relevance to existing intentions; and what is the role and contribution of attentional processes? The following set of eleven experiments attempts to throw light on the way that functional characteristics of familiar objects can influence response performance.

The first two experiments of this work use pictures of everyday familiar objects, presented at varying orientations, offering affordance to a particular side of space. Observers are required to make simple reaching and touching responses. Reaction times are measured and comparisons made between trials, in terms of correspondence between object orientation (affordance), and responding hand. The initial aim of this work is to replicate those effects found by Tucker and Ellis (1998).

Chapter 5 describes a series of three experiments investigating the time course of affordance-based correspondence effects, and examines more closely their origin and nature. The purpose is to determine whether facilitation is a result of affordance-based activation for a specific (responding) limb, or due to generation of a more abstract, lateralised response code for that side of space.

Chapter 6 investigates attributes of the stimulus set, not specifically based upon perceived object function. Chapter 7 describes attempts to disambiguate the effects of attention from those of object affordance. Finally, Chapter 9 uses a radically different methodology to study the nature of acquisition and maintenance of object affordance; that of training participants to interact with novel objects.

Chapter 4

4. Reaching Towards Familiar Objects

4.1. Experiment 1 – Introduction

One way to assess whether the visual affordance of an object target elicits representation for action is to test for and measure correspondence effects between the responses to a target and an afforded action. That is, if objects do tend to evoke actions, then responses that in some way correspond with such affordance should be faster and more accurate than non-corresponding responses. Michaels (1988) observed that spatial compatibility effects to a looming stimulus were based not on the physical location of the target, but on its apparent destination. In this way, a target appearing to move from the far left to the near right would be responded to more quickly with the right hand than with the left. Michaels (1988) argued that these results were consistent with the notion that the looming stimulus preferentially afforded catching or interception by the hand nearest the apparent destination, and that this hand was therefore activated for response (but see Proctor, Van Zandt, Lu, and Weeks, 1993).

Studies by Craighero, Fadiga, Umilta, & Rizzolatti, (1999); Craighero, Fadiga, Rizzolatti, & Umilta (1998) show evidence to support the operation of what they refer to as a 'visuo-motor priming effect' linking the 'representation of an object's visual properties with the specific motor programs to act upon it' (Craighero, Fadiga, Rizzolatti, & Umilta, 1998). One of their tasks required participants to 'prepare' to grasp (to imagine a grasp based on given information) one of two bars that differed in orientation. Upon presentation of a visual stimulus, they were required to execute a speeded grasping movement to a bar located in front of their hand. The visual stimulus was a picture of a bar in one of the two possible orientations. Response analysis showed that where the prepared grasp and the orientation of the visually presented bar corresponded, then response times were significantly faster than when they did not. The authors, whilst attributing much of the now improved performance to various methodological shortcomings, did note that facilitation observed on corresponding trials might have been due to the influence of the visual stimuli on the execution of the (corresponding) grasping movements. They went on to suggest that preparation of the grasping movement facilitates visual processing of stimuli sharing the same intrinsic properties; what they term 'a visuo-motor priming effect'.

However, of central importance in the following studies, is the previously mentioned and extremely interesting study by Tucker and Ellis (1998; see also Ellis & Tucker, 2000), looking at response activation initiated by specific affordance for action. Tucker and Ellis (1998) presented images of everyday graspable objects with handles (for example, cups, knives, teapots). The objects themselves could appear either upright or inverted, with the handles randomly oriented to either the left or right side of space. Participants had to key speeded left or right-hand responses to indicate whether the target object was upright or inverted. The question of interest, however, was whether the affordance suggested by the handle potentiated any form of action. Tucker and Ellis (1998) found a significant correspondence effect based on whether the affording handle appeared on the same side of space as the responding hand, for example, left hand responses were faster (and less error prone) when the handle appeared on the left side of space than when it appeared on the right.

All of these studies lend support to the idea that action related information is represented automatically, and that the mere state of action possibility, taking into account any restraints of either the stimulus and/or the response set, is sufficient to somehow prime the organism for response. To test this hypothesis, the first two experiments investigate whether the orientation of the physical handle of an object might automatically prime motor responses for the most afforded hand, even when the orientation of the object is not relevant to the response. Individual images of either a 'cup and saucer', a screwdriver, a frying pan, or a coffee-pot were presented to observers who were required to make speeded touch-responses to the computer screen. The design allowed that each of the objects would be oriented so that the handle offered either a left, or a right-handed action. A third orientation was that of neutral in which the handle was centralised and thus invited no spatial preference for action. In summary, this first experiment aims to replicate the Tucker & Ellis effects in a reaching and pointing task.

The hypothesis for Experiment 1 is that where the affordance of a target object corresponds to a responding hand, then speeded response performance will be superior to that, when responding hand and affordance do not correspond. The null hypothesis is that there will be no significant differences in performance between conditions of correspondence.

4.1.1. Experiment 1 Method

Participants

A sample of ten undergraduate students (all registered as major psychology students with the University of Wales, Bangor) took part in this study; each receiving one course credit for their participation. All participants reported having normal or corrected to normal vision, and except for one, were right-handed, and naive to the purpose of the study.

Apparatus/Stimuli

Stimuli comprised nine (10x10 cm) 2D pictures [1]of three common objects (frying pan, cup and saucer, and screwdriver), each offering three orientations of affordance (neutral, left, or right). Thumbnails of these objects are shown in Figure 4.1 below.

---

[1] Note. Images of Objects courtesy of Michael J. Tarr (Brown University, Providence, RI).

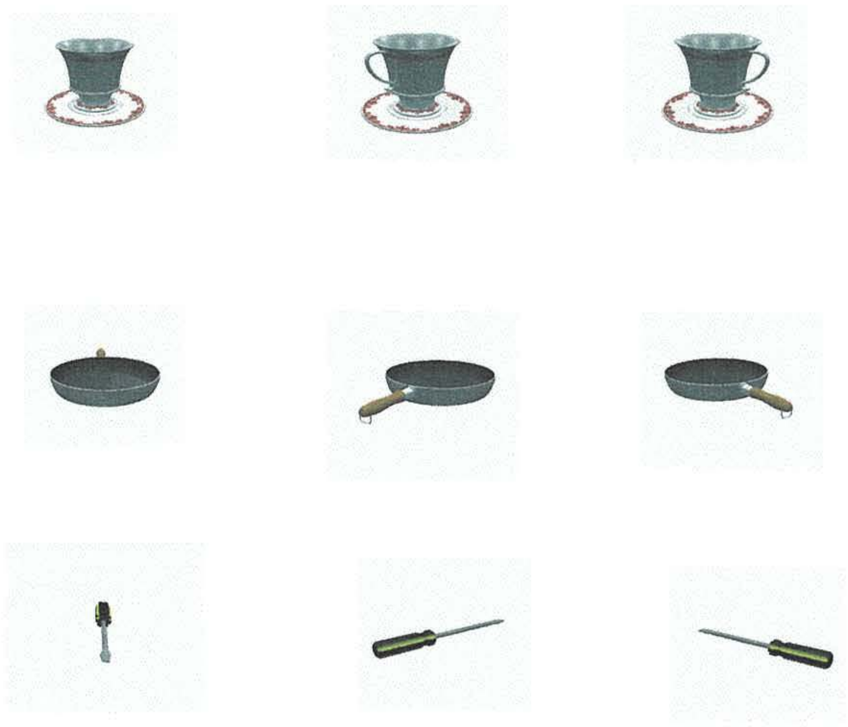


Figure 4.1. Stimuli used in Experiments 1 and 2. Experiment 2 also included a coffee-pot (not shown). Each object was presented to left or right of screen subtending 14^{o} of visual angle (Experiment 1) or to upper or lower screen; subtending 17^{o} degrees (Experiment 2), at a viewing distance of 50 cm.

All objects were presented in colour against a white background. All objects were chosen for their comparatively high frequency of common usage, and for their ability to be (normally) grasped or manipulated using only one hand. The orientation of the object offered an affordance (in this case a handle) to either left or right hand (in the case of neutral affordance the handle would be facing directly away from the participant, see Figure 4.1). Images were presented on a 12-inch 'AppleColor' hi-resolution RGB 'TouchScreen' monitor (refresh rate of 15.058 ms) connected to a Power PC 8500-120 computer using TouchStar™ touch-screen software. The experiment was run on PsyScope version 1.2.2 software. Responses and timings were recorded by the computer, and made through a standard three button, button box and touch-screen connected to the computer.

Design

The experiment comprised of four blocks of ninety trials each based around a 2 x 3 x 3 within-subjects design, manipulating the following three factors; a) target Side of screen with two levels (either Left or Right); b) target Object with three levels (Pan, Cup and Saucer, or Screwdriver); and c) target Affordance with three levels (Left, Right, or Neutral). There were thus eighteen randomly presented and equiprobable conditions yielding an average of twenty trials per stimulus over the four blocks. The dependant variable in all cases was reaction time.

Procedure

The experiment began with a series of thirty practice trials to familiarise the participant with the required hand movements. The trial sequence began by simultaneously depressing both the left and right buttons of the button box with left and right fingers respectively, these buttons being held down until presentation of, and response to target; thus, the participant controlled initiation of each trial. The 'button down' action initiated presentation at screen centre of a central fixation point (CFP) on a blank screen for 1500 ms. The participant was asked to focus upon this point. The target image then appeared (randomly) at either screen left or screen right, and remain on screen until response. The task was then to respond as quickly as possible, using the hand ipsilateral to target side, by 'touching' the screen image (centrally) with the middle finger of that hand. Lifting the hand from the button recorded reaction time; touching the screen ended the trial and cleared the screen.

A new trial began by releasing the remaining finger from the button box and simultaneously depressing both buttons again. An error trial occurred where the participant lifted the finger from the button contralateral to the target side. In this case, an error beep sounded, the error was recorded, and a new trial began. Between each of the four blocks of trials, an opportunity was given for a five-minute break. During these breaks, participants were reminded to respond as quickly and accurately as possible during the next block of trials.

4.1.1. Results and Discussion

Error data - Data was initially analysed by participant in order to identify response errors (4%), time-out errors comprising RTs greater than 1000 ms. (3%), and those RTs greater than three *SD*s from individual means, plus the mean, for the remaining valid trials (1%). Eight percent of experimental trials were therefore excluded from the analysis[2]. A brief analysis of errors by Object and Correspondence showed little difference in percentage errors between Corresponding, Neutral, and Non-corresponding trials; respectively 26%,39%, and 34%. Errors for individual objects irrespective of affordance were almost twice as large for the Cup (47%) compared to the Pan (24%), and the Screwdriver (28%). A WS ANOVA comparing Correspondence by Object failed to reveal any main effect of either Correspondence $F(2,14)<1$, or Object $F(2,14)=1.13, p=.806$. Figure 4.2a illustrates the comparisons between Objects, over Correspondence.

Reaction-time data - Mean trial response times for Neutral trials (*M*=356; *SD*=62.7) were the same as for Corresponding (*M*=356; *SD*=58.4), both being slightly faster than Non-corresponding trials (*M*=358; *SD*=66.7). Figure 4.2b clearly shows the minor differences between mean RTs for Corresponding, Non-corresponding, and Neutral conditions across objects. Error for the Non-corresponding trials was slightly more than for Corresponding and Neutral. Mean RTs for trials presented to left of screen (*M*=356;*SD*=67.1) differed little from RTs for right screen targets (*M*=357;*SD*=57.5).

[2] Note that throughout this thesis, experimental data will initially be treated to the same iterative process where any RTs greater than (3 standard deviations from the condition mean, plus the condition mean) will be removed as outliers. Prior to this process, any reaction times less than 200 ms will be removed as anticipations, as will RTs greater than an upper limit appropriate for a particular experiment, This upper limit process simply shortens the iterative process and is shown to produce almost identical results.

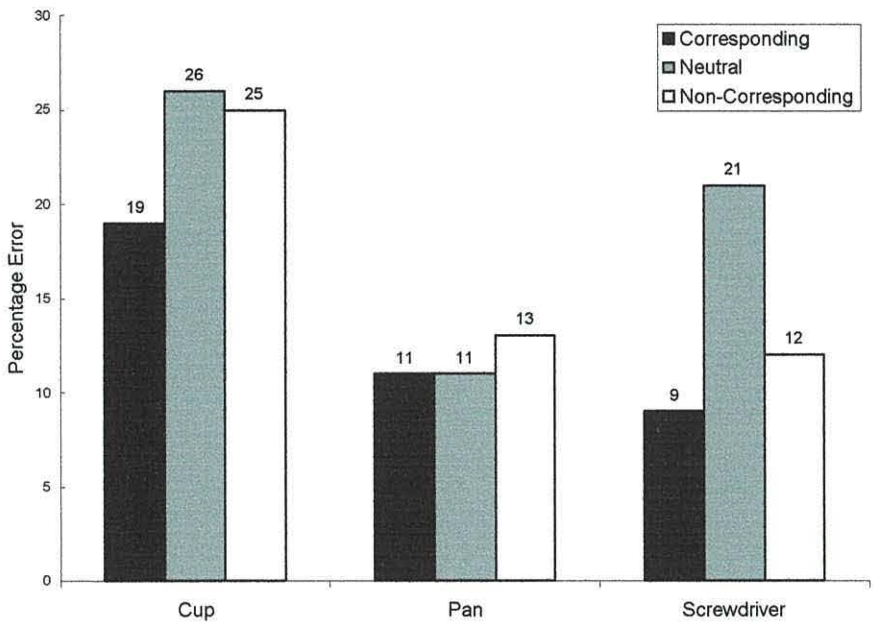


Figure 4.2a. Showing the mean error percentage across objects.

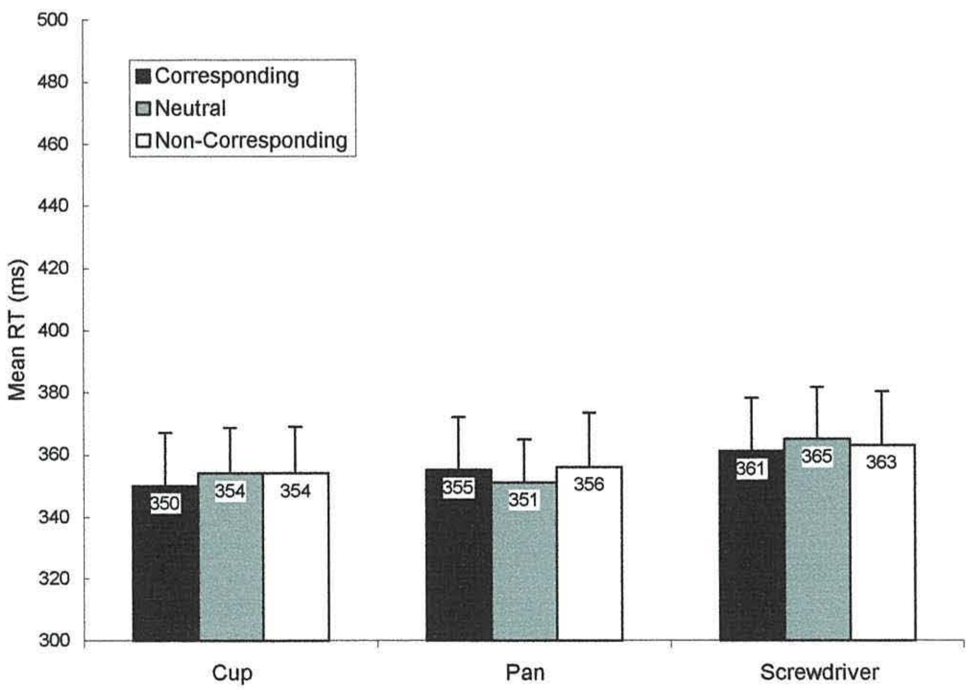


Figure 4.2b Showing mean reaction times by Object and Correspondence. Error bars represent the standard error of the mean for each experimental condition shown.

Results were further investigated through a three-way analysis of variance, with the *WS* factors of Correspondence, Object, and target Side. Tests showed a significant main effect of Object; overall RTs to the cup (*M*=353; *SD*=63.7) being 10ms faster than to the screwdriver (*M*=363; *SD*=64.5); $F(2,14)=10.54$, $p=0.002$. There were no other significant main effects or interactions.

Overall trial response (reaction time plus movement time) followed a similar non-significant pattern with Corresponding (*M*=667; *SD*=142.1), neutral (*M*=679; *SD*=140.1), and Non-corresponding (*M*=669; *SD*=139.6). Further analysis was not considered necessary.

The results of this experiment were disappointing. Although this experiment supplied the first set of exploratory data of this study, it yielded little in the way of showing that affordance (as defined earlier) had any observable effect on response performance, or if it did, then effects probably could not be measured within this sort of experimental environment. However, one of the main purposes of this study was to determine under what conditions effects of affordance-based correspondence could be achieved. As it was, the results raised more questions than answers.

Quite conceivably, images of objects do not elicit the same kind of reaction as might be expected with real objects. Perhaps the whole experimental environment was too artificial and not ecologically convincing enough to produce what might be a quite subtle effect.

Another consideration might lie in the task relationship between object and actor; for example, there was no intention or requirement for the participant to actually perform the act of picking up the cup or other object, but merely to touch the screen as a response. Furthermore, the high number and repetitiveness of trials may have caused some type of habituation behaviour within the perceiver inasmuch as the onset event alone may have elicited an almost reflexive hand response, without the participant actually processing any part of the presented stimulus object.

In particular, it was considered that the most likely explanation was simply that the observer was not processing the image to a necessary degree, that is, was not attending to the physical affordance of the object. In the experiment, the observers' only goal was to respond by touching the screen image with either the left or right hand, dependant upon which side the image appeared. Perhaps the effect of the physical affordance had no time to be processed during this speeded task, and response mechanisms were not being captured by the affordance, but by the image onset itself. If this was the case then attention needed to be drawn less to the onset event and more to the stimulus object.

Along the same line of argument, the idea that the effect of an irrelevant element of a stimulus set on RT performance may take time to develop, has been previously suggested by Kornblum et al., (1999). In their task, correspondence effects between irrelevant aspects of stimulus attributes (Stroop task) only became evident when a temporal delay existed within the stimulus presentation task. Without this delay, the Kornblum task showed a null effect of correspondence. Whether this is the case here remains to be investigated in the following experiment.

4.2. Experiment 2 – Increasing Exposure to the Object

4.2.1. Introduction

Following the inconclusive results of Experiment 1, it was considered necessary to somehow expand the available time for stimulus object processing, prior to making the speeded response. In the absence of any instruction or intention to utilise the displayed object, its only salience to the observer was in terms of the instruction 'touch the object when it appears', rather than somehow using or interacting with the object on a more functional level, dependant on it's perceived utility.

Most object related actions have some meaning or salience to an actor, that is, they are motivated. They either result from an intention to perform an object related task, or have some other more abstract actor-object associations, perhaps motivated by interest or curiosity. Although the purpose of the experiment was to investigate any 'automatic' effect of object affordance, the artificial environment, where salience and interaction, on a functional level, are absent, coupled with the repetition of the experimental task, may have served to reduce the sensitivity of the object-action representational system, in a way analogous to how one may eventually fail to notice a repetitive or monotonous sound, until it stops.

Experiment 2 utilized a different methodology to overcome possible confounds of Experiment 1. A discrimination task was introduced, requiring participants to make speeded choice key press responses to presented objects. By giving participants some kind of object oriented discrimination task, albeit similarly irrelevant to the objects function, it was thought to a) better involve the respondent in the object-related task; b) extend the subject-object exposure, prior to response selection; and c) increase the mean reaction time, thereby giving latitude to any effect/s that may be more 'latent', in their expression.

4.2.2. Method

Participants

A fresh sample of eight undergraduate students (all registered as major psychology students with the University of Wales, Bangor) took part in this study; each receiving one course credit for their participation. All participants reported having normal or corrected to normal vision, were right-handed, and naive to the purpose of the study.

Apparatus/Stimuli

Stimuli consisted of those 2D pictures used in Experiment 1, with the addition of a coffee-pot), each offering three orientations of affordance (neutral, left, or right). Equipment used was the same as in Experiment 1. Locations of presented objects randomly alternated (between trials) between Upper or Lower screen ports. The Upper port was set to approximately three cm above screen centre and the Lower port approximately 3 centimetres below screen centre.

Design

The experiment comprised of two identical blocks of four hundred trials each based around a 2 x 4 x 3 within-subjects design. The within-subjects factors were of; a) target Position with two levels (either Upper or Lower); b) target Object with four levels (Pan, Cup and Saucer, Screwdriver, or Coffee-pot); and c) target Orientation with three levels (Left, Right, or Neutral). There were thus twenty-four randomly presented and equiprobable conditions giving an average of thirty-three trials per stimulus over the two blocks. The dependant variable in all cases was reaction time. The experimental task was to make a speeded response to the stimulus image, after determining whether the image appeared in an Upper or Lower screen position. The task was not overly difficult, but did require a good degree of attention and judgement. In order to counterbalance for any effect of natural SR mappings, for example Up = Left; half of the participants were required to respond with the Left hand to an Upper image and with the Right hand to a Lower image, the other half using the reverse mapping.

Procedure

The experimental procedure was identical to that of Experiment 1, with the exception that the target image (random object and orientation) would either appear in an Upper or Lower screen position.

4.2.3. Results

Error data - Data was initially analysed for response error and timeouts. Errors are defined as reaching with the incorrect hand, and timeouts as RTs greater than 1500 ms. These exclusions accounted for 12% of all trials, the spread, excluding neutrals, outlined in Table 4.2 below.

Table 4.2 Frequency and percentage of errors and timeouts averaged over subjects. The table shows values for each of the stimulus objects, for both corresponding and non-corresponding conditions. The correspondence is between the Left/Right Orientation of the object, and the responding Left/Right hand.

	Stimulus Object							
	Tea cup		Fry pan		Coffee Pot		Screwdriver	
	Corr	*Non*	*Corr*	*Non*	*Corr*	*Non*	*Corr*	*Non*
Errors	34	41	79	100	25	57	23	119
Timeouts	7	5	22	19	9	18	8	27
Total Excluded	41	46	101	119	34	75	31	146
Percent %	0.8	0.7	1.6	1.8	0.5	1.1	0.4	2.3

It is clear from Table 4.2 above, that all objects attracted many more response errors and timeouts in the Non-corresponding as opposed to the Corresponding conditions.

With the exception of the cup and pan, the number of time-outs (> 1500 ms) was also considerably greater for the Non-corresponding trials. These data are shown in Figure 4.3 on the following page.

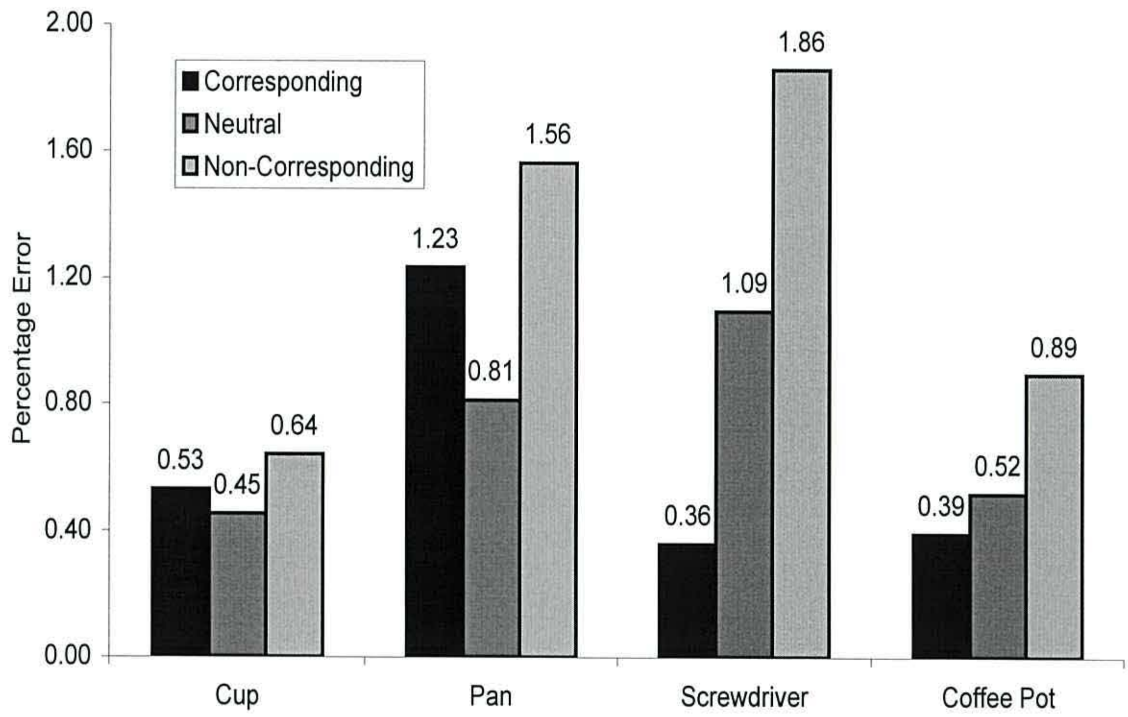


Figure 4.3. Overall percentage of errors, by Correspondence and Object, averaged over subjects. Error percentages may differ from those in Table 4.2 because a) errors for Neutral trials are not included in the table, and b)Table 4.2, percentages in this chart do not include timeouts, whereas the table percentages do.

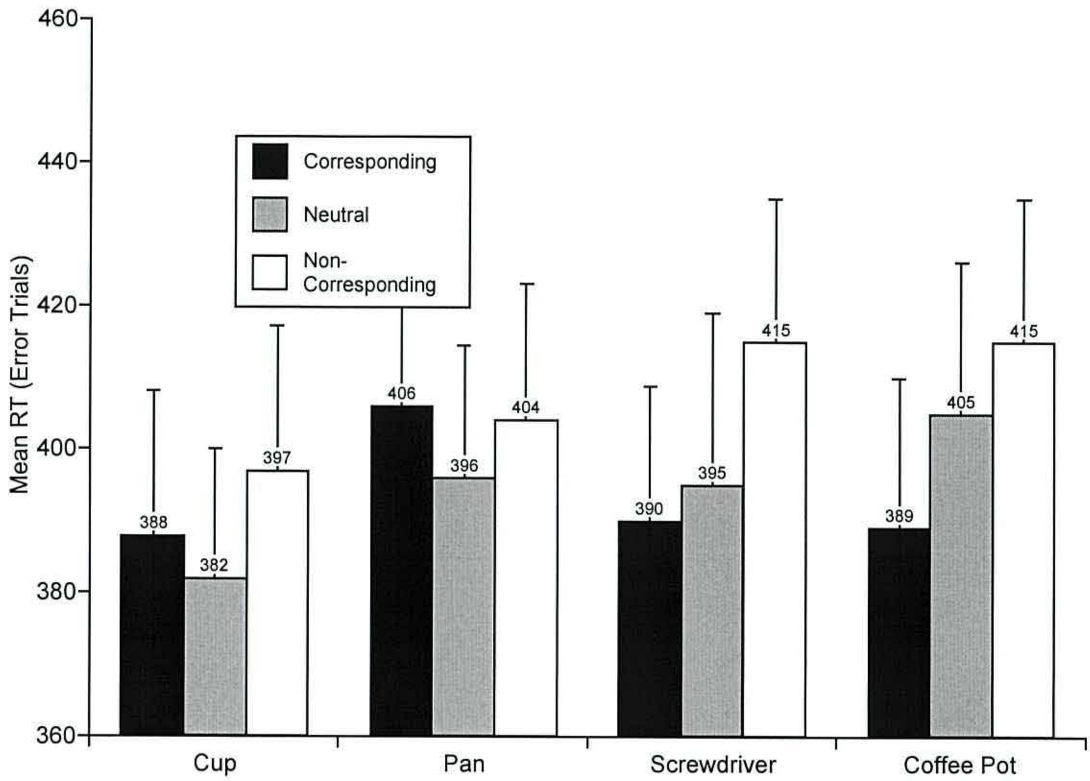


Figure 4.4. Mean RTs for error condition across Correspondence and Object.

With the exception of the pan, Figure 4.4 also demonstrates the error performance advantage for Corresponding over Non-Corresponding trials. Further error analysis using a three-way ANOVA investigating Correspondence, target Position, and Object, supported this initial observation of greater error frequency (4.9%) for Non-corresponding trials, compared to Corresponding (2.5%), and Neutral (2.8%). Significant main effects of Correspondence, $F(2,14)=23.48, p=.001$, and Object $F(3,21)=22.83$, $p=.001$ were obtained, such that the Pan (3.6% errors) and Screwdriver (3.3% errors) attracted almost twice the number of errors as the Cup (1.6% errors) and the Coffee pot (1.8% errors). Target

Position showed no main effect *F*(1,7)=3.49, *p*=104. There was however, a significant interaction between Object and Correspondence, *F*(6,42)=5.86, *p*<.001, mainly due to the highly increased error rate for the Corresponding compared to the Non-corresponding screwdriver (23 against 119 errors respectively). Further interactions between the Object and Position *F*(3,21) = 16.32, *p*<.001; and a three-way interaction between Object, Correspondence, and Position was also shown, *F*(6,42) = 20.60, *p*<.001.

Further analysis using paired t-tests showed that for Upper positions the effect of Correspondence was significantly larger for the screwdriver and the Coffee-pot, *t* (7)=2.4, *p*=.04 and *t* (7)=3.2, *p*=.01, respectively. In the Lower positions the only significant effect of Correspondence was for the Screwdriver, *t* (7)=4.0, *p*=.005. These results indicate that the Screwdriver is the most potent of the four objects, eliciting more errors for Non-corresponding against Corresponding trials for both Lower and Upper positions. This correlation between error frequency and Correspondence suggests evidence of object evoked action, showing that Correspondence between object Orientation and responding hand results in significant improvements in response efficiency, over Non-corresponding mappings.

Total Response time data - Response errors and time-outs were removed from the data set. A further iterative process (described earlier) excluded a further 2% of all trials. Approximately 14% of all trials were consequently removed from the data set. Initial analysis of the overall response times (reaction time plus movement time) showed a considerable advantage for Corresponding (M=1034;SD=168.0) over Non-corresponding trials (M=1083;SD=172.7). Mean response times for the Neutral condition were more centrally positioned with a mean of 1062 ms (SD=191.0). Overall means for Corresponding, Non-corresponding, and Neutral trials are illustrated in Figure 4.5, below.

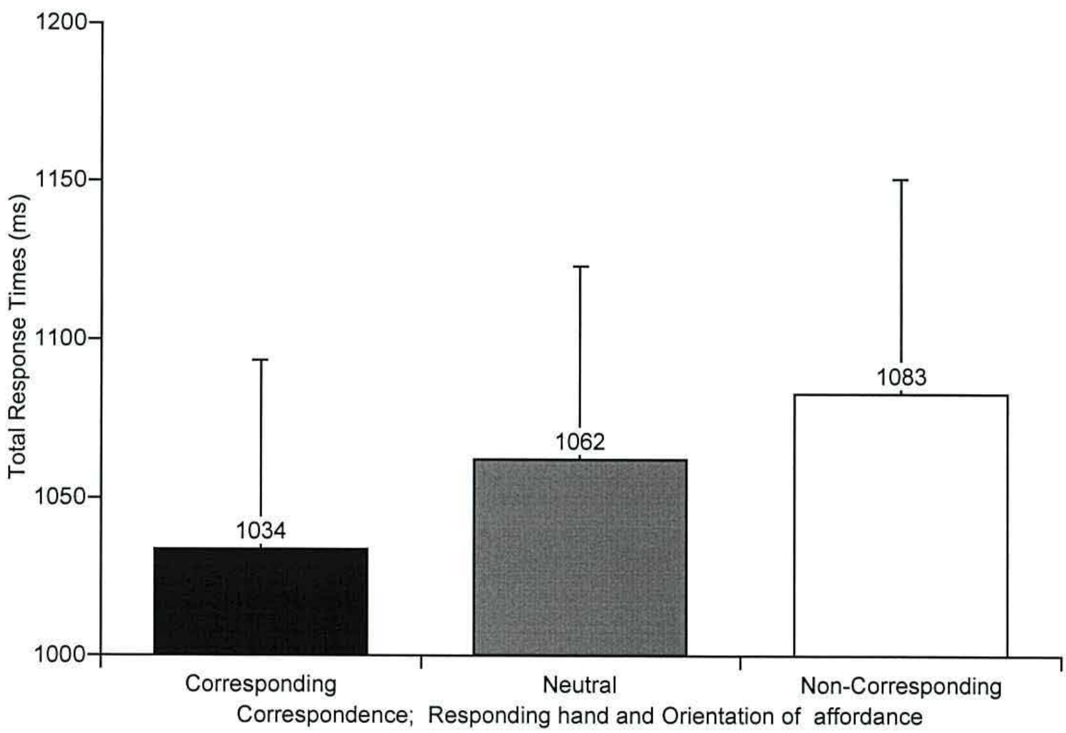


Figure 4.5. Mean total response times to objects by hand/affordance correspondence. Response time includes reaction time and movement time. Error bars represent standard error of the mean.

Figure 4.5 shows a 50 ms. benefit in overall response performance for Corresponding over Non-corresponding trials. Not only are the response times for these trials faster than Non-corresponding or Neutral, but also standard error is reduced by 6 ms. Further analysis of these overall response times, shows considerable difference in correspondence effects between the objects. The response time advantage for Corresponding over Non-corresponding trials, between objects is 4, 40, 127, and 26 milliseconds for the cup, pan, screwdriver, and coffee-pot respectively. The actual means are described in Figure 4.6 below.

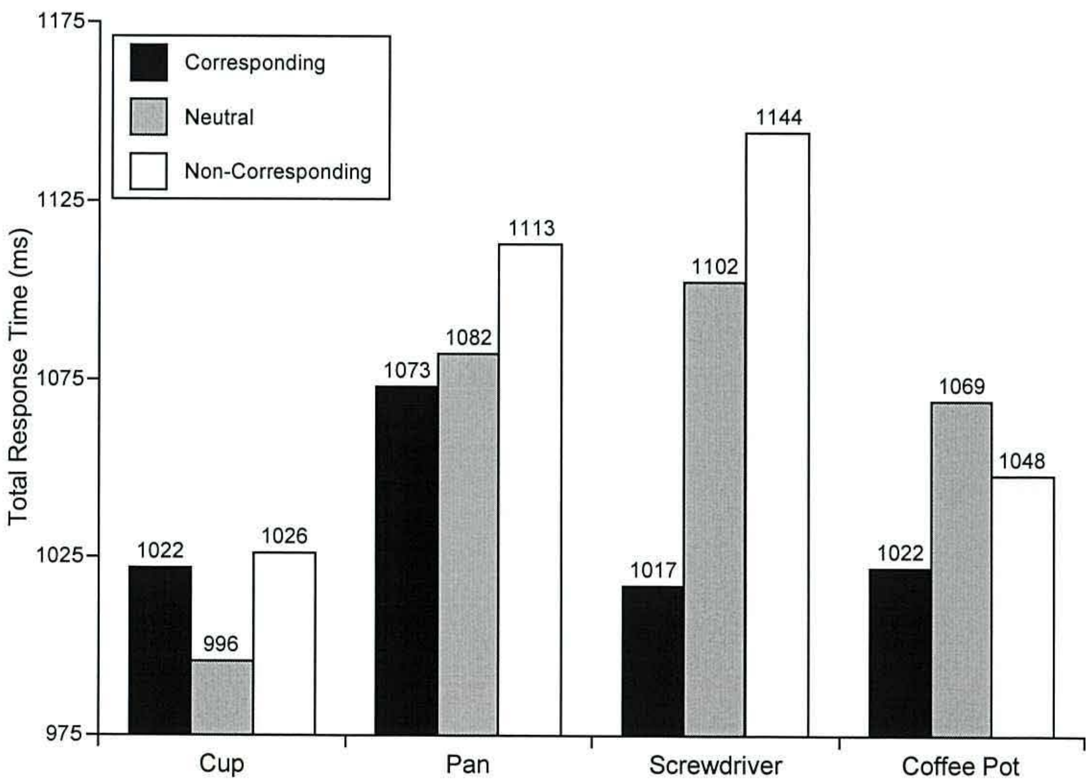


Figure 4.6. Between objects: Mean total response times for Correspondence over Objects.

Response data was examined using a two-way, within-subjects, analysis of variance investigating the factors of Correspondence and Object. Results showed a significant main effect of Correspondence, $F(2,14)=7.69$, $p=.006$. There was also a significant main effect for Object $F(3,21)=16.54$, $p=.001$; and a significant interaction between Object and Correspondence $F(6,42)=10.93$, $p=.001$. Further between-object analysis using paired t-tests showed the correspondence effects for the screwdriver to be significant at: $t = -5.71$, $df = 7$, $p=0.001$. Both the pan and the coffee pot neared significance at $t = -2.22$, $df = 7$, $p=.062$ and $t = -2.34$, $df = 7$, $p=.052$ respectively. The effects for the cup were minor ($d = 4$ ms), and non-significant [$t<1$, $df=7$, *ns*].

Note that the analysis thus far relates to the total response time, which comprises not only reaction time, but also movement time. The analysis now looks at the two areas independent from each other. For the purposes of these experiments, reaction time alone is considered the more reliable indicator of the presence of any affordance-evoked effects of Correspondence, movement time being affected by many potentially confounding factors.

Reaction time data – (the time taken to lift the responding hand from the response effector) was extracted from the data file and analysed using the same procedures as for total response time. A similar pattern of results was obtained showing clear benefits in performance for

Corresponding trials over all objects, with the exception of the cup; see Figure 4.7 below.

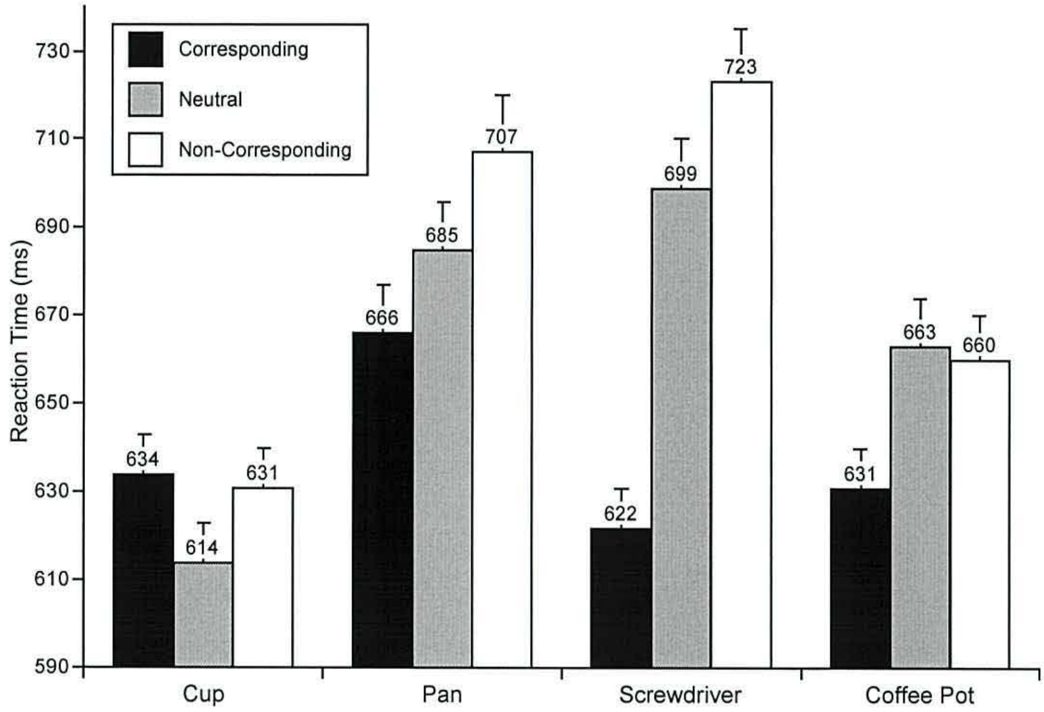


Figure 4.7. Mean reaction times to objects by hand/affordance correspondence. Error bars represent standard error of mean.

Figure 4.7 clearly shows the performance advantage of Corresponding over Non-corresponding trials for three of the four stimulus objects. Only the cup failed to provide a Correspondence effect. Collapsed over Object, Corresponding trials are seen to attract faster (by 40 ms) responses (M = 638; SD = 212.1) than Non-corresponding (M = 678; SD = 235.2); with Neutral trials (those with no obvious physical affordance, lying somewhere in between (*M* = 664;*SD* = 228). There were only minor differences in response times due to mapping of the Upper or Lower target to either left or right hand. For those trials presented to the Upper screen, responses were 23 ms faster overall (*M* = 648;*SD* = 220.5), than for objects to the Lower screen (*M* = 671;*SD* = 229.3). Correspondence effects (collapsed over Objects) were smaller for images presented to the Upper position (32 ms), than the Lower position (48 ms). Table 4.3 below is added to show the association that is now becoming evident between increased exposure duration, and the magnitude of Correspondence effects; these Correspondence effects being defined as faster and more accurate responding for Corresponding over Non-Corresponding conditions.

Table 4.3 Showing general response performance collapsed over all factors except corresponding and non-corresponding conditions.

Performance Measure	Corresponding		Non-corresponding	
	n	%	n	%
Timeouts (> 1500 ms)	45	0.7	69	1.1
Response Errors	161	2.5	317	4.9
Mean Reaction Time (ms)	638	--	680	--
Overall Standard Dev.	112	--	127	--

Reaction time data was processed using a three-way, within-subjects repeated-measures ANOVA investigating the effects of

Correspondence, Object, and Position (Upper v. Lower stimulus presentation). Results showed no main effect for this target Position $F(2,14) < 1$, *ns*, with means of 671 and 648 ms for responses to Upper and Lower targets respectively. There was however, a significant main effect of Correspondence, $F(2,14) = 12.05$, $p=.001$; a significant main effect for Object, $F(3,21) = 22.11$, $p=.000$; and a significant interaction for Object by Correspondence $F(6,42)=9.30$, $p=.001$.

Further post hoc analysis (paired t-tests) identified the coffee-pot, the pan, and the screwdriver images, as attracting significantly faster responses for Corresponding over Non-corresponding trials; coffee-pot; $t = -2.68$, $df=7$, $p=.031$; pan; $t=-.289$, $df=7$, $p=.023$; and screwdriver; $t=-5.44$, $df=7$, $p=.001$.

Movement time data - The analysis of movement time, that is, the time taken from lifting the response button to touching the screen object was subject to the same treatment as reaction time. Although the Participant's' response preparation stage (reflected by RT) is considered the 'fertile' ground on which to reflect any affordance effect, it was also considered important to monitor any residual effect on movement times.

It is less clear that the effects of Correspondence over Non-correspondence carry through to affect movement times in a similar trend to that of reaction time. The screwdriver attracted the best effects (d = 30 ms); less so for the cup (d = 9 ms), with little effect for the remaining two items. Movement time performance benefits amount to 9, -5, 30, and –2 ms. for the cup, pan, screwdriver, and pot respectively. A three-way analysis of variance (WS) again shows a significant main effect for Object, $F(3,21) = 5.56$, $p=.006$, but not for Correspondence, $F(2,14)<1$,ns. However, a significant interaction between Object and Correspondence; $F(6,42) = 3.09$, $p=.013$ was also shown.

Post hoc t-tests revealed that movement times in response to the screwdriver where significantly faster for Corresponding over Non-corresponding trials; $t = -3.09$, $df = 7$, $p=.017$. There were no significant differences in MTs for Correspondence for any of the other objects.

4.2.4. Discussion

The purpose of this experiment was to determine whether, and under what conditions, pictures of familiar and everyday objects might affect speeded response performance, based on their perceived affordability for action. More specifically, the purpose was to determine whether any measurable effect of affordance might be related to the degree of exposure (or perhaps attention) given by the observer, to the object, prior to action. In this experiment, images of objects were oriented to offer or afford, either a left or right handed action to the observer, the observer being required to make a judgement about the 'Upper or Lower' position of an object, and depending on that judgement, executing a speeded left or right hand, touch-screen response. In corresponding trials, the responding hand was compatible with the physical object affordance, whereas, in non-corresponding trials, this mapping was reversed.

The design of this experiment incorporated a fairly demanding spatial discrimination task, which ensured that the observer fully attended to the object, this attendance providing a salient observer-object relationship, during which the effect of hand /object correspondence could manifest itself; and/or some kind of temporal 'space' within which, this effect might need to build.

The hypothesis that these images of objects would produce some form of motor priming effect for the best-afforded action appears to be fully supported by the results. All objects, except for the cup, provided significant improvements in response performance for corresponding over non-corresponding trials. In addition, the incidence of response errors was greatly increased in situations of Non-correspondence.

The results obtained in this experiment, are in accordance with those of Tucker & Ellis (1998). The present correspondence effects however are significantly larger, and this could be due to the Tucker & Ellis participants having to respond with a key-press, rather than towards the object, and/or having less 'object processing' time (Tucker & Ellis overall mean RTs are approximately fifty milliseconds faster than those obtained here). One issue arising from the present results relates to the fact that some objects produce better correspondence effects than others; to be precise, if the obtained results are attributable to correspondence effect through affordance, then why should one object produce much stronger effects than another. One answer may be that the amount or strength of affordance must depend on the familiarity of the observer, with the object. However, if that is the case then why should the screwdriver have such a large performance advantage (101 ms) for Corresponding over Non-corresponding trials, whilst the cup had a negative three milliseconds. As to whether a screwdriver should afford action so strongly, compared to the much more familiar and everyday simple cup, is unknown.

A strong possibility exists is that the effects are not due to affordance, but to some other attentional or perceptual phenomenon; in addition there remains the pure Gibsonian view that the object affords action, based purely on its physical or perceptual characteristics, and not necessarily on its familiarity to the observer. The screwdriver certainly has an inviting physical affordance for picking up, but this wouldn't explain the magnitude of the correspondence effect obtained for the almost symmetrical and dull coffee pot. So, why didn't the cup produce evidence of affordance-evoked action? There are many possible answers; it is a delicate object, and speeded responses towards delicate objects are not appropriate. The cup was on a saucer and this might have evoked a left *and* right hand action; perhaps because a teacup's contents are normally hot, or perhaps because we might knock it over or spill it; even possibly because it's not our favourite cup. These examples serve to highlight the difficulty this type of experiment has in controlling for between-subject salience and familiarity of stimulus objects. Perhaps future experiments using such images may reveal more varying and subtle effects within affordance based object-action relationships.

There remains another factor that may be responsible for the differences in response times between objects; the screwdriver (best effect) was a more difficult object with which to make the up-down discrimination judgement, thus leaving more time for object processing. The mean overall response time for the cup was a full fifty-one milliseconds faster than the screwdriver, falling exactly within the mean range of RTs that Tucker & Ellis observed with their comparatively minor compatibility effects. In fact, the cup attracted the fastest responses by twenty-five milliseconds over the next fastest object RT. Therefore, are the effects of affordance-based correspondence a function of length of object exposure? Based on these results, it certainly seems so. These questions relating to time course, within the affordance based SR relationship, are addressed in the following chapter.

Another issue raised in the present experiment is why the objects afforded any action at all, given that their affordance was irrelevant to the task in hand. In general, the present results suggest that objects *automatically* afford action, and that the very act of perceiving an object has the effect of priming the motor system to engage with that object. Where an object better offers an action, i.e. in this case, through its perceived ease of grasping, via orientation, then it better affords that action over other possible object-related actions. This affordance primes the motor system for affordance-compatible action. In that sense, this experiment lends support to the idea that objects can automatically evoke mental representations for action, based on their affordance, manipulated through object orientation. Furthermore, the present results accentuate the importance of exposure latency in order for the affordance-based effects to be observed. Because of this study, various questions arise such as; how long does the perceiver need to be exposed to the 'action-affording' object before any correspondence effects emerge; what is the basis for these effects, and how long do these effects remain active? These issues are approached in the following chapters.

Chapter 5

5. Timecourse and Specificity of Response Activation

5.1. Introduction

The findings of Experiment 2, along with those of Tucker & Ellis (1998), carry interesting and important implications for understanding how the organisms' perceptuo-motor system processes and utilises visual information relating to objects in the environment. It was shown in Experiment 2 that object affordances can bias response performance in favour of an afforded action, even when these affordances are irrelevant to a task. What is not clear is exactly how long the effects of facilitation might last, and whether there exists any optimal S-R configuration that might fully reveal the 'life-cycle' of the S-R codes involved. In addition, can the nature of these activated responses be more precisely defined?

Tucker and Ellis (1998) interpreted *their* compatibility effects as lending support for the idea that "certain action related information, in this case, the hand most suited to grasp the object, is represented automatically when the object is viewed in peri-personal space" (p.836). Such a conclusion promotes an account of action specificity from visual affordances: that is, the visual affordances of an object potentiate the specific motor acts which are best suited for manipulating and interacting with the target object.

Within this chapter, these issues are explored by using a methodology that differs in two major ways from the one used previously. Firstly, it allows precise timing and manipulation of object presentation prior to a subject's response. This makes possible monitoring and control of any temporal factor within the SR relationship that may be necessary to elicit effects attributable to object affordance. Secondly, in the Tucker & Ellis experiment (as in Experiments 1 and 2 here), an attribute of the affording object, i.e. its orientation, was always relevant for response. Recall that the previous task was to determine the relative location of an object (upper or lower), or in the case of the Tucker & Ellis (1998) study, the vertical orientation of the affording object (upright or inverted). Here, the question of whether these same object affordances evoke action even when the objects themselves are totally irrelevant to current goals, is examined. This design was chosen to better demonstrate the automaticity of any effect in the absence of object-observer salience.

In this chapter, three experiments investigate the issue of action specificity, and time course, from visual affordances. Do the visual affordances of an object potentiate a specific response code for the hand or limb most suited to respond to the affordance; or do they activate 'more abstract' spatial codes, which may potentiate a wide variety of responses to the afforded side of space?

In the first experiment of this chapter (Experiment 3), the objective is to replicate the previously found correspondence effects using a method that separates presentation of an object affordance from presentation of an imperative target. In this experiment, an image of a familiar graspable object is presented as a prime display. The prime object has a handle oriented towards the left or right, but is totally irrelevant to an imperative task of executing a left or right hand button press dependant on target shape. After a variable stimulus onset asynchrony (SOA), a target, requiring a left or right key-press response is superimposed onto the centre of the object. Reaction time (RT) to the target is measured as a function of correspondence between the target response side and the orientation of the prime handle, and as a function of stimulus onset asynchrony (SOA) between prime and target. This method allows measurement of the timecourse of response activation generated by the irrelevant prime.

5.1.1. Experiment 3 Method

Participants

Eight undergraduate students took part in this experiment; all were registered as major psychology students at the University of Wales, Bangor. All were right handed (self -report), and had normal or corrected to normal vision. Participants were naive to the purpose of the study. Each received one course credit for participation.

Apparatus and Stimuli

On each trial there appeared an image of a 'prime' object; and a small visual target (I—IIII or IIII—I) symbolising either a Left or Right response (assignments counterbalanced across participants). The set of possible primes consisted of four images of a frying pan, each image showing a particular orientation of the handle (see Figure 5.1): the handle could appear either oriented to the left or right, at an apparent depth either toward or away from the viewer. The orientation and depth of the handle simulated an apparent affordance for grasping with either left or right hand. In addition, a fifth neutral prime display presented the handle oriented along the midline. At a viewing distance of 50 cm., these images subtended 21.7 degrees (horizontal) and 9.2 (vertical) degrees of viewing angle and were presented centrally, in colour upon a white background.

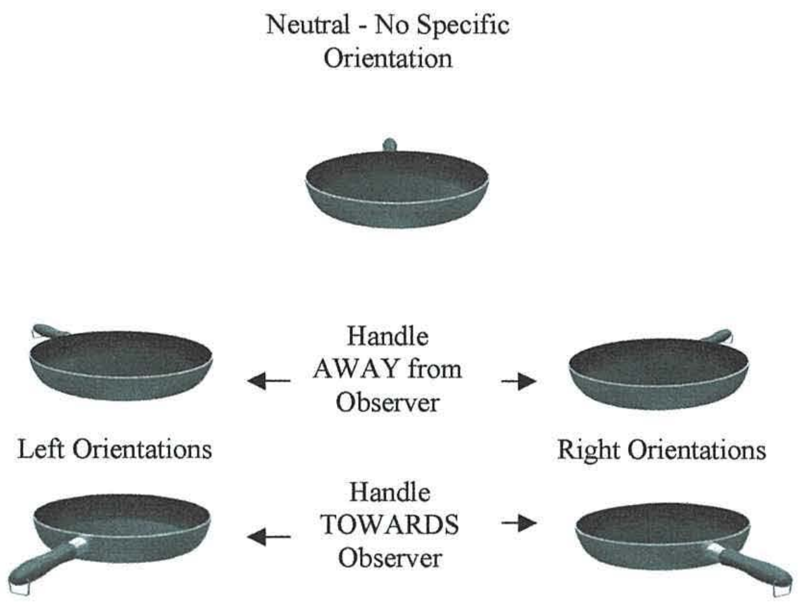


Figure 5.1. Examples of the five priming images showing left and right orientations of handle. These left/right orientations were either Towards (bottom) or Away (top) from the observer. The Neutral position is top of figure. The exact same images were also used in Experiments 3 and 4. A right target would be Corresponding with either of the right oriented objects, as would the left orientations with a left target.

The target appeared in the centre of the display, superimposed over the prime, and subtending a viewing angle of 2.9 (horizontal) and 1.1 (vertical) degrees (viewing distance of 50 cm.). Two alternative targets differed in their arrangements of horizontal and vertical lines (see Figure 5.2). The mapping of the two targets to left and right response keys was counterbalanced between participants. Analyses showed no main effect of this mapping or interactions with Correspondence, and therefore, all reported findings are collapsed over both mappings.

Figure 5.2. Sequence of events for Experiments 3, 4, and 5. Actual figure shows a Corresponding trial for those participants where IIII—I denotes right key response. A case where the handle was pointing away from the participant but still to the right would also be classed as Corresponding.

Prior to the prime and target displays, a central fixation marker consisted of four vertical segments of the same width and size as those in the target, black on a light screen background. All images were presented on a standard Hi-Res 17 inch Apple vision monitor connected to a Power

PC 8500/120 Macintosh computer. The experiment was run on PsyScope version 1.2.2 software (Cohen, MacWhinney, Flatt, and Provost, 1993).

Design

The experiment comprised two blocks of 320 trials each in a within-subject four-factor design. The factors consisted of Response (the response key indicated by the target; Left or Right); Correspondence (the left/right orientation of the handle in the prime in the same or opposite direction to the target response; either Corresponding or Non-Corresponding); Depth (apparent orientation of the handle in the depth plane; either Toward or Away from the viewer); and SOA[1] between the prime and target presentations (0, 400, 800, or 1200 ms). Within each block, were added 80 Neutral prime trials, whose presentation was systematically varied by SOA and Target Response (but not Correspondence or Depth).

Procedure

Participants were positioned sitting down and facing the computer monitor at a face to screen distance of approximately fifty centimetres. The keyboard was placed in front of the monitor and participants were asked to place the index fingers of left and right hands over the respective

[1] Note that the remainder of the experiments in this thesis, with the exception of Experiments 10 and 11, were carried out using a Hi-Res 17 inch Apple vision monitor with a refresh rate of 11.764 ms. This rate corresponded almost exactly with the reported PsyScope SOAs of 400, 800, and 1200 and therefore, in contrast to the later Experiments 10 and 11, timings remain as reported.

response key whilst resting arms on the desk that supported the monitor. Left responses were to be made by depressing key 'z' with a left hand finger; and right responses by depressing of key 'm' with the right hand finger. Instructions to participants were to fixate on the central fixation marker until it was replaced by a target indicating left or right response, then to respond as quickly as possible by pressing the relevant key. Participants were told to ignore any other screen image and to focus at screen centre where fixation and target would appear.

An experimental trial began when the fixation marker was displayed at screen centre for 1500 ms., this marker then being replaced by the prime image. The target, indicating either a left or right side response would then appear superimposed upon the prime image. The onset of the target would vary between 0, 400, 800, or 1200 ms after prime onset. The target and prime would remain visible until receipt of the speeded keyboard response. Feedback tones were given on incorrect trials. Participants received a short practice block of 30 trials before beginning the actual experiment.

5.1.2. Results and Discussion

Response errors accounted for 2.5% of trials. Analysis of response errors showed significantly higher error rates for Non-Corresponding response mappings than Corresponding, $F(1, 7) = 14.67$, $p = .006$, but there were no other main effects or interactions for error data. Mean reaction times

(RTs) were computed for correct trials only. Reaction times greater than 1000 ms were excluded as timeouts as were RTs greater than three standard deviations from the subsequent grand mean. In addition, RTs of less than 200 ms were excluded as anticipations. These exclusions represented 1.9 % of all trials.

The remaining RT data was submitted to a three-way repeated measure ANOVA examining Correspondence, Depth, and SOA; the resulting means are shown in Figure 5.3 below.

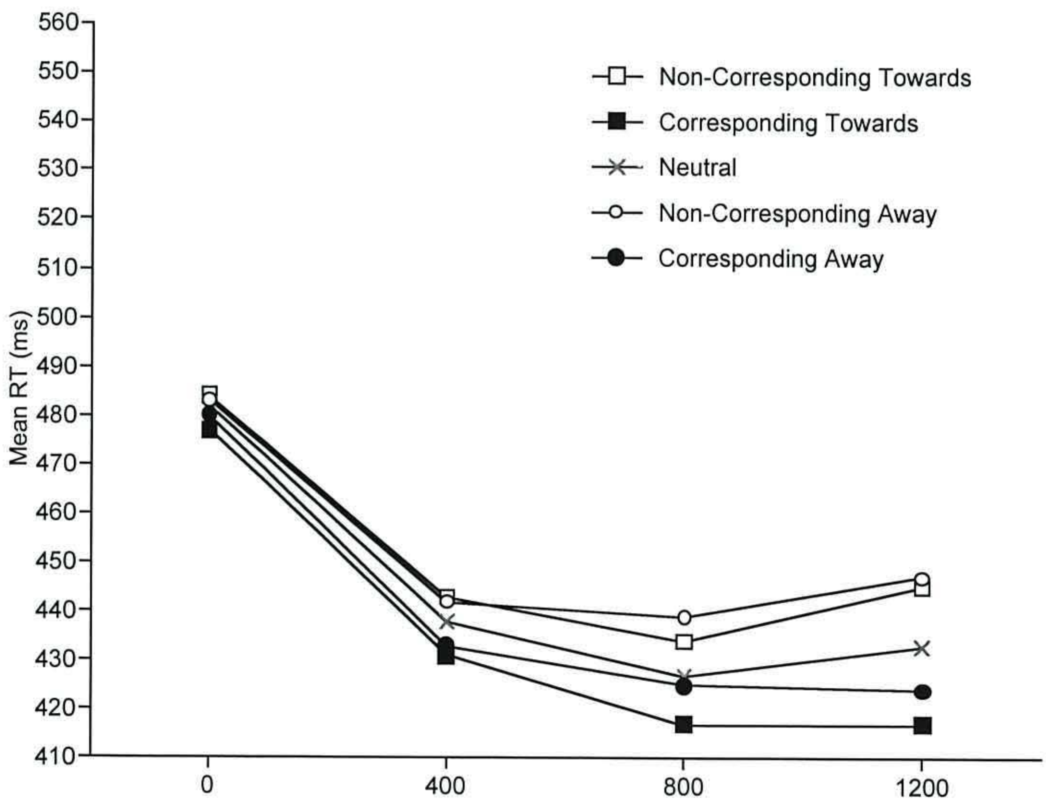


Figure 5.3. Mean reaction times for all orientations of prime object, showing facilitation for Corresponding over Non-Corresponding mappings, grouped by SOA. Those handle orientations Towards the observer (both Corresponding and Non-Corresponding trials) are depicted as squares (solid and open), whilst Away orientations are shown as circles.

Results from the ANOVA showed a significant main effect of Correspondence, such that Corresponding trials were faster than Non-Corresponding, $F(1, 7) = 8.64$, $p=.022$. A highly significant main effect of SOA was also obtained, such that RTs at 0 ms SOA were slowest, as apparent in Figure 5.3; $F(3, 21) = 24.45$, $p= .001$. However, of most interest was a significant interaction between Correspondence and SOA, $F(3, 21) = 4.53$, $p =.013$, such that the benefit for Corresponding over Non-Corresponding trials increased with SOA. There was no significant main effect or interaction involving Depth, that is, whether the handle was apparently towards or away from the observer, and no other significant interactions at an alpha level of .05.

The results (Figure 5.3) showed a significant benefit of Corresponding over Non-Corresponding mappings between the handle Orientation and the Responding hand. In this sense, results from the present experiment replicate those found by Tucker and Ellis (1998), even though the prime object was wholly irrelevant to the response task. It is tempting to suggest that the findings are consistent with the claims of Tucker and Ellis (1998) that objects can evoke specific responses related to their apparent affordances. However, there are several puzzling aspects to the present data, which do not fit easily with this notion. First, the benefits of correspondence between the prime's handle and the responding hand developed gradually over a period of 1200 ms. This pattern of response activation from the irrelevant prime affordance is quite different from irrelevant response activation found in the Simon and Stroop tasks. In Simon-type tasks, response activation from an irrelevant stimulus attribute decays after a much shorter interval of roughly 200, and perhaps around 400 ms in Stroop tasks (Hommel, 1993a; Kornblum, Stevens, Whipple, and Requin, 1999). The results do concur with the findings of the previous chapter, where the benefits of correspondence were somewhat positively correlated to an object's mean response time. Not all automatic behaviours must show the same rapid timecourse; some automatic behaviours may develop only gradually. On the other hand, any adaptive (evolutionary) advantage from the perception of affordances on automatic response would surely lie within the realms of speed and immediacy of effect, rather than in its 'gradual' build up. Thus, the idea of 'building' over time-periods of approximately one second might not comfortably fit the general idea of a functional automaticity, or "direct route" to action (Eimer, Hommel, and Prinz, 1995).

A second potential puzzle is that, if the correspondence effects here are due to action potentiation for the most afforded hand, then it seems reasonable to expect that the response activation would be strongest where the orientation was towards rather than away from the observer. That is, a handle that is apparently rotated towards the hand would offer greater ease of action than the same handle rotated away from the hand. In this case, one might have expected a Depth x Correspondence interaction, such that Toward primes would generate both greater benefits in Corresponding trials, and greater interference in Non-corresponding trials than Away primes. The effects of Depth are considered in more detail in the General Discussion, but for now it is noted that in this experiment, there were no significant effects involving Depth, and further, the general trend was simply that Toward primes produced slightly faster responses than Away, both for Corresponding and Non-Corresponding trials (see Figure 5.3). It is not suggested that these considerations can be telling by themselves, but they do suggest that alternative accounts of the response activation, generated by the prime affordance, are tested and considered.

One alternative interpretation of the results is that, rather than potentiating a specific motor response, the affordance may be generating some form of abstract spatial coding. This is arguably, what happens in Simon tasks, for example. In these tasks, it is clearly not the case that an object appearing on the left side of space simply activates the left hand for response. In Simon tasks, it has been found that the location of an object activates a constellation of spatial response codes, including multiple codings based upon the relative positions of other objects (Roswarski & Proctor, 1996; Danziger, Kingstone, & Ward, 2001), body-centred frames of reference (Hommel, 1993a), and codings based on the location of anticipated effects of the response (Hommel, 1993b).

Although the timecourse observed here suggests that response activation is not directly analogous to Simon-type activation, it may be similarly abstract. For example, a handle oriented towards the left might evoke a generalised "left" code, facilitating all sorts of responses towards the left side of space. This alternative account to action specificity, that the affordance does not potentiate a specific activation of the hand most suited to response, but instead evokes a more abstract spatial-response code, was previously anticipated by Tucker & Ellis (1998).

In a second experiment to test the relative contributions of abstract coding and action specificity, Tucker & Ellis (1998) asked Participants to respond to the target's upright or inverted orientation using two fingers of the same hand, rather than fingers of separate hands as in their first experiment. By an account of action specificity, any effect of action potentiation from the object handle would not differentially activate the fingers of a single hand; however, an abstract spatial code could produce such differential activation (as found e.g. in variants of the Simon task using fingers of the same hand, (Shulman & McConkie, 1973).

In this second experiment, Tucker & Ellis (1998) did not find compatibility effects; i.e., there was no significant interaction of object orientation and side of response. Tucker & Ellis interpreted the elimination of compatibility effects in this experiment as consistent with the idea that the position of the handle activated the ipsilateral hand and not any generalised response code. However, there are several reasons why the results of Tucker & Ellis (1998) Experiment 2 are probably not conclusive.

First, it is a reported absence of abstract coding rather than a positive demonstration of effect. Second, interactions between responding hand and affordance orientation, while not significant, are present as trends which would be consistent with abstract coding; that is, for leftward-oriented objects, left-finger presses were both faster and more accurate than right-finger presses. However, with rightward-oriented objects, the advantage for left-finger over right-finger responses was reduced in the RT measure, and reversed in the error measure. Finally, it can be seen from results obtained here that correspondence effects from object affordances build over time. The prime and target form a single object and so appear simultaneously in Tucker & Ellis (1998); with longer exposure to the prime, (as suggested in Experiment 2), larger correspondence effects may have emerged.

The next Experiment (4) investigates further the possibility that response activation from the appearance of a graspable object produces abstract response coding not tied to a specific hand.

5.2. Experiment 4: Responses with Crossed hands

The aim of Experiment 4 was to examine further whether the facilitation produced by correspondence between the irrelevant prime's orientation and the responding hand, was due to action potentiation for a particular hand evoked by an affordance, as per an action specificity account. In Experiment 3, Correspondence effects could be attributed either to correspondence between the prime handle and the responding hand, or simply between the prime handle and the side of the response. This difference is theoretically significant.

Consider a pan with a handle oriented towards the right. For co-ordinated and effective manipulation of the pan, the handle should preferably be grasped with the right hand, regardless of which hand happens to be initially closer to the handle. If the affordance offered by the right-pointing handle produced an automatic response activation to facilitate functional interaction, this activation should be specific to the right hand. However, if the handle (affordance) produces a more generalised "right" response code, it might then activate the rightmost or closest hand, or any of a number of right spatial codes, which would not necessarily promote interaction with the affordance.

In this experiment, these alternatives are explored by asking participants to respond to the target with their hands crossed. If the results of Experiment 3 were due to a specific hand being primed by the appearance of an affordance, then when hands are crossed, that priming effect should follow the hand most suited to dealing with the object in a useful and economical manner. The factor of Correspondence is still defined with respect to the response side. Because of crossing of hands, Non-Corresponding mappings are now responded to with the (assumed to be) afforded hand, and Corresponding mappings are responded to with the non-afforded hand, as depicted in Figure 5.4 below.

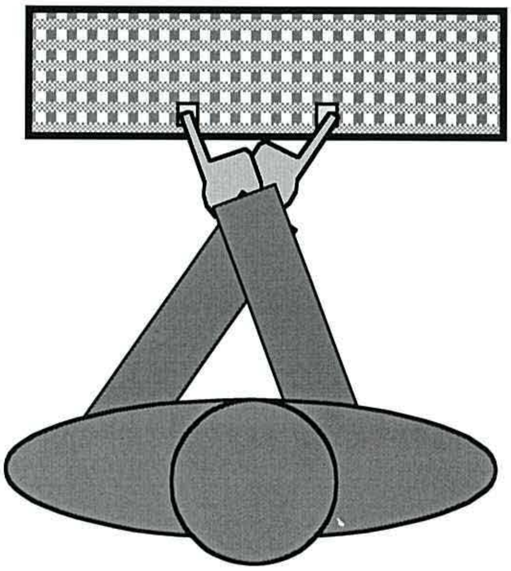


Figure 5.4. Responses to stimuli were exactly as in the previous experiment. A left target is still responded to with a left effector button and vice versa. Correspondence of the trial has not been affected by crossing hands, although hand correspondence has.

Therefore, if the response activation found in Experiment 3 is due to specific activation of the most appropriate hand, then slower response latencies should now be seen for Corresponding than Non-Corresponding trials.

5.2.1. Method

Participants

A fresh sample of eight undergraduate students took part in this experiment; all were registered as major psychology students at the University of Wales, Bangor, and all received one course credit for their participation. All reported having normal or corrected to normal vision, were right handed, and naïve to the purpose of the study.

Apparatus, Stimuli, Design, and Procedure

The method was identical to Experiment 3, with one exception. Participants now crossed their hands, so that left-key responses were made by depressing the left key with the right index finger, and right-key responses made by depressing the right key with the left index finger. Participants were free to choose whether their right hand crossed over the left, or left crossed over right. The design of this experiment (unlike Experiment 3) allowed that Corresponding mappings between orientation of the handle (left or right), and response side (left or right, as indicated by the target), would now be Non-Corresponding mappings between the handle orientation and responding hand. Likewise, Non-Corresponding trials would now be Corresponding mappings of handle orientation and responding hand (crossed-hand effect), as previously used in Simon tasks, (see Nicoletti, Umilta, & Ladavas, 1984; Bradshaw, Willmott, Umilta, Phillips, 1994).

5.2.2. Results and Discussion

Response errors accounted for 2.2% of trials. As in Experiment 3, analysis of response errors again showed higher error rates for Non-Corresponding than Corresponding trials, at only a marginal level $F(1, 7) = 5.3$, $p = .054$. No other main effects or interactions approached significance at the .05 level. Mean RTs were computed for correct trials only. Timeouts and anticipations were defined as in Experiment 3, and excluded from analysis. These exclusions represented 4.5 % of all trials.

As in Experiment 3, the resulting RT data were submitted to three-way repeated measures ANOVA examining Correspondence, Depth, and SOA. Figure 5.5 shows the resulting means when Correspondence is defined only by the side of response, and not by the responding hand. The pattern of data is very similar to that obtained in Experiment 3. There was a clear main effect of Correspondence, showing faster response for Corresponding compared to Non-Corresponding trials, $F(1,7) = 125.06$, $p=.001$. A main effect of SOA was also obtained, such that latency was longest at the zero ms SOA, $F(3, 21) = 10.23$, $p=.001$. Again, there was a significant interaction between Correspondence and SOA, $F(3, 21) = 3.20$, $p=.044$, so that the benefit for Corresponding over Non-Corresponding trials developed gradually, in this case peaking at an SOA of 800 ms. Despite the crossing of hands, these effects replicate all the significant outcomes found in Experiment 3. The results clearly show that an affordance, in this case, perhaps a *right* oriented handle, does not necessarily activate responses for the *right* hand.

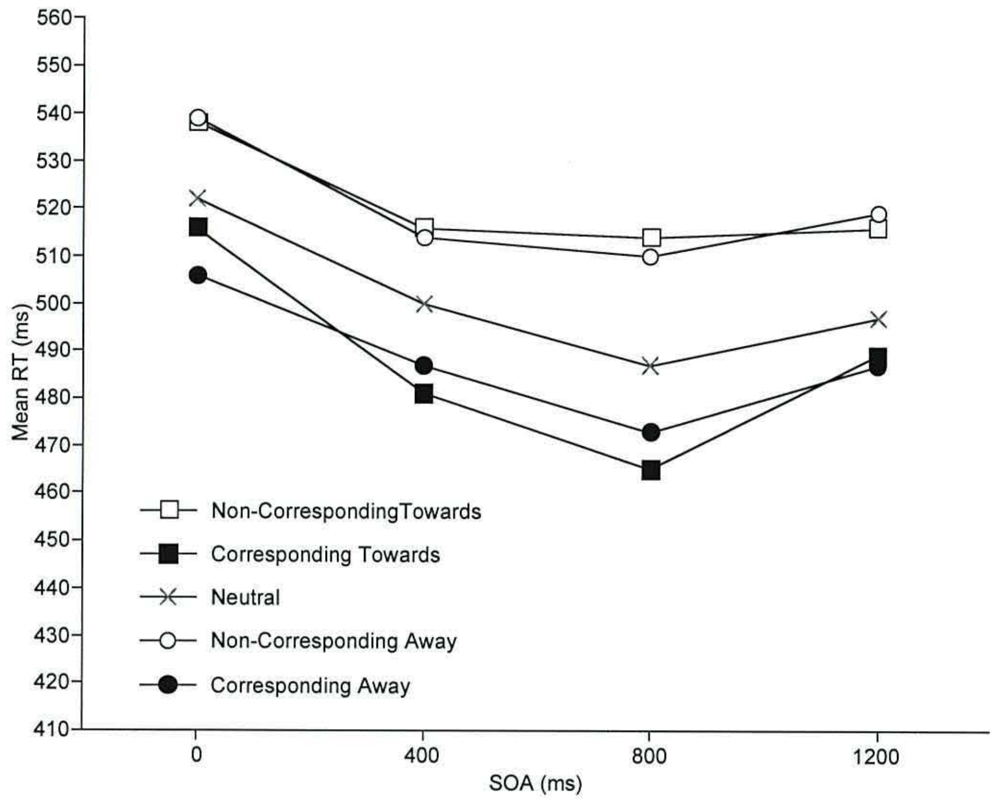


Figure 5.5. Hands crossed. Mean reaction times for all orientations of prime object, showing facilitation for Corresponding over Non-Corresponding mappings, grouped by SOA. Those handle orientations Towards the observer (both Corresponding and Non-Corresponding trials) are depicted as squares (both solid and open), whilst Away orientations are shown as circles.

There were no other main effects or interactions significant at an alpha level of .05. Whereas the Correspondence x SOA x Depth interaction did not quite reach significance $F(3, 21) = 2.87$, $p=.060$, the trend was that handles oriented Toward the observer produced slightly larger Correspondence effects than those pointing Away, especially at

800 ms SOA (see Figure 5.5). Again, detailed consideration of the Depth effects is deferred to the general discussion for this chapter.

Other than the position of the hands, Experiments 3 and 4 used identical stimuli and procedures. It has already been shown that main effects and interactions that were significant in Experiment 3 were significant in Experiment 4, and vice versa. However, a more detailed comparison of results was made between experiments in a four-factor, between-subjects ANOVA examining Hands (Crossed or Uncrossed) x Correspondence x Depth x SOA. As expected, effects that were significant in the separate analyses of Experiments 1 and 2 were also significant in this combined analysis: main effects of Correspondence; $F(1,14) = 68.76$, $p = .001$, and SOA were found $F(3,42) = 33.07$, $p = .001$, as well as a significant interaction of Correspondence and SOA; $F(3,42) = 4.62$, $p = .007$.

There were two other significant interactions, both involving Hands. First, the effect of Correspondence was larger for Crossed than for Uncrossed Hands, as illustrated in Figure 5.6, and indicated by the significant interaction of Correspondence and Hands, $F(1,14) = 10.60$, $p = .006$. This effect may be best understood in light of a second interaction involving Hands. The greater effect of Correspondence in the Crossed condition was not equivalent across all SOAs, as indicated by the three-way interaction of Hands x Correspondence x SOA, $F(3,42) = 3.22$, $p = .032$.

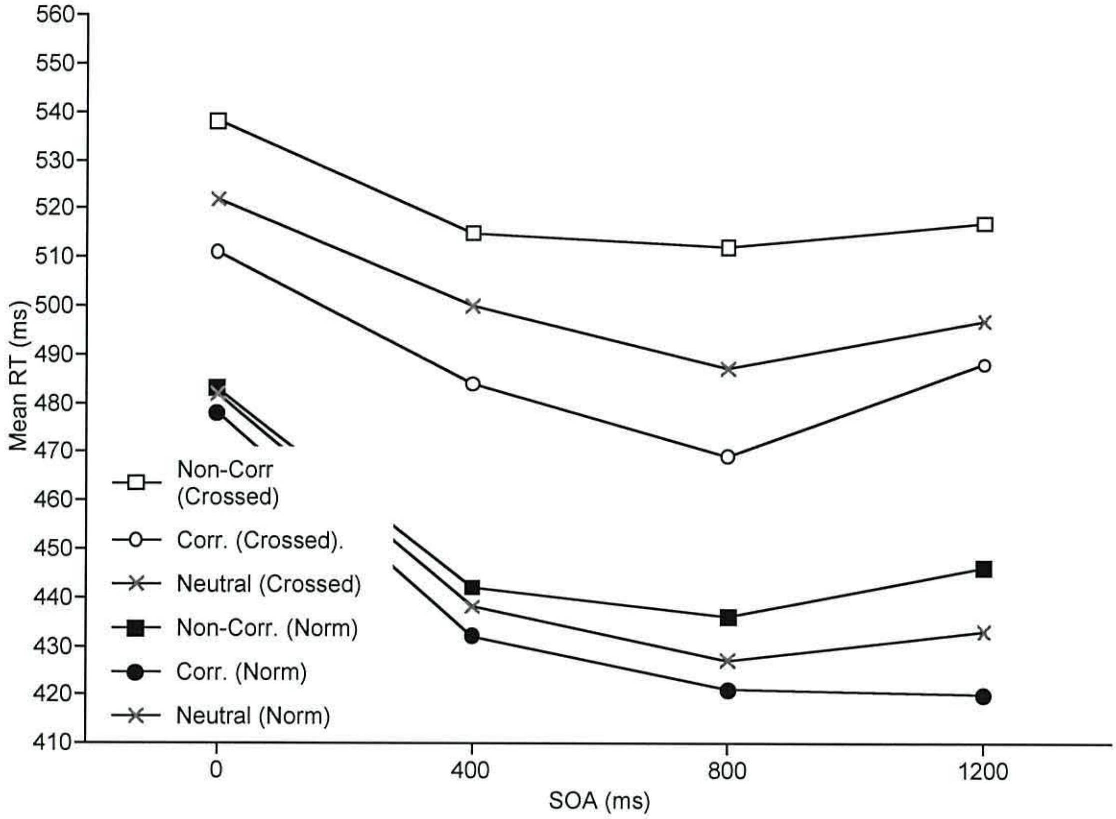


Figure 5.6. Comparison of Mean reaction times for both experiments showing the generally slower RTs for Crossed V. Uncrossed hands, and over all factors of compatibility and SOA.

Post-hoc independent t-tests showed significantly larger effects of Correspondence for Crossed relative to Uncrossed conditions for SOAs of 0, 400, and 800; t (14) = 2.7, p = .017, but not for SOA 1200; t (14) = 1.27, p =. 223. Most obviously this is seen at SOA 0, where there is a significant Correspondence effect for Crossed Hands; t (7) = 4.56, p = .003, but not Uncrossed; t (7) = 1.09, p = .309. It is suggested that the difference in Correspondence effects at SOA 0 may reflect the overall slower RTs in Experiment 4. In both experiments, it is shown that longer delays between presentation of the prime and response tend to produce larger Correspondence effects.

The slower RTs in Experiment 4 may have allowed more time for the influence of the prime, and therefore produced larger effects of Correspondence. If correct, this suggestion may also account for the larger overall Correspondence effect found in Experiment 4 compared to Experiment 3. However, at present, the influence of slower RTs on Correspondence effects is only a tentative suggestion, and in any case, these outcomes do not affect the main conclusions. Beyond the effects described here, the between-experiment analysis showed no other significant effects at an alpha level of .05.

The results from this experiment show clearly that a leftward pointing handle does not necessarily activate responses of the left hand. As in other response compatibility paradigms (e.g. Nicoletti et. al., 1984; Bradshaw et. al., 1994), what seems to be more important is the correspondence between elements of the stimulus set and the actual response location. These results are consistent with the idea of a visual affordance evoking an abstract response code facilitating all kinds of lateralised action, as opposed to potentiating a specific motor response for interacting with the affordance. However, an alternative account of action specificity is possible. The belief so far has been that regardless of starting position, the left hand is best suited for grasping a leftward pointing handle. Instead, it could be the case that any affordance effect may be more 'location' based, that is to say, the hand situated closest to the object's handle may be the hand most or best afforded the action. The next experiment further examines the distinction between action specificity and abstract response coding accounts of visual affordances.

5.3. Experiment 5: Foot-press responses

In an effort to disambiguate the action specificity account from an abstract coding account, a third experiment was devised. The basic idea was to replicate the results of Experiment 3 with an important alteration in method of response. According to an account of abstract response coding, all sorts of lateralised responses should be affected by the correspondence between the stimulus (in this case, the affordance suggested by the prime) and the response effector. In this experiment, participants no longer responded by pressing keys with their left or right hands, but instead, by pressing switches with their left or right feet.

According to an abstract coding account, the form of response is largely immaterial, as long as correspondence between stimulus and response is maintained. If an abstract coding account is correct, then similar effects of Correspondence as in Experiments 3 and 4 should be seen, despite the change of response modality. However, by an action specificity account, while the affordance suggested by the prime object might potentiate a specific response from the most proximal or otherwise most afforded hand, it would be unlikely to afford any specific action for a particular (or indeed any) foot. An action specificity account should therefore predict no effect of Correspondence in this experiment.

5.3.1. Method

Participants

A fresh sample of thirteen undergraduate students took part in this experiment; all were right handed (self report), and had normal or corrected to normal vision. Participants were naive to the purpose of the study. Each received two course credits for participation.

Apparatus and Stimuli

The apparatus and stimuli were identical to that used in the previous experiments with the exception of the introduction of two response effectors in the form of foot switches (placed to left and right feet of Participants). These micro-switches were connected and programmed through the PsyScope button box.

Procedure

The procedure only differed from the previous experiments by way of response effector. Instead of responding to the target by depressing a left or right button with the left or right hand, Participants now responded by pressing a left or right footswitch with the left or right foot, respectively. Participants held their hands in a natural position in their lap. All other aspects of the experiment were identical to those of Experiment 3.

5.3.2. Results and Discussion

Response errors accounted for 2.7% of trials. As in the two previous experiments, analysis of response errors showed higher error rates for Non-Corresponding than Corresponding responses, $F(1,12) = 10.06$, $p = .008$. There were no other main effects or interactions for the error data. Mean RTs were computed for correct trials and processed as in the two previous experiments. Timeouts and anticipations were excluded from the analysis. These exclusions represented 3.3% of all trials.

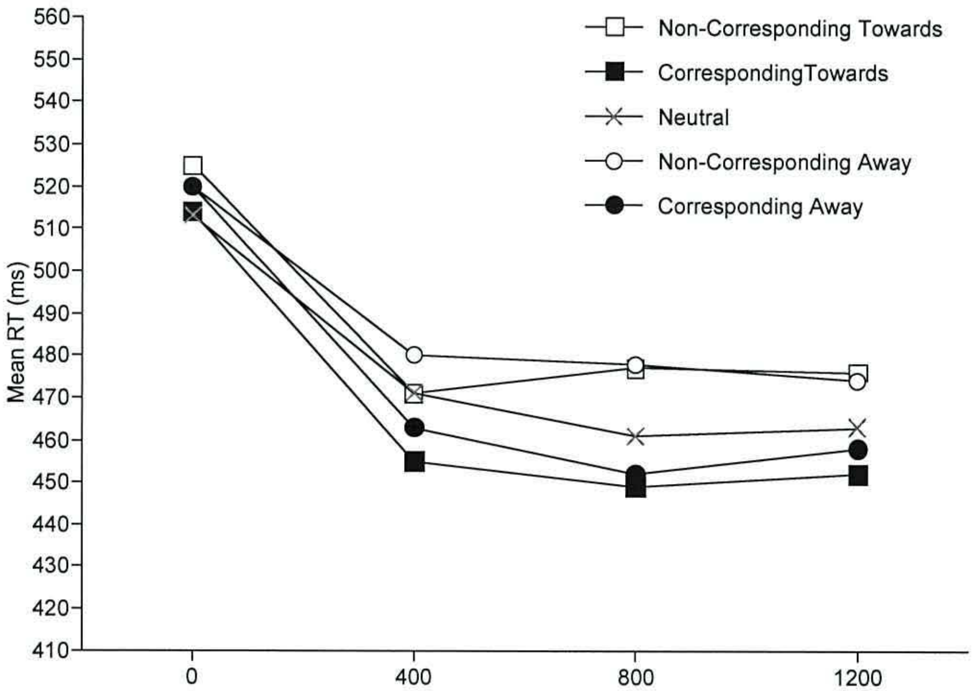


Figure 5.7. Mean reaction times for all orientations of prime object, showing facilitation for Corresponding over Non-Corresponding mappings, grouped by SOA. Those handle orientations Towards the observer (both Corresponding and Non-Corresponding trials) are depicted as solid and open squares, whilst Away orientations are shown as circles.

The resulting RT data were analysed using a three-way repeated measures ANOVA examining Correspondence, Depth, and SOA; the resulting means are shown in Figure 5.7.

Results from the ANOVA showed a now familiar pattern, demonstrating a highly significant main effect of Correspondence, such that Corresponding trials were faster than Non-Corresponding, $F(1,12) = 29.8$, $p = .001$; and a highly significant main effect of SOA, such that RTs at 0 ms SOA were slowest $F(3,36) = 24.4$, $p = .001$. Also in accordance with previous results was a significant interaction between Correspondence and SOA, $F(3,36) = 5.20$, $p = .005$, such that the benefit for Corresponding over Non-Corresponding trials increased with SOA, in this case peaking at 800ms. There were no other interactions significant at an alpha level of .05.

These results replicate previous outcomes from Experiments 3 and 4, and argue that at least some form of the abstract coding account must be correct. They demonstrate that the effects of the prime affordance can be found even on responses unlikely to be specifically activated for manipulation of the affordance.

In summary, the aims of the experiments in this chapter were to investigate whether the action representation evoked by the presentation of a visual affordance, potentiates a specific motor response bias for the limb most suited to perform the afforded action; or whether it catalyses an interaction between more abstract representational codes generated by the overall S-R set. These issues were investigated by developing a method where the prime object and the orientation of its handle (i.e. the appearance of its affordance for grasping) were irrelevant to the participants' task.

Separating the target display from the image of the affording prime, allowed examination of whether the appearance of an irrelevant affordance could produce response activation, and the timecourse of that activation. Results from all three experiments show clearly that visual affordances of objects can potentiate action, even when these objects and affordances are irrelevant to current goals, and that this action potentiation, at least in this experimental configuration, is probably based on the priming of the action system, to respond to that side of space. The general discussion provides a more in depth review of this chapter.

Chapter 6

6. What is the Contribution of Attention to Correspondence Effects?

6.1. Experiment 6 – Introduction

The present research shows that affordance plays little, if any role in producing a response bias for a specific limb. Both the Crossed hands and the Foot experiments showed that correspondence effects were a function of correspondence between handle orientation and response effector location, rather than orientation and responding hand. This is not to imply that an object's affordance has no action-based sensori-motor effect on the observer, but it does bring into question the *way* that affordances might operate in evoking object-action preparedness. One explanation, based on results from the previous three experiments, is that the Correspondence effects may be due to the production and influence of more abstract, spatial codes, rather than to any direct affordance-limb association. Possibilities that may be considered are 1) attention is drawn to the affordance; that is, the affordance behaves like an attentional cueing device resulting in performance benefits to that side of space; 2) that the handle is perceptually directing attention to that side of space, as might a pointing finger, and 3) that when attention goes to the handle then this directional shift of attention results in generation of a spatial code (saccade programming), that interacts with that code generated by response side (see attentional shift mechanism discussed earlier).

By way of further explanation of point one, implicit in the possibility that the pan handle may act like a cue, is the pre-supposition that it can attract or capture attention, even though irrelevant to the imperative task.

The term 'attentional capture' was introduced by Yantis and Jonides (1984) to identify the capacity of an irrelevant stimulus to act as a cue and thus to affect reaction time performance on visual search or spatial cueing tasks. Early data (e.g. Yantis & Jonides, 1984; Jonides & Yantis, 1988) suggested that the abrupt onset of a stimulus on the visual display can capture attention, even when participants are explicitly informed that it bears no useful information regarding the upcoming task. Since then, however, accumulating evidence suggests that attentional capture need not be solely determined by the onset of a stimulus; the 'capturing' stimulus may be processed to a higher, semantic level and can capture attention on the basis of such higher level processing. For instance Folk, Remington, and Johnston (1992) showed that the irrelevant stimulus only captured attention when it shared the property with which the target was associated, i.e. abrupt onset, brightness or colour.

Similar evidence has recently been obtained for other types of features capable of attentional capture, such as motion (Hillstrom & Yantis, 1994). Such evidence has been put forward to suggest the operation of top-down (goal-driven) factors that modulate attentional capture. In this context, it is possible that, although irrelevant to the task, the pan handle may have acted as an endogenous cue (or attention capturing feature) on the grounds of its salient nature/functional significance (affordance).

One way to investigate the presence and magnitude of any effects of attentional cueing is to use a variant of the *spatial cueing task* (Posner, 1980). In the original spatial cueing task, orienting of attention, either endogenously or exogenously may result in facilitation of detection of a subsequent target that appears in the cued location, when the SOA between cue onset and target onset is short (approximately 100-150 ms). However, at longer SOA, target detection times are slow for targets that appear in the previously cued location (Posner & Cohen, 1984; Maylor & Hockey, 1985). This latter effect of cueing has been termed *inhibition of return* (IOR) by Posner & Cohen (1984), and has since been used to refer to the bias against re-orienting attention to a previously attended to location. In the present experiment, the same spatial cueing principle is used with the exception that the target appears in one of four possible locations, two of which spatially overlap with the location of the (alleged) cue (pan handle).

The aim of this experiment is to pin down the effect of attention and to simplify possible confounding variables relating to Correspondence that may have been present in the previous experiments. The question of interest is whether an affordance operates (at least in part) by attracting attention to itself either through its functional significance (endogenous) or through its physical presence to the right or left of space (exogenous). In order to provide a realistic parallel to the earlier work, the experiment retained the concept of a priming image at various SOAs preceding the target, but simplified response down to one finger on only one button i.e. go, no-go. In this experimental situation, and as in the Tucker and Ellis (1998) unimanual condition, there could be no effect of correspondence between responding finger (effector position) and orientation of the image; in this way, any correspondence effects in this experiment are between the two stimulus dimensions, that is, orientation of the pan and subsequent location of the imperative target.

Figure 6.1. Depicting a 'go' trial; the 'go' target '888' appearing in the location previously occupied by the 'rightward' pointing handle.

In this experiment, the target could also appear at one of four equidistant locations in any of the corners of the image. The two Lower targets were designed to *exactly* coincide with the Left or Right handle locations of the previously presented prime image; note that prime and target were never presented simultaneously. The two Upper targets, on the other hand, corresponded only with the *side of space* of the affordance (handle).

The important distinction is between what shall be termed Correspondence Upper and Correspondence Lower. Corresponding lower effects will be between the prime's handle and the targets that exactly overlap with the prime handle, (see Figure 6.1 above). On the other hand, corresponding Upper effects will be between the prime handle and the targets that appear in the same hemi space, but in the Upper fields. In this way we may investigate whether attention is likely to be involved in producing the Correspondence effects previously gained. If attention is being drawn only to the affordance, then some form of inhibition should be expected where the target appears in the same location as the handle, but not to that overall side of space. Note that Correspondence effects of *affordance* require the involvement of relative left-right effector positions, not used here.

6.1.1. Method

Participants

Fifteen volunteers between ages of 18 and 37, all undergraduates at the University of Wales (Bangor), received one course credit for taking part in this one-hour experiment. All participants were right handed and had normal or corrected to normal vision.

Apparatus and stimuli

The experiment was run on a Power PC 8500/120 Macintosh computer with images presented on a standard Hi-Resolution 17-inch Applevision monitor and responses made on a standard apple keyboard using the arrow-down key only. The experiment was run on and controlled by PsyScope version 1.2.2 software.

The central fixation point (CFP) consisted of a period type symbol (Mac-cmd-8) presented at screen centre, black on white, font size 18. Target stimuli consisted of a row of either three eights (888) for a 'go' trial, or three zeroes (000) for a 'no-go' trial. Target stimuli were presented to one of four corners of an imaginary square on a blank computer screen; the location of the two lower corners coinciding with the handle of the prime image when it was oriented to that direction (see Figure 6.2 below).

All targets were presented in 'Chicago' bold font size 18 and black on white background. The priming image was a full screen colour image of a frying pan at one of three orientations to the participant; handle left, right or neutral

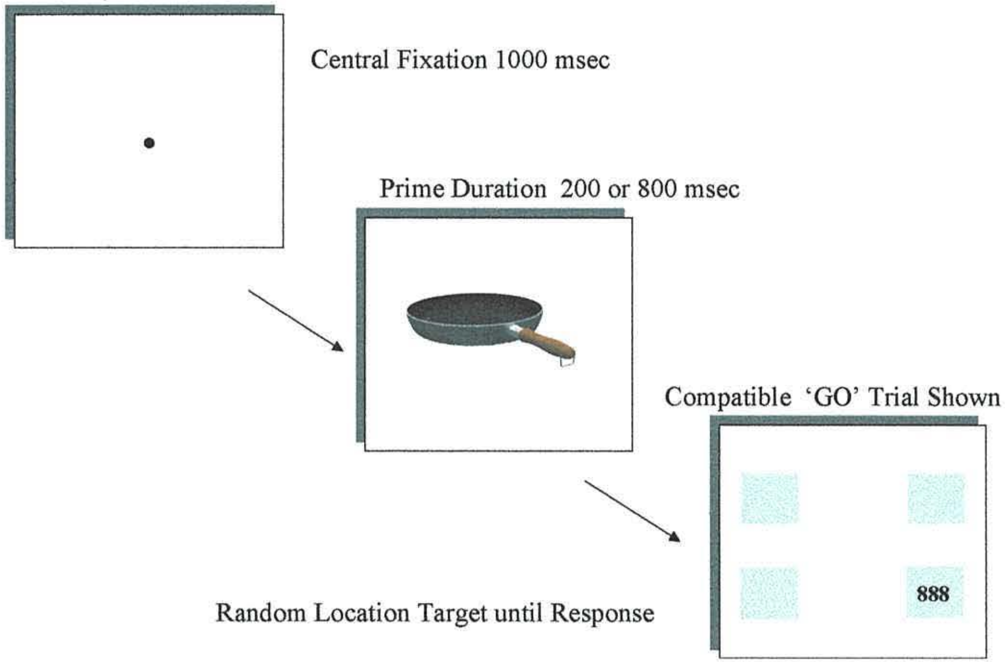


Figure 6.2. Showing the sequence of trial events, from central fixation point to presentation of the prime object, and the subsequent presentation of the target to one of the four corners of the screen. Note that the four shaded squares were not displayed, and are included here only to indicate the possible target positions.

Design

The experiment randomly manipulated a 3 x 2 x 2 x 2 within-subjects design providing twenty-four equiprobable conditions. The independent variables were a) Orientation of the prime image (x3) handle to the participants Left, Right, or Neutral; b) Target Vertical (x2) Upper or Lower; c) Target Horizontal (x2) Left or Right; d) SOA (x2) of either 200 or 800 ms, and e) Target Type (x2), either '888' (representing a Go response), or '000' (a No-Go response). The dependant variable was always response time. In Go trials, where the target appeared on the same side of space as the pan's handle (Left or right), then this mapping was termed Corresponding; See Figure 6.1.

Procedure

Participants were seated facing the computer monitor at a face to screen distance of approximately 50 cm, with forefinger of the right hand lightly resting on the arrow-down key of the keyboard. A trial began automatically with the presentation at screen centre of the CFP on a blank screen (Figure 6.1). Participants were asked to focus on this point when it appeared. After a period of 1000 ms, the CFP would be replaced by a full screen image of the prime object at one of the three orientations, subtending 21.7 degrees (horizontal) and 9.2 (vertical) degrees of viewing angle at a viewing distance of 50 cm. The prime was always presented centrally, in colour, upon a white background.

Participants were instructed to pay no attention to this image, that it was irrelevant to the task, and only to respond to an upcoming target. Following a random period of 200 or 800 ms, a target would appear in one of the four possible positions on the screen, at a horizontal visual angle of 2°, subtending 1° vertical. If the target was '000' then no response was required and after a period of 1000 ms, the next trial began. Where the target was '888', the participant responded as quickly as possible by depressing the response key. The trial was recorded and a new one automatically initiated. Responses to no-go trials evoked a warning noise and initiated the next trial. All participants completed a minimum of ten practice trials and subsequently completed two blocks of 400 experimental trials, taking a five-minute rest period between blocks.

6.1.2. Results and Discussion

There were 12,000 trials across the fifteen participants, yielding 6000 'go' trials. Response errors and anticipations (RTs of less than 200 ms) representing 2.3% of all trials were removed. Analysis of error frequency showed 54% errors for Corresponding and 46% for Non-corresponding trials; 20% errors for Lower targets as opposed to 80% for Upper targets, evenly spread over SOAs. The following percentage errors are for Corresponding Lower targets (12%), Corresponding Upper targets (41%), Non-corr. Lower (8%), and Non-corr. Upper (39%). A *WS* ANOVA with factors of Correspondence x 2 (Correspondence or Non-correspondence); Target Position x 2 (Upper or Lower); and SOA x 2 (200 or 800 ms) revealed significantly more errors for Upper targets than for Lower targets [$F(1,14) = 40.42$, $p < .001$]. There were no other main effects or interactions with Correspondence at [$F(1,14) = 0.980$, $p = .339$]; and SOA at [$F(1,14) = 2.22$, $p = .158$].

Reaction time data for all participants was computed, each trial processed in terms of mean RT for each experimental condition, and by Correspondence between physical Orientation of the prime (Left, Right, or

Neutral) and Target Side (Left or Right). Table 6.1 below, shows RTs split over visual field, SOA, and Correspondence.

Table 6.1. Mean response times by Correspondence for Upper and Lower target fields, and SOA.

	Lower Fields				Upper Fields			
SOA	**200**		**800**		**200**		**800**	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Mean	439.7	28.07	447.2	29.13	432.6	30.74	441.1	30.2
Corr.	438.3	23.10	454.0	30.59	431.8	35.77	444.1	27.88
Non-Corr.	439.7	30.06	441.8	29.69	434.0	27.34	441.8	32.32
Neutral	441.1	32.19	445.9	27.69	431.9	30.65	437.5	31.95

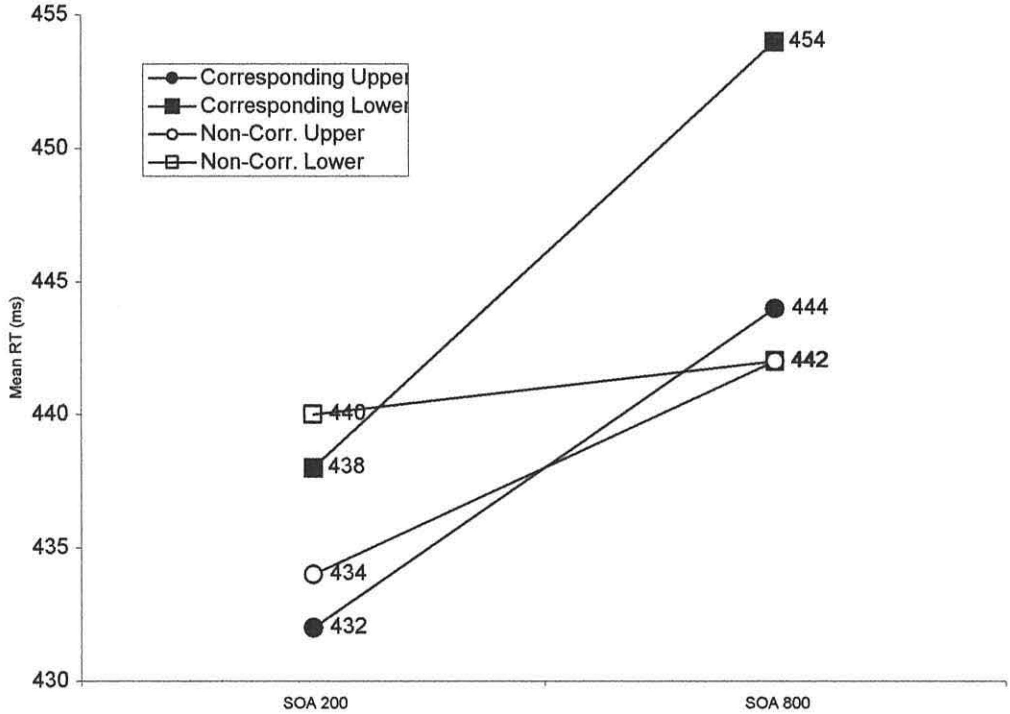


Figure 6.3. Illustrating the relationship between effects of Correspondence over the two SOAs, for the Upper and Lower target fields.

It can be seen from the above Figure 6.3 that a slight response advantage exists for Correspondence for targets presented in Upper and Lower positions at SOAs of 200 ms. However, at longer SOAs of 800 ms the situation provides equivalence in performance for Upper target positions over Correspondence, but shows a reversal of the correspondence effect at 800 ms for the Lower visual fields.

Data was entered into a within-subjects ANOVA with factors of Target Location (x4), SOA (x2), and object Orientation (x3). The analysis showed a significant main effect for Target Location, $F(3,42)=3.14$, $p=.03$, with mean RTs to Upper field targets faster than overall mean RTs to Lower field targets. There was also a significant main effect of SOA, $F(1,4)=6.41$, $p=.02$ reflecting the significantly faster RTs at 200 SOA over RTs at 800 SOA. The effect of Orientation was not significant, $F(2,14)=1.4$, *ns*. Critically, there was a significant three way interaction between the Orientation of the object (affordance), the SOA and Target Location, $F(6,84)=2.77$, $p=.01$.

Post-hoc tests were carried out to investigate this three-way interaction between Target Location, object Orientation and SOA. Target Location was collapsed to two levels, Upper and Lower. The RT data was arranged in terms of Correspondence between Orientation of object, and Target side, all by SOA. At 800 ms SOA, Corresponding trials for *Lower* targets ($M = 454$) were significantly slower than Non-Corresponding trials for the Lower targets ($M = 442$), $t(14)=3.061$, $p=.008$; (see Figure 6.1). At

800 ms SOA for the *Upper* targets, there was no significant RT difference between Corresponding (M = 444), and Non-Corresponding trials (M = 442); $t(1,14) < 1$. At 200 ms SOA there was no significant Correspondence effect for Upper or Lower targets, $t(1,4)=1.1$ and $t(1, 14)<1$, respectively.

In addition to this, RTs for Corresponding Lower field targets at SOA of 800 ms, were significantly slower than RTs for Corresponding Upper field trials at 800 ms, $t14)=2.310$, $p=.037$; whilst at the same SOA of 800 ms, RTs for Non-Corresponding Upper field trials, were identical to Non-Corresponding Lower field trials, $t(14)<1$. Thus, in those Corresponding Lower field trials (where the target appeared in exactly the *same location* as the handle), response times were significantly slower than in Corresponding Upper trials (pan handle and subsequent target appeared in the same hemi-field).

The effects of Correspondence for the Upper and Lower targets at each SOA are illustrated in Figure 6.4. As shown, for those trials, where the target appeared on the exact same location as the pan's handle (Lower field targets) there was a significant (but reversed) Correspondence effect at SOAs of 800 ms (d = 13 ms). However, when the target appeared on the same side of space as the handle (Upper field targets), then there was no effect of Correspondence at any SOA; (d = 2 ms at both SOA).

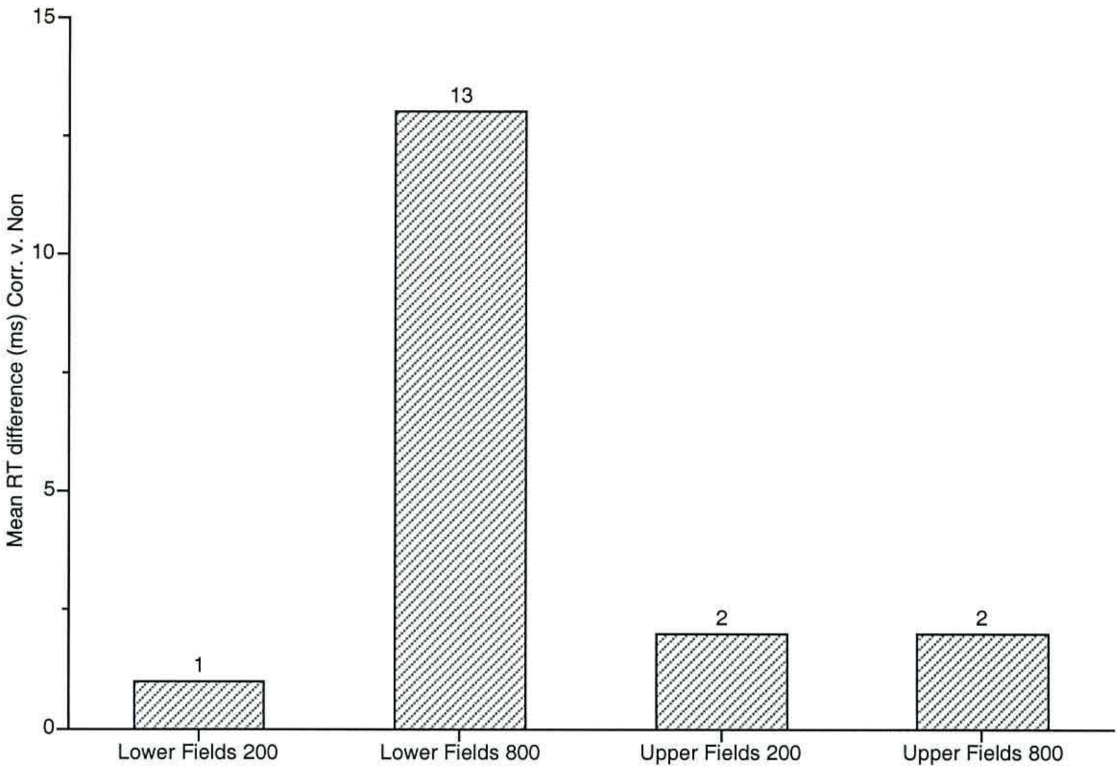


Figure 6.4. Upper versus Lower target fields at 800 ms SOA only, showing the discrepancy for Correspondence effects by field.

In the introduction to this experiment, it was predicted that if the pan handle acted as a cue, drawing attention to the location in space it occupied, there would be a significant RT difference compared to when the target appeared in a Corresponding but Upper location. In other words, there would be a significant RT difference between Corresponding Upper and Corresponding Lower trials.

Three important findings emerge from the present results. First, a significant effect of overall Correspondence at SOA of 800 ms was observed when the target appeared in the same hemispace as the pan handle (collapsed over Upper and Lower fields); this effect being inhibitory.

Second, the overall effect of Correspondence was due in total to effects for Lower target fields at 800 SOA, whilst no effects for Upper field Correspondence were observed. Third, there was a significant difference in response times for Corresponding Lower and Corresponding Upper trials at SOAs of 800 ms. Responses to targets that appeared at the *same location* as the pan's handle were significantly slower than targets that appeared on the same *side of space* (but not in the same location) as the pan's handle (Upper fields). This pattern of results was identified as showing inhibition of return (IOR) for targets appearing in the same location as the pan's handle (cue). Thus, the effect of the pan's handle did not generalise to the whole hemi field, producing IOR for targets appearing in the same side of space as the handle, but rather IOR was only significant for targets appearing on the exact same location as the cue (handle).

In summary, attention is being strongly drawn to the object's handle, demonstrated by an inhibitory effect in trials where the target appears in the same location (Corresponding Lower) as the affordance. From this experiment, it can tentatively be concluded that the affordance initially acts to draw attention to itself, as opposed to the whole hemi-field.

The job of separating out any effects of cueing from those of affordance is a difficult task as attention is conceivably an important component of any affordance. Perhaps any effect of affordance relies on an ability of first attract attention to itself, or perhaps the act of drawing attention to itself is the sum of the affordance.

Experiment 7 – Investigating the Effect of Exogenous Cueing

6.2. Introduction

The previous experiment employed a variant of the spatial cueing task in order to explore the possibility that the pan's handle may act like a cue attracting attention to itself. Indeed IOR was observed for targets that appeared at the same location as the handle. However, the finding that the pan attracts attention to itself does not exclude the possibility that previous Correspondence effects were only attributable to the directing or cueing effect of the object's affordance. Thus, one important question is whether the pan's handle acts *solely* as an exogenous attentional cue, this cueing capacity of the handle merely a pre-requisite to evocation of an affordance effect.

Experiment 7 is a brief investigation, designed to determine whether the facilitatory effects for Correspondence achieved in the previous Experiments 3,4, and 5 could be successfully replicated using images of grey blank patches projected to Left or Right of screen, rather than a differentially oriented image of a pan. This short experiment attempts to ascertain the contribution of cueing effects to the overall attentional effects found in the previous experiment, and of the Correspondence effects of Experiments 3,4, and 5. Basic aspects of the earlier experiments such as SOAs remained the same. However, in place of the priming image would be a simple left or right exogenous uninformative cue, followed by a centrally located, endogenous, target that indicated either a Left or Right response. These Left or Right cues might be hypothesized to cause the same attentional bias effect as the pan handle seemed to create in the earlier experiments, but without the complicating factor of object affordance. In this experiment, Correspondence is defined as being between the location of the prime, and the response side shown by the imperative target.

It is predicted that, if the pan's handle acts *solely* as an attentional cue, then in the current experiment, where the non-affording cue has replaced the pan's handle, there should be similar correspondence effects. Conversely, if the Correspondence effects in the previous experiments were due to the cueing of attention to the affordance (by the pan handle), then a non-affording cue should produce no spatial correspondence effects.

6.2.1. Method

Participants

A fresh sample of ten undergraduate students took part in this experiment; all were registered as major psychology students at the University of Wales, Bangor, and all received one course credit for their participation. All participants reported having normal or corrected to normal vision, were right-handed and kept naive to the purpose of the study.

Apparatus/Stimuli

Cues comprised of a 2 x 2 cm, two-dimensional square, shaded light grey and presented on a white screen background, 10 cm to the left or to the right of a central fixation point. The target consisted of a presentation of a symbolic arrow exactly identical in form and size to that used in the earlier Experiments 3,4, and 5; 'IIII—I' indicating right, and 'I—IIII' indicating left response. This mapping was reversed for half of the participants. The central fixation point (CFP), as always consisted of a simple dot ' • ' using size 18 Chicago font. The experiment was run on PsyScope version 1.2.2 software and was presented on a standard Hi-Resolution 17 inch monitor connected to a Power Mac G3 computer. All response timings were calculated and recorded by the computer, and responses made through a single standard 'Apple Design' keyboard using keys 'z' (left response) and 'm' (right response). Screen presentation and timings were exactly as in Experiments 3, 4 and 5, as were the response effectors.

Design

The experiment comprised four blocks of two hundred trials per subject, based around a 2 x 3 x 4 within subjects design. The factors consisted of a) Target, indicating Side of response, with two levels; either Left or Right: b) Cue (uninformative), with three levels; Left, Right, or Neutral; and c) SOA of either 0, 400, 800, or 1200 ms.; a total of twenty-four randomly presented and equiprobable trial possibilities. The experiment was designed to replicate the important aspects of Experiments 3, 4, and 5, but using blank shapes instead of pan images. Therefore, the design remained (otherwise) identical.

Procedure

Participants were seated facing the computer monitor at a face to screen distance of approximately fifty centimetres. The keyboard was placed in front of the monitor at desktop height. The participant was asked to place the preferred finger of the left and right hands over the 'z' and 'm' keys respectively. Each trial consisted of the following events: A central fixation point would be displayed (centrally) on a blank screen until target presentation (see Figure 6.5. below).

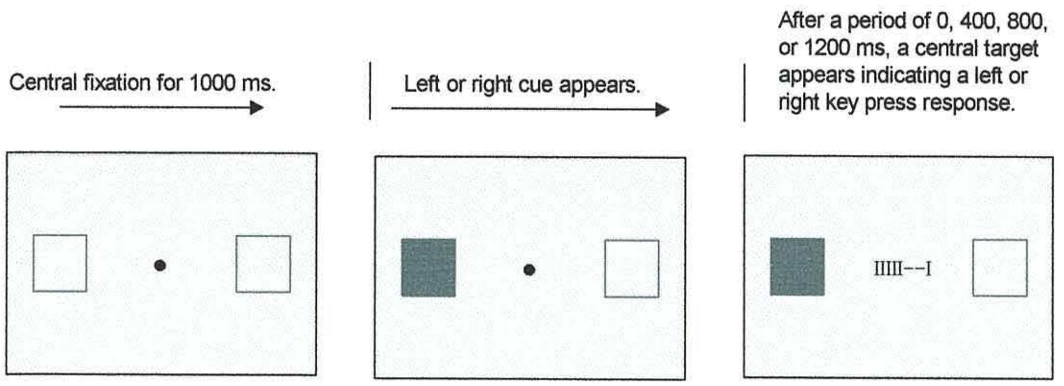


Figure 6.5. The diagram illustrates a typical trial sequence. For Corresponding trials, the cue will appear on the same side of space as the target- directed response. For Neutral trials, both Left and Right cues appear simultaneously. At SOAs of zero, the cue and target appear simultaneously.

The participant was instructed to remain visually fixated on the CFP throughout the trial. After 1000 ms., a cue would appear at 10^0 of visual angle from central fixation, to either screen Left, screen Right; or in the case of 'Neutral' condition, both left and right, and vertically screen centred. The cue would remain visible for a time of 0, 400, 800, or 1200 ms following which, the target, subtending a viewing angle of 2.9 (horizontal) and 1.1 (vertical) degrees at 50 cm viewing distance, would appear, always at screen centre, indicating a left or right key-press response. The target would remain visible until response. Any response would automatically initiate the next trial. Where a response was 'incorrect', a warning 'beep' sounded, the trial recorded as an error, and a new trial initiated. In the case of a correct response, the screen cleared and a new trial began; in this way the software controlled initiation of trials within blocks. All participants completed thirty practice trials before running the experiment.

6.2.2. Results and Discussion

Data from all of 8,000 trials were collated and 206 incorrect responses (representing 2.6% of all trials) were removed. All trials greater than 1000 ms (1.7% of all trials) were also removed. The total excluded trials, including elimination of outliers accounted for 5.6% overall. Further analysis of errors showed 37% were for Corresponding as opposed to

Non-corresponding trials. Further analysis of errors was not considered helpful at this stage.

Data was re-arranged in terms of Corresponding, Non-corresponding, and Neutral trials (Correspondence is in terms of cue-side and response side), and then processed through a WS analysis of variance in order to test for significant variations between mean RTs for Correspondence and SOA. Figure 6.6 below shows the resulting means in the form of a line graph chart, grouped in terms of Correspondence within the factor of SOA.

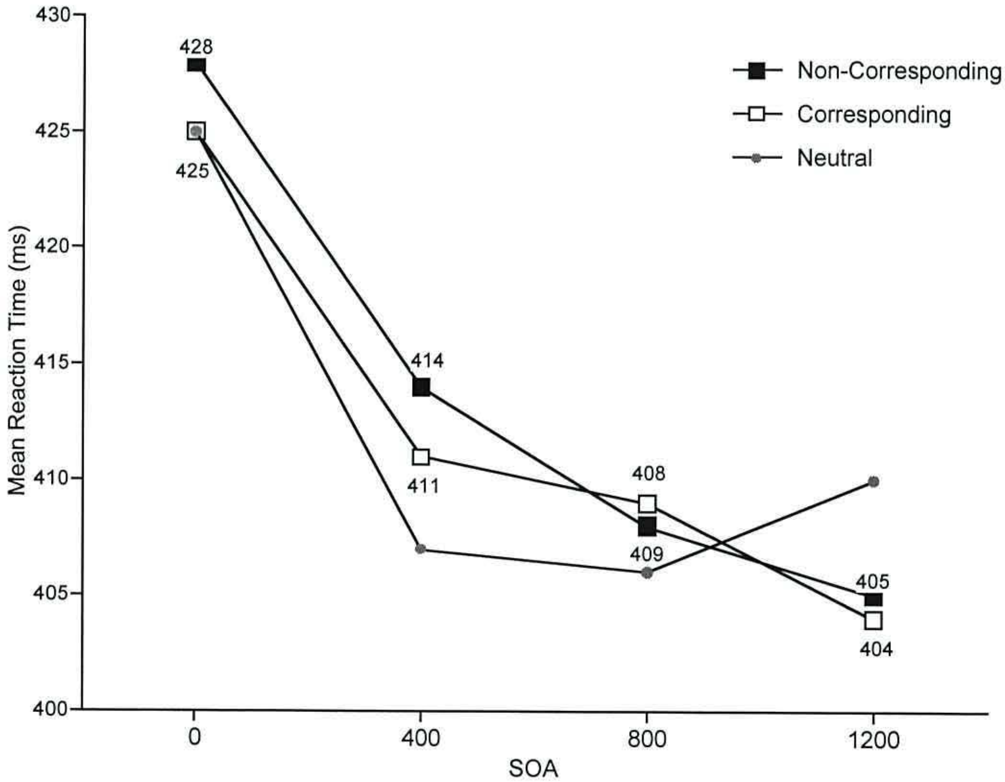


Figure 6.6. Mean response times for Corresponding, Neutral, and Non-corresponding trials by SOA.

Results show only minor differences between Corresponding and Non-corresponding trials, the only significant main effect being that of SOA; $F(3,27)=11.76, p<.001$. Responses are slow at 0 SOA and steadily even out over 400,800, and 1200 SOAs. Over the SOAs, there is only ever a few milliseconds difference between Corresponding and Non-Corresponding trials. The cue is seen to have an indeterminate effect regardless of any Correspondence with Target-side.

These results clearly indicate that the cue had little effect on the experimental task performance. In the previous experiment, it was shown that the pan's handle could successfully act as a cue, producing IOR for targets with which it spatially overlapped. However, the results of the present experiment could be taken to suggest that the cueing capacity of the pan's handle did not lie simply in it's physical presence, but perhaps in it salience as the functional interface of the object.

If the handle relied solely on it's perceptual qualities, then similar effects of Correspondence to that of Experiments 3, 4 and 5 should have been observed here. The absence of any correspondence effects between the cue and the target in the present experiment may indicate that the action possibilities that may be associated with the pan's handle, contributed to the effects of Correspondence over and above those effects that may be attributed to attention alone. That is, although the affordance attracts attention to itself, it also seems likely that the priming of action is a result of something different and perhaps more complex.

There are of course other possible explanations for this null effect. In all of these experiments, participants were told to ignore the prime object, in this case the cue, as it was irrelevant to the task. There is a possibility that this was more effectively achieved when the prime was just a small grey square and not a full screen colour image of a frying pan. In addition, the cue was presented at maximum eccentricity to either screen left or right, whereas the pan's handle either pointed towards or away from the participant and never at the extreme left or right of subsequent target. However, bear in mind that in the previous experiments (3, 4, and 5), handles oriented maximally away from the participant did produce a similarly strong effect as those pointing towards.

In summing up, although this experiment showed little effect of cueing, this does not exclude the possibility that the handle of the pan behaved in a similar manner. The preferred explanation for the present results (Experiments 6 and 7) is that the pan's handle acts like an endogenous cue, capturing attention via its representation for action, as opposed to its onset. The null effect obtained in Experiment 7 accentuates this point, suggesting that in earlier experiments (Experiments 3 – 6), the pan handle did produce an affordance effect by way of attracting attention to itself through both its perceptual, and functional salience

The issue that remains a concern is that object asymmetry may, as shown earlier, produce attentional effects that may confound the investigation of affordances per se. Manufactured objects are designed to attract attention to their functional parts, i.e. handles, buttons etc.; by manipulating visually perceptual factors such as colour, material type, or labelling, and/or on a more physical level such as extending hand grips, buttons etc. Whatever the method, object design will normally result in the physical affordance producing some form of perceptual asymmetry, thus potentially confounding these types of investigation. The case of physical object asymmetry is further addressed in Chapter 8.

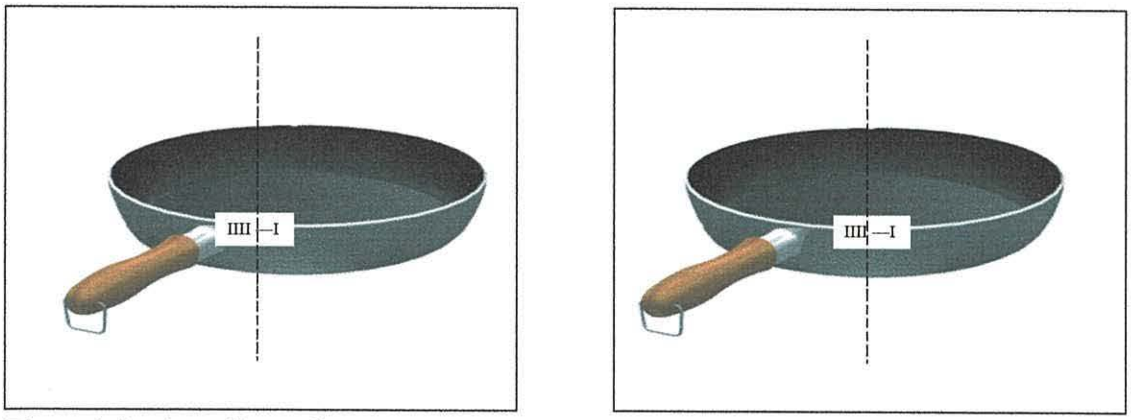
Of equivalent concern is the issue relating to perceptual balance, that is, the overall perceptual (spatial) relationships between primes and targets, in the visual presentation of priming or cueing types of experiment. The possible effects of spatial frames of reference (relating to stimuli and primes used in the previous experiments) are investigated in the following Chapter 7.

Chapter 7

7. The Consequences of Spatial Asymmetry between Prime Object and Superimposed Target

7.1. Experiment 8 - Introduction

This pilot study was carried out in order to further investigate any effects of prime/target spatial relations that may have contributed to the fairly robust effects of Correspondence, found with the Pan object, in the previous Experiments 3, 4, and 5. Concern about the effects of relative pan / target locations began after taking a screen snapshot of the pan/target configuration used in these experiments. The photographic software printed a line border around the stimuli that did not appear in any actual trials. This line border had the effect of highlighting the differences in pan / target spatial relations dependant on pan orientation; (See Figure 7.1 below.)



The original configuration as used in the previous experiments

The new perceptually 'tidy' configuration used here.

Figure 7.1. The picture on the left shows the original pan/target configuration used in all earlier experiments. The pan is situated centrally as is the target. However, because of the handle, the pan base appears shifted to the right of the target. See horizontal centre line. The right picture shows the 'tidied up' version of the same trial configuration. This time, the pan base has been centralised, rather than the whole pan. See centre line. Note: Neither horizontal centre line nor lined frame appeared on the trials. They have only been added to accentuate the offsets.

This border highlighted the fact that when a pan was presented with a Right orientation, the pan base appeared shifted to the Left – to make room for the handle on the Right. Similarly, when the pan was oriented to the Left, the pan base was shifted to the right, even though the picture of the Pan, and the subsequent Target, were always presented centrally. This shifting was seen to have at least two possible effects. Firstly, between trials, there was a constant left/right shifting of the pan base between Left, Right and Neutral trials. Secondly and potentially more importantly, this shifting affected the spatial relationship between the pan base and the central target, that is, the central target appeared slightly offset from pan centre. Although this central offset between the 'to be ignored' pan and the target was hardly perceptible within the confines of the testing environment, it was considered necessary to run a pilot study to investigate the effects of this potential confound. A direct replication of Experiment 3 was arranged, but with one modification in stimulus presentation methodology. Instead of presenting the whole pan (base and handle) as a picture at the centre of the screen, now, the base itself would always be centred, regardless of its orientation.

7.1.1. Method

Participants

A sample of ten undergraduate students took part in this pilot study. All were registered as major psychology students at the University of Wales, Bangor. They received one course credit for their participation. All were right handed, reported having normal or corrected to normal vision, and were naive to the purpose of the study.

Apparatus/Stimuli

Stimuli were identical to those used in Experiment 3,4, and 5, as were the viewing angles and stimulus sizes. However there was one important exception. Rather than centralising the whole image of the pan on the screen, the pan base was centralised, with the handle attached to either the Left or Right side. This had the effect of eliminating any spatial displacement between pan base and subsequent target location. The Neutral condition involved presentation of the pan base only, that is, with no handle attached.

Design and Procedure

Apart from the slight changes made in order to perfectly centralise the pan base with the target, the only other difference between this and the experiments in Chapter 5, lay in the exclusion of the Depth factor. There was only a Left or Right Orientation as depicted in Figure 7.1. The design and procedure was otherwise identical to that used in Experiments 3, 4, and 5.

7.1.2. Results

Response errors accounted for 2% of trials. As the aim of this pilot was to quickly assess the effect of altering the target to prime spatial relationship, and due to the low percentage error rate, further analysis of errors was considered unnecessary at this point. Error information relating to this new design is presented in the following Experiment 9.

Mean reaction times (RTs) were computed for correct trials only. Reaction times greater than 1000 ms were excluded as timeouts as were RTs greater than three standard deviations from the grand mean. RTs of less than 200 ms were excluded as anticipations. These exclusions represented 4% of all trials. The remaining data was arranged in terms of Correspondence between Response side and Orientation by SOA. The resulting means are shown in Figure 7.2 below.

The figure clearly shows the minor differences between reaction times for Corresponding trials (*M*=413:*SD*=53.08) and Non-Corresponding (*M*=414:*SD*=51.7). Analysis using a two-way *WS* ANOVA only revealed a significant main effect of SOA [$F(3,27) = 11.76$, $p<.001$]. There were no other main effects or interactions.

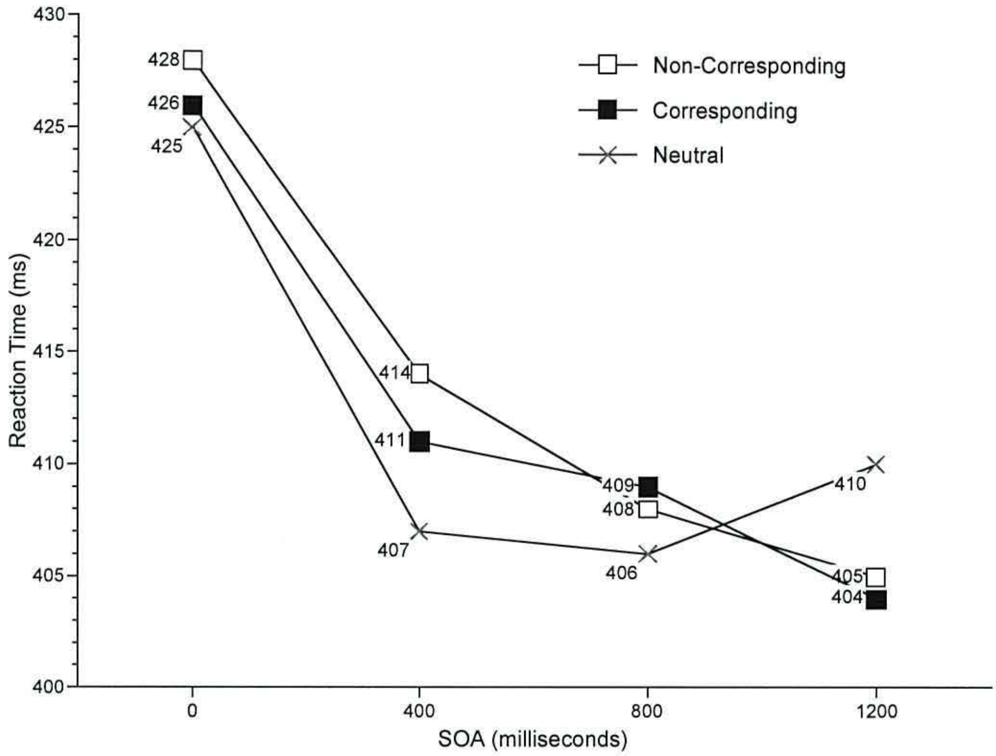


Figure 7.2 Figure shows mean reaction times by Correspondence and SOA.

7.1.3. Discussion

This pilot investigation revealed that, what had previously been shown to be a robust effect, had now, all but disappeared. The only design modification had been to centralise the pan *base*, a shift of around two cm from the original configurations; by way of tidying up the presentation. However, the effect was dramatic.

There are two possible explanations for the results. The first is that the target position, in relation to the pan base, may have generated a form of spatial reference code that interacted with that generated by the subsequent target indicating response side. By eliminating the conditions responsible for the frame of reference effect, the Correspondence effect was also eliminated, resulting in a minor effect of correspondence for orientation of affordance.

A second explanation considers the effect of repetitively, on each trial, re-displaying the pan base in exactly the same position on the screen. Remember that Participants were told to remain fixated at screen centre, the place where the initial trial fixation point appeared, followed by the 'to be ignored' prime, and then by the target in exactly the same central position. This eliminated any between trial 'movement' effects that were present in the previous experiments. In retrospect, it is easy to see how an centrally fixated observer might have succeeded in ignoring the prime. In summary, it is considered that some form of habituation to the stimuli (over 800 trials) may have occurred. In order to test this hypothesis further, it was decided to run another experiment that would systematically manipulate the frame of reference effects, whilst also addressing any habituation problem.

7.2. Experiment 9 - Introduction

Experiments 1 and 2 showed that effects of correspondence could be obtained by extending the length of stimulus presentation prior to response. Experiment 3 showed that these effects were robust and built over time. Experiment 4 showed that effects remained even when hands were crossed, implying that the affordance was not for a particular limb, but rather for a particular side of space. Experiment 5 showed the same correspondence effect could be achieved using left or right feet.

Throughout these experiments, the general theme of object affordance is based on the observation that affordance / effector correspondence results in response bias to that side of space. That is, the affordance 'operated' by biasing responses to the side of the affordance. The *way* that the affordance worked was, however, unclear. Experiments 6 and 7 investigated the role of attention and showed that attention seemed to be drawn to the handle on the basis of its functional salience. In this light, other aspects of the perceptual group comprising the prime and target were more closely investigated. In particular, the spatial relations between these two elements of the stimulus set. Pilot Experiment 8 showed that a frame of reference effect may have indeed contributed to the significance of Correspondence effects, the magnitude of this contribution, yet to be established.

In summary, and to consolidate, the common finding in all previous experiments is the effect that properties of an irrelevant stimulus, i.e. the handle of the pan, has on responses to an imperative target. The phenomena within the SRC paradigm to which the effect is most closely related is that of the Simon effect. A Simon type effect, in the current experimental environment, occurs in tasks where irrelevant stimuli with varying (but irrelevant) orientation on the computer screen, are responded to with left or right key responses. Under such conditions, when a target stimulus requiring a *left* response (depending on an attribute other than its location) is presented to the *left*, it is responded to *faster* than when the same stimulus is presented to the right. This effect of irrelevant stimulus dimension on response is typically short-lived (e.g. Lu & Proctor, 1995; Hommel, 1994).[1] For example, Hommel (1994) first showed that during difficult tasks that increase response latency, the Simon effect is eliminated (also see De Jong, Liang & Lauber, 1994). This fact is not consistent with current findings, thus the term Simon 'type' effect.

One issue arising in the Simon effect literature lies in the very ambiguity of the terms *left* and *right*. In other words, the spatial location *left* can be defined with respect to a variety of environmental and viewer-centred *frames of reference*, such as the fixation point on a computer screen, another object on the screen, the viewer's direction of sight, body mid-line, and so on (e.g. Roswarski & Proctor, 1996). In most investigations these two frames of reference are not dissociated, thus

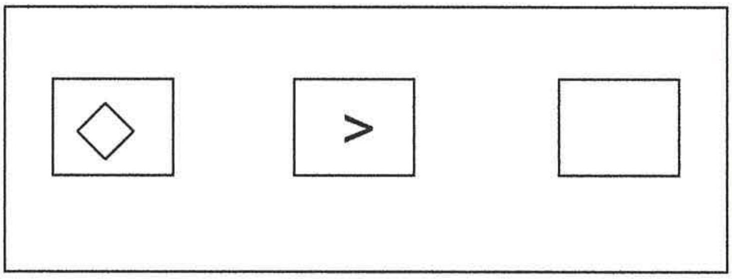
---

[1] It is noted here that the 'short-lived' attribute is not present in the current experiments 3-5. Rather, the effect is seen to build over time.

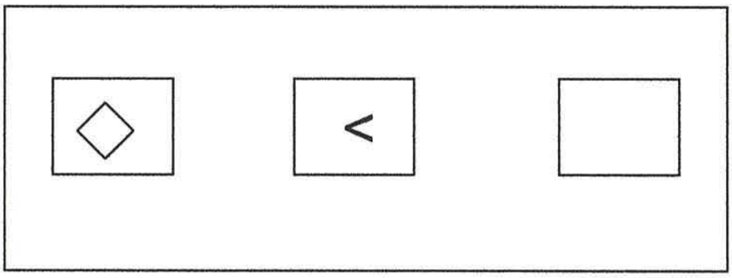
leaving open the possibility that correspondence effects result either from coding relative to one or both frames of reference.

Recently, Danziger, Kingstone, and Ward (2001) investigated the way that environmental frames of reference can influence spatial coding. They used a spatial cueing task, where participants were asked to respond accordingly to a left or a right pointing arrow (Figure 7.3). The critical manipulation was that the target arrow was preceded by a cue appearing on the right or on the left of the fixation box. This cue defined an environmental frame of reference for the target; the target would appear left or right relative to the cue. This design dissociated the environmental (set by the cue) and the egocentric (set by the viewer's midline) frames of reference. Danziger et al. (2001) argued that if the time-course of the Simon effect and that of frame of reference coding were similar, they would find that 'compatibility' effects would decay as the SOA between cue and target increased.

They found that targets that pointed to the same location as their relative position (relative to the cue) (Figure 7.3) attracted faster responses than those that did not. Furthermore, this compatibility effect was observed at SOAs of about 1 second. Danziger et al. (2001) argued that their findings support the existence of two separable spatial codes. One is transient and facilitates activation of response. The other is a longer-lived frame of reference code and maintains stimulus spatial coding once the effect of the transient response code has ceased to activate response mechanisms.



(A)



(B)

Figure 7.3. (Adopted from Danziger et al., 2001). Panel A depicts a corresponding trial; the target location is to the *right* of the cue and the target identity requires a *right* response. Panel B depicts an Non-Corresponding trial – the target location is coded *right* but the target identity requires a *left* response

Experiment 9 will address the possibility that correspondence effects in Experiments 3, 4, and 5 were caused by target coding relative to the frame of reference as defined by the position of the pan on the screen in relation to the superimposed target. The reasons for this are two-fold.

First, as shown in the introductory pilot experiment, when the pan-base was positioned at 'dead centre' on the screen the handle-target Correspondence effects were all but extinguished. Second, as briefly reviewed above, effects of irrelevant stimulus dimensions on subsequent target responses, known as the Simon effect, do not usually persist for longer than 300 milliseconds. However, in all the experiments reported in this thesis, these correspondence effects increase as the time gap (SOA) between the presentation of the irrelevant stimulus and the subsequent target increases. It is therefore important to ascertain whether previous results were confounded by the longer-lived effects of frame of reference.

Experiment 9 sets out to investigate the effect of the spatial relationship between prime position and imperative target, the so-called 'frame of reference' (FOR) effect. It will also attempt to show that both FOR and affordance are co-factors in producing correspondence effects observed in Chapter 5.

In summary, despite the fact that in previous experiments, both the prime object, and the target were presented at screen centre, a perceived left / right shifting of the target relative to the pan base, may have generated a left-right spatial code that would be matched in terms of correspondence with the code created by the required response to that target. Any correspondence effects should be in the same *direction* as that which might be expected from attentional or affordance based effects, that is, the spatial code would always match that of the affordance.

Therefore, it is now considered that the response bias currently attributed to object affordance may, in part, be due to an effect of frame of reference between prime and superimposed target. Thus, the purpose of this experiment is to re-examine the basis of the correspondence effects, previously attributed to effects of affordance (Experiments 3, 4, and 5), by manipulating the prime-target spatial configuration, with a view to separating out any FOR effects from those of affordance.

7.2.1. Method

Participants

A sample of fifteen undergraduate students took part in this experiment. Eight major psychology students (University of Wales, Bangor), received one course credit, and seven other volunteers were paid. All were right handed, reported having normal or corrected to normal vision, and were naive to the purpose of the study.

Apparatus/Stimuli

Stimuli consisted of a prime (full screen picture of object) and a small target to be superimposed on the prime, always presented at screen centre. The primes consisted of a two images of a frying pan base with a handle attached in one of two positions, either left or right side, and a third image of the pan base with no handle (see Figure 7.4).

Figure 7.4. The three prime images used throughout the experiment. The pan on the left has a left Orientation, in the centre, a Neutral Orientation, and on the right, a Right Orientation. Degree of Orientation is identical to the Near Orientations of Experiments 3,4, and 5.

Each of the prime images was scaled to fill the display at full size, each presented in colour upon a plain white background. The 'perceived' Orientation of the image was set to offer an affordance (via the pan handle) to either the Left or Right hand of the subject. In the 'Neutral' case, the 'handle' would not be attached at all (see Figure 7.4 above). The target consisted of either a sequence of four uppercase 'I's followed by a '--' and then one more 'I' thus; 'IIII--I; which in the first 50% of participants (1-8) would be a Left target and in the remaining 50% a Right target; or the reverse; 'I--IIII' (Right target for first 50% and Left target for remainder). All targets were presented in 'Chicago' bold font size 18 in black using inverse video.

The central fixation point consisted of four uppercase I's (IIII) of the same font, size and colour. All images were presented on a standard Hi-Res 17 inch Apple vision monitor connected to a Power PC 8500/120 Macintosh computer. The experiment was run on PsyScope version 1.2.2 software. RT timings were recorded by the computer, responses made using either the 'z' key (left response) or 'm' key (right response) of a standard 'Apple Design' keyboard.

Design

The experiment comprised two blocks of four hundred trials based around a 3 x 2 x 2 x 4 within subjects design. The WS factors consisted of; a) prime object Orientation with three levels – either Left, Right, or Neutral (no handle attached); b) Response Side indicated by target – either Left or Right; c) relative target position (RTP) with two levels, shifted two cm to Left of subsequent central target location, or shifted two cm to Right; and d) SOA with four levels – either 0, 400, 800, or 1200 ms.; thus yielding a total of 48 randomised and equiprobable experimental conditions.

The design allowed that in one half of trials the prime image was shifted Left, and in the other half, Right, the effect being to make the subsequent central target appear slightly shifted to either the Left (RTP = Left) or to the Right (RTP = Right); See Figure 7.5 below.

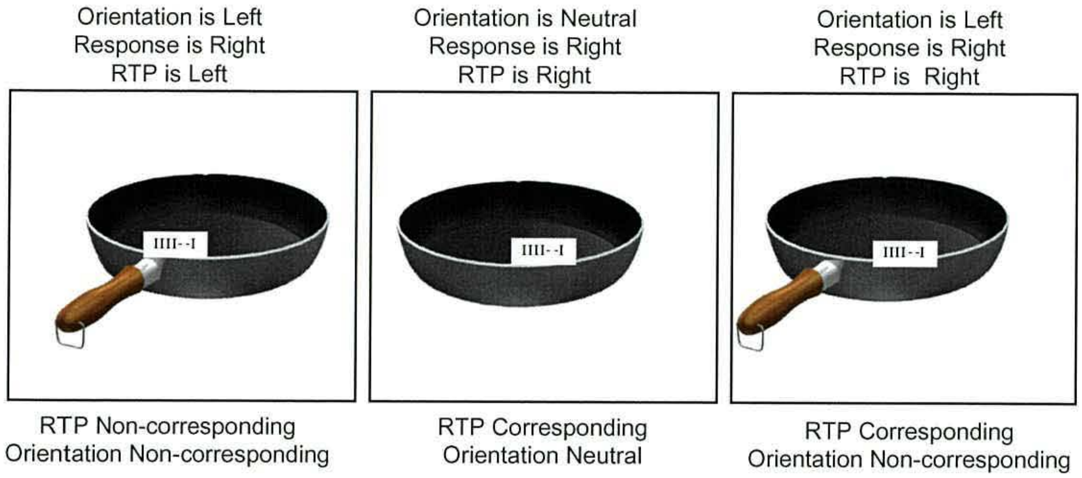


Figure 7.5. Sample stimulus displays. The figure shows the Left or Right shifted pan along an imaginary horizontal central line. The target always appears at dead centre of the screen. Therefore, the target position, relative to the pan base (RTP) is always either Left (first picture) or Right (second and third picture). All targets in this figure indicate Right response. Shown Orientations are Left, Neutral, and Left, respectively. Orientations *could* also be Right, and Targets *could* indicate Left.

Therefore, if a Right shifted pan appeared as the prime (RTP = Left), the central target would appear to be relative Left of the pan base. If the subsequent target indicated Left response, then this would be classed as a trial where the RTP Corresponded to response side. The position of the pan s handle would then determine whether the Orientation of the pan Corresponded with response side. Similarly, in the case of a Left shifted pan, (RTP = Right), if the subsequent target indicated Left response, then the RTP would be classed as Non-corresponding, along with the appropriate classification for Orientation.

In one-third of the trials, the pan would have zero Orientation, that is, only the pan base was presented. These were classed as Neutral trials. In these trials, as in all others, the factor of RTP Correspondence was always relevant, but in Neutral trials, there was no Correspondence factor for Orientation ($Corr_{ORI}$) It is important to remember that throughout the experiment (as in all others), the target would always appear at absolute screen centre. Figure 7.5 above, illustrates a selection of possible trial configurations where, for clarity, the target is always indicating Right response.

Each participant completed eight hundred trials in two blocks of four hundred. The spatial significance of the symbolic target was counterbalanced between the two halves of the experimental group as described in the 'stimuli' section. Presentation of all experimental conditions was automatically controlled and randomised by the PsyScope software.

Procedure

Procedures were identical to those used in Experiment 3.

7.2.2. Results

Error data - Response errors accounted for 1.6% of all trials. Analysis of response errors showed greater error frequency for Non-$Corresponding_{RTP}$ (56% of errors) over $Corresponding_{RTP}$ (44%), irrespective of Orientation. There were fewer errors for $Corresponding_{ORI}$

(34%) over Non-corresponding$_{ORI}$ (50%) trials, with Neutral trials attracting 16% errors.

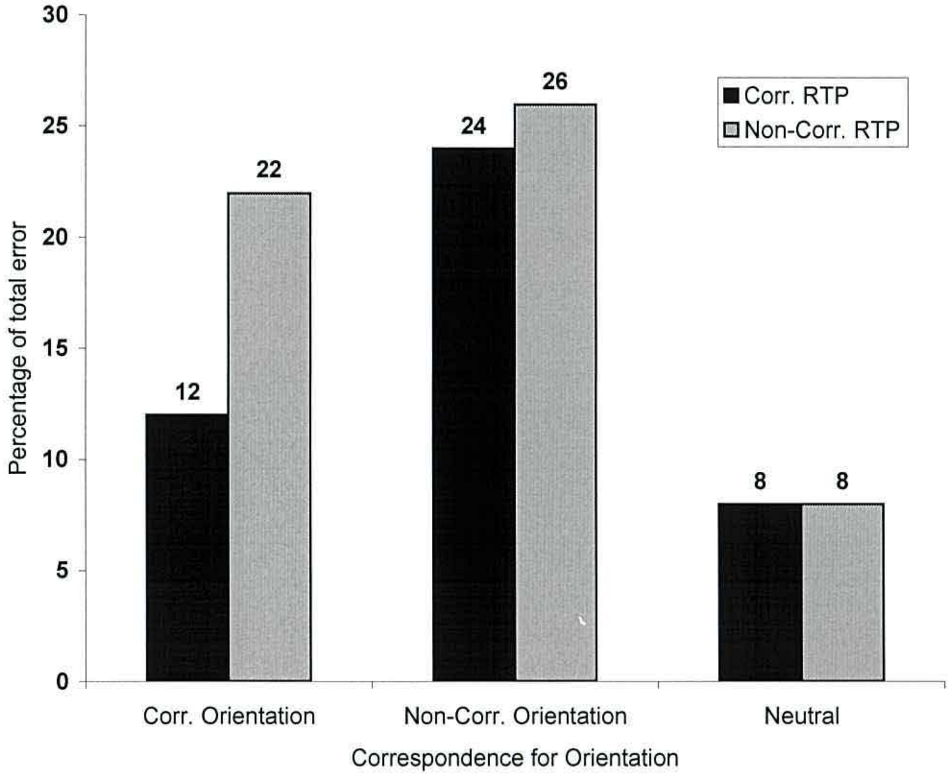


Figure 7.6a Showing percentage **Error** for Correspondence over RTP and Orientation

The above Figure 7.6a shows that where both RTP and Orientation have Correspondence, fewer errors occur than when either one does not correspond. Least errors occur in the Neutral position regardless of correspondence. A three-way analysis of variance investigating the factors of Correspondence$_{RTP}$, either Corresponding or Non-corresponding, $\text{Correspondence}_{ORI}$, with the same levels, and SOA with levels of 0, 400, 800, and 1200 ms., showed significantly higher error rates for SOAs of 0 over the other three SOAs [$F(3,42) = 4.30$, $p=.010$]. There was also a main effect of Orientation [$F(2,28) = 46.98$, $p=.001$] with significantly more errors for Non-corresponding trials, compared to Neutral, and to a slightly lesser degree, Corresponding trials. An interaction between SOA and $\text{Correspondence}_{RTP}$ was sourced both by the greatly increased errors for 0 ms SOA compared to other SOAs, and the higher rates (although *ns*) for Non-corresponding over Corresponding RTP; [$F(3,42) = 3.21$, $p=.032$].

Reaction time data - Mean reaction times (RTs) were computed for correct trials only. Reaction times greater than 1000 ms were excluded as timeouts as were 'anticipatory' RTs of less than 200 ms (1.4%). RTs greater than three standard deviations from the subsequent grand mean were also removed (1.4%). RT exclusions therefore, represented 2.8% of all trials. The remaining RT data was processed and re-arranged in order to reflect; a) spatial Correspondence between RTP and Response side (Corr_{RTP}), and b) spatial Correspondence between Prime Orientation and Response side (Corr_{ORI}). To aid clarity, Neutral trials were analysed separately from those with a Left or Right Orientation factor. As we are dealing with two Correspondence factors, the factor relating to the spatial

Correspondence between the Relative Target Position and Response side will always be termed 'Corr$_{RTP}$', with the factor relating to the Correspondence between the Orientation of the Pan and the Response side being termed 'Corr$_{ORI}$'.

Analysis of trials with Prime Oriented to Left or Right side of space

The results of the first analysis where each prime exhibited an Orientation are illustrated below in Figure 7.6a.

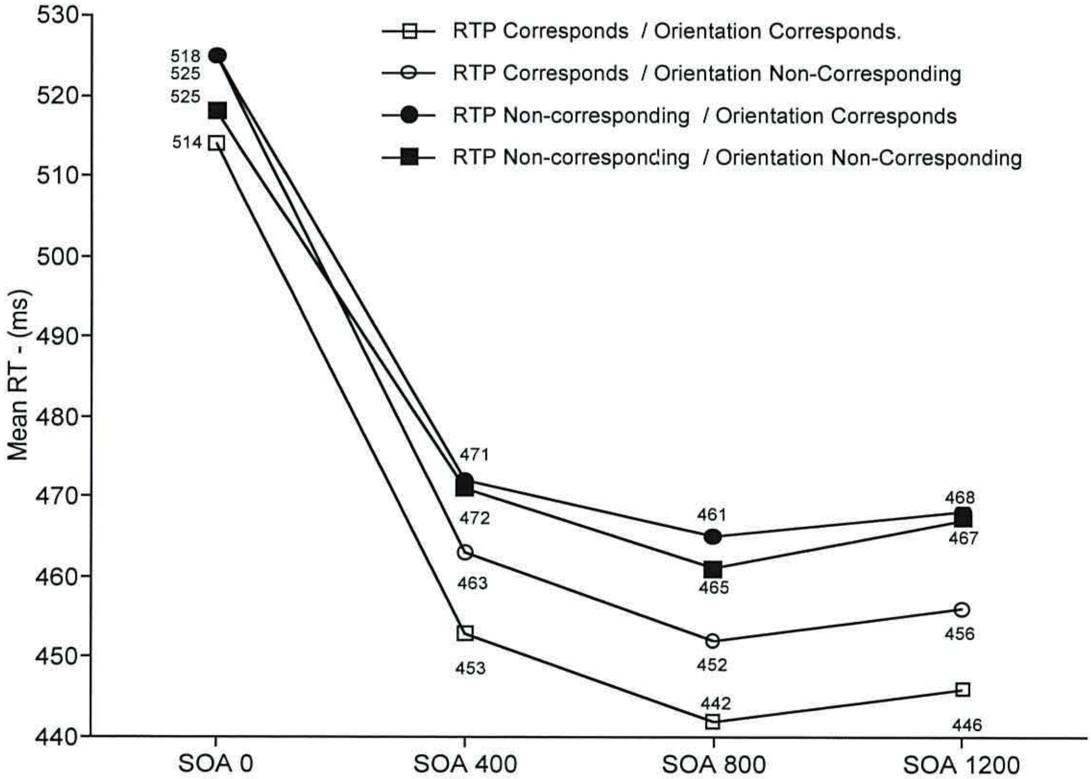


Figure 7.6a Overall RTs for each Correspondence conditions over the four SOAs. The un-filled symbols represent RTP Correspondence whilst filled symbols represent RTP Non-correspondence.

Figure 7.6a clearly shows that slowest responses occurred for those trials where both the prime and the target appeared simultaneously at zero SOA; *M*=520.3;*SD*=62.74; compared to joint mean RTs for the other SOAs; *M*=459.7;*SD*=61.08. At these SOAs of 400, 800, and 1200, RTs show a remarkable consistency over experimental conditions with fastest overall responses at SOAs of 400 (*M*=465) and slowest overall at 800 (*M*=455). A within-subjects ANOVA investigating factors of $Corr_{RTP}$, $Corr_{ORI}$, and SOA shows a significant main effect for SOA [$F(3,42) = 109.3$, $p<.001$], and a significant main effect of $Corr_{RTP}$, [$F(1,14) = 10.63$, $p=.006$], reflecting a distinct advantage for $Corr_{RTP}$ trials (overall *M*=468.8;*SD* = 69.24) over Non-$Corr_{RTP}$ (overall M=481.0;*SD*=63.59), regardless of prime Orientation. There was also a significant main effect for $Corr_{ORI}$, [$F(1,14) = 6.19$, $p=.020$], with trials consistently faster than $NonCorr_{ORI}$ trials (d= 3,4,3, and 4 ms, over 0,4,8 and 1200 SOA respectively). The interaction between $Corr_{RTP}$ and SOA was significant [$F(3,42) = 5.36$, $p=.003$]. Critically, there was also a significant interaction between $Corr_{RTP}$ and $Corr_{ORI}$ [$F(1,14) = 6.86$, $p=.020$], reflecting a significant difference between $Corr_{ORI}$ and Non-$Corr_{ORI}$ for trials where the RTP corresponded (see Figure 7.6b).

Paired-samples t-tests revealed that for $Corr_{RTP}$ trials, RTs where the *Orientation corresponded* with response side ($Corr_{ORI}$; *M*=464;*SD*=66.8) were significantly faster than RTs where the *Orientation did not correspond* with the response side (Non-$Corr_{ORI}$; M=674;

SD=71.7), *t* (14) = 2.6, *p* = .03. However, in Non-$Corr_{RTP}$ trials the difference between $Corr_{ORI}$ (*M*=482.6;*SD*=65.85) and Non-$Corr_{ORI}$ (*M*=479.5;*SD*=61.76) was not significant, *t* (14) < 1,*ns*.

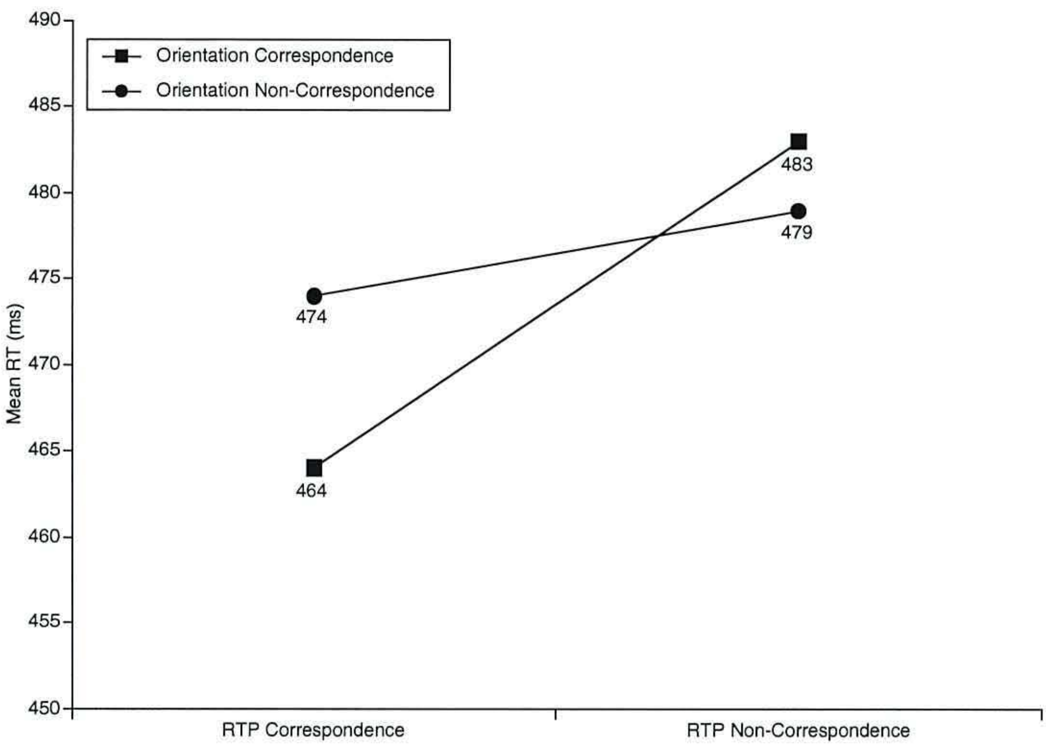


Figure 7.6b. Showing the interaction between Correspondence for RTP and Correspondence for Orientation.

Analysis of neutral trials (pan base only)

Analysis was performed on those trials where the pan was presented without a handle, that is, the pan base only. Results are shown in Figure 7.7 below.

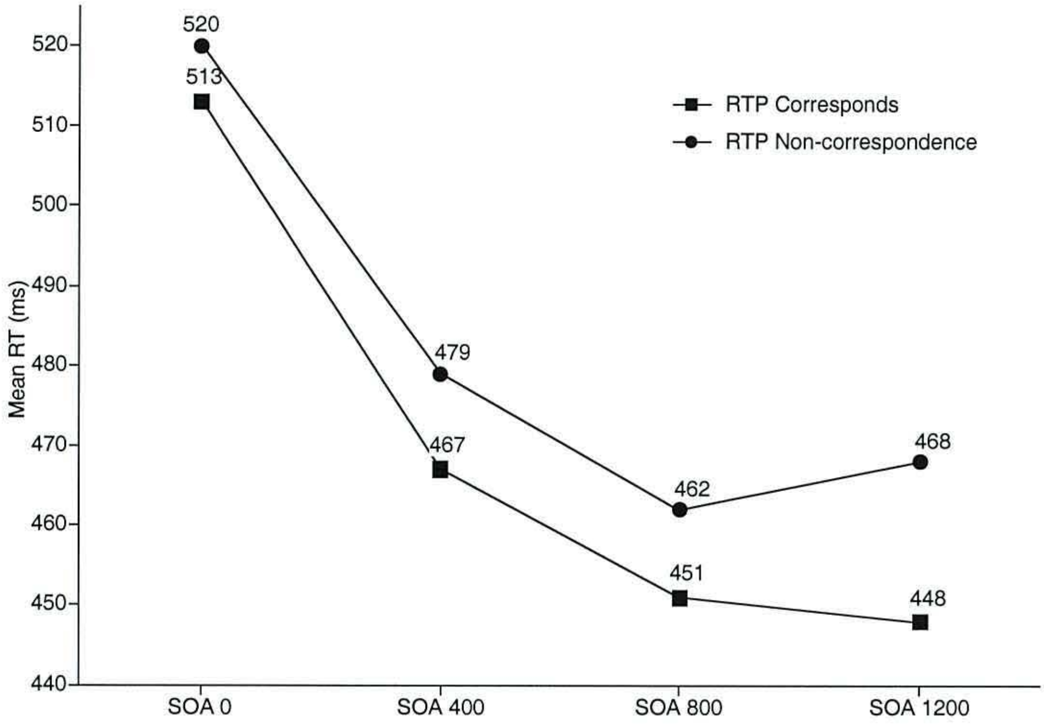


Figure 7.7. Mean RTs for Neutral trials where the RTP either did, or did not spatially correspond with the Response side. Trials are grouped by SOA. These trials therefore have no Correspondence factor for Orientation.

The above figure shows that even in the absence of an Orientation factor, there remain consistent differences in performance between RTs for NonCorr_{RTP} trials (Overall M=482:SD=66.8) compared to Corr_{RTP} (M=470:SD=64.7). This is especially pronounced at 1200 SOA (d=20 ms), but is true of all SOAs. A within-subjects ANOVA comparing factors of Corr_{RTP} (x2) and SOA (x4) showed significant main effects for Corr_{RTP} [$F(1,14) = 20.38$, $p<.001$] and for SOA, [$F(3,42) = 57.62$, $p<.001$]. The interaction was not significant.

Effects of RTP - Corr$_{RTP}$

These significant effects of Corr$_{RTP}$ in the absence of any affordance (Orientation) show evidence for the creation of some kind of reference based spatial code, this code being strong enough to affect subsequent responses in such a way that where it corresponds to response side (as indicated by the target), performance is consistently better than when it does not. Figure 7.7 above shows this 'Corr$_{RTP}$' effect is evident even in the Neutral trials where there is no 'affordance'. The effect of collapsing down the Orientation factor for those non-neutral trials where there *was* an Orientation (affordance) is shown in Figure 7.8 below.

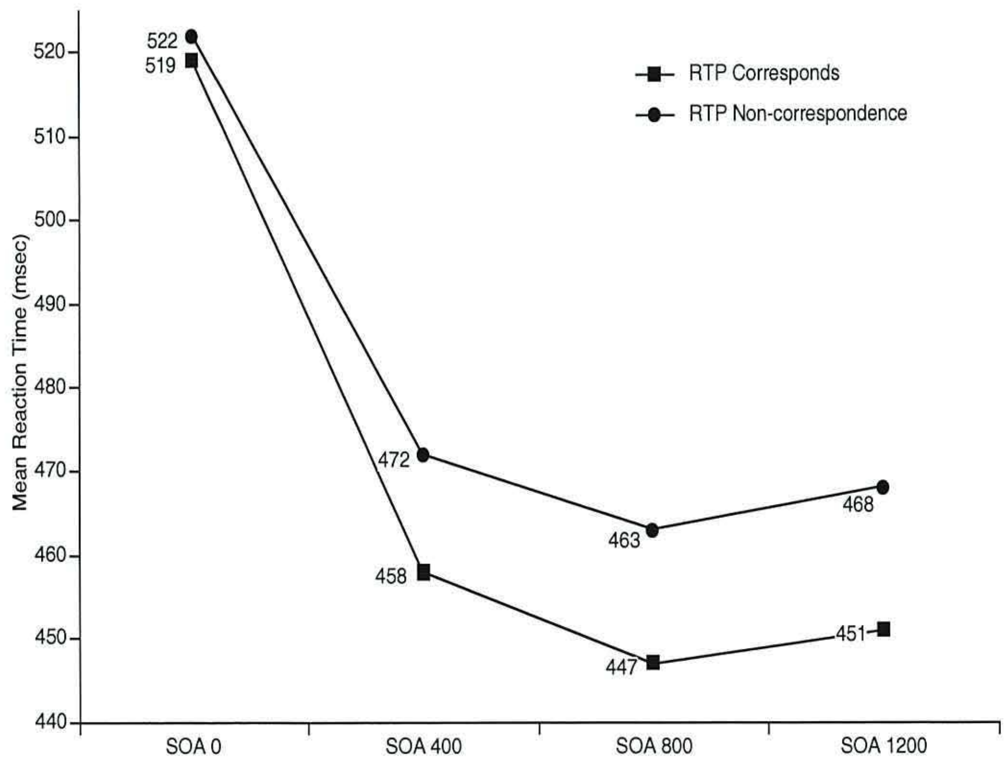


Figure 7.8 Showing mean RTs for RTP by Correspondence over SOA.

Figure 7.8 illustrating the interaction between $Corr_{RTP}$ and SOA, suggests that Orientation is not the only factor that may play a role in obtaining what might previously have been termed general Correspondence (or affordance) effects.

Effects of Orientation (affordance) - $Corr_{ORI}$

Main effects of $Corr_{ORI}$ were also shown to be significant. In Figure 7.9 below, the factor of RTP has been collapsed across Correspondence in order to isolate the $Corr_{ORI}$ effects.

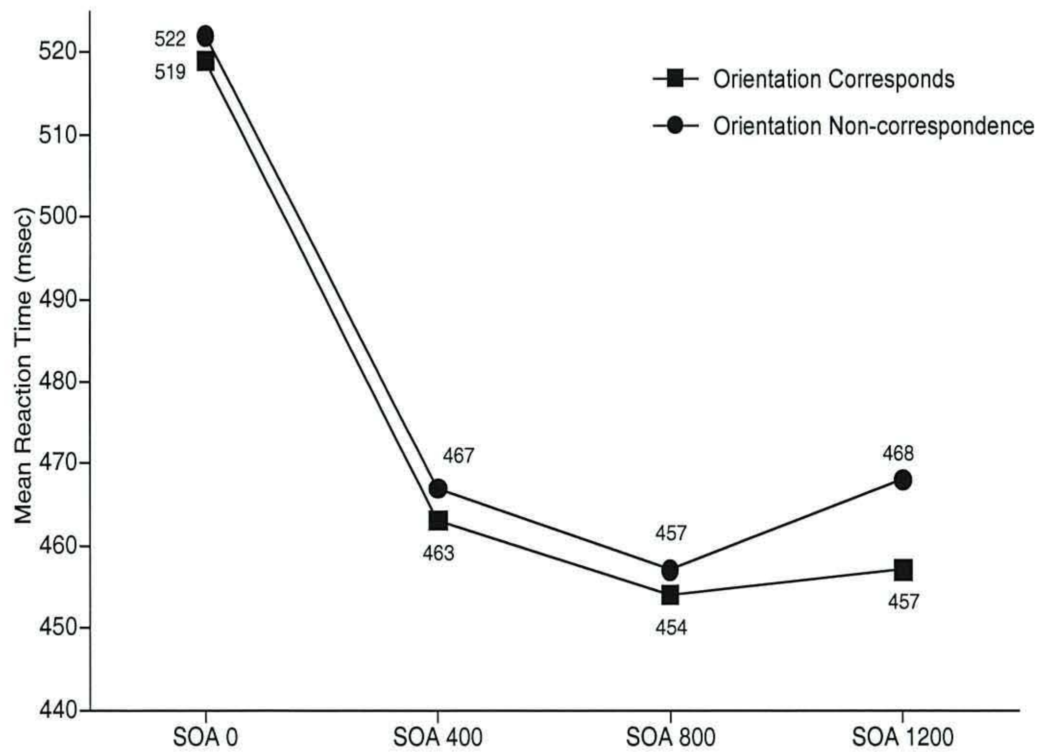


Figure 7.9 Showing mean reaction times for Orientation / Target side Correspondence.

Figure 7.9 illustrates the disparity between response times for trials in which the spatial relationship between the handle of the prime and the response side of space either Corresponded, or did not, regardless of any spatial relations between target locations relative to prime. Again, an advantage for $Corr_{ORI}$ over $NonCorr_{ORI}$ trials is evident, and as per the earlier analysis, is significant [$F(1,14) = 6.19$], $p = .020$]; mainly due to the trials at SOAs of 1200 ms ($d = 11$ ms). Interestingly, and in contrast to the relationship between $Corr_{RTP}$ and SOA, there was no significant interaction between $Corr_{ORI}$ and SOA; [$F(3,42) = 0.13$, $p = .942$].

7.2.3. Discussion

This experiment provides ample evidence to support the hypothesis that the spatial relations between an irrelevant object and its superimposed target can greatly influence or bias response selection. Overall correspondence effects have shown visually similar trends of correspondence for relative target position in terms of time-course and magnitude, as those elicited in all of the earlier experiments.

From these results, it is shown that Correspondence for RTP effects continue to peak at around SOAs of 800 ms, although right across SOAs the trend of facilitation for this type of Correspondence is robust. Where the relative target position and response side correspond, there is shown to be significantly faster response times than in Non-

Corresponding trials, regardless of the Orientation of the prime. However, where the prime Orientation also corresponds, there is again, significantly extra facilitation across SOAs, including that of 0 ms; thus, there is a additive effect of the $Corr_{RTP}$ and $Corr_{ORI}$ interaction in terms of response performance; where the Orientation corresponds with response side, *and* relative target position corresponds, then maximal benefits are observed.

The overriding question in this experiment was that of identifying and separating out those effects due to the frame of reference, from those resulting from affordance. It is shown that whilst the effects of both forms of correspondence are similar in trend, those for correspondence between affordance and target side ($Corr_{ORI}$) do not really become evident until the longest SOA of 1200 ms. In contrast, the effects of correspondence for frame of reference is evident much earlier in the time-course (between 0-400 ms) and continues to build up to 1200 ms. In summary, both time-course and magnitude differ between effects. What does the identification of these two apparently separate effects mean?

Certainly, the magnitude and time-course of the frame of reference effects more closely parallel those earlier results of Experiments 3-5. If we previously accepted that some form of abstract spatial coding produced the basis for the earlier correspondence effects, then it is now reasonable to suppose that the existence of other spatial asymmetries will also generate abstract spatial codes that will interact with any others, contributing to any effect where multiple correspondences exist. In order to isolate the RTP based phenomena, it was useful to look at those trials where the handle was absent from the pan (Neutral trials). In these trials, the now familiar trend of facilitation is fully maintained; in fact the magnitude of the effect slightly increases, and the effects continues building past 1200 ms. It is therefore difficult to label this an effect of affordance.

Extremely similar results were found for the trials with Orientation (affordance) when this factor was collapsed down over trials and analysed by RTP only. However, where RTP was collapsed down over orientation, we continued to observe significant effects of Orientation that could not have been attributable to a frame of reference factor. These effects followed a slightly different time-course with only slight benefits of correspondence until 1200 ms where the effects become clearly marked. The basis for the previous interpretation of results for Experiment 3-5 is questioned. Clearly, there is the possibility that the magnitude of any 'affordance' effects have been confounded (even overshadowed) by the frame of reference effects. However, what also seems clear is that correspondence effects previously attributable to the operation of the affordance continue to remain significant in their own right. The effects of correspondence in Experiment 2, where no frame of reference effect would have been likely (differing objects, no target) would fit nicely into this time-course scenario. Where responses were immediate (no judgement task) there were no Correspondence effects. However, when the judgment task was included, this effectively slowed down the response times to around 800 ms. This approximates the longer SOAs in the current experiment, where the effects of Correspondence for orientation become evident. In this delayed configuration of Experiment 2, the effect of correspondence was significant. Although these results do not shed any light on the nature of effects of affordance, they serve to both clarify the interpretation of earlier effects, and to throw some indication of the time-course of affordance effects.

More than anything, this experiment serves to highlight and strengthen the need for these types of experiment to be carried out within a perceptually balanced S-R environment using perceptually balanced stimuli. Perhaps in this way a more reliable form of affordance- evoked action may be measured.

Chapter 8

8. Acquisition of Affordance

8.1. Experiment 10 – Introduction

Previous experiments have shown that correspondence effects attributed to object affordance is susceptible to confounds, either from attentional effects due to perceptual segmentation, or by effects of target-prime spatial relationships. The design behind the two experiments in this chapter was driven by the need to tackle issues of both stimulus balance and prime-target spatial arrangement; however, the notion of irrelevant prime and imperative target was preserved.

Whereas earlier experiments used 'common everyday objects' as primes, Experiment 10 used horizontally symmetrical novel objects upon which the imperative target would appear at a perfectly central (horizontal) position in relation to both the prime and the screen itself. This design would serve two useful purposes; firstly, it would remove the possibility of any left-right frame of reference effect between the target and prime, (everything is presented centrally), thus separating any such effect from that of object affordance; secondly, it would tidy up the perceptual balance of the prime, separating affordance based effects from attentional cueing type effects.

A perceptual affordance, such as a handle or button may work by initially drawing attention to itself [1] merely through its physical features, that

---

[1] In the case of perceptual affordance the implication is that the physical characteristics of the handle, cue attention; this as opposed to affordance for utility where the affordance is seen as capturing attention through salience, see General discussion.

is, it's colour, texture, shape etc. This attention drawing may be used as a pre-cursor to affordance for utility, or perhaps attention is initially drawn to the affordance through its salience for action, based only on an observer's knowledge and experience of the object's action possibilities. In all probability, the two types of affordance are interdependent and inseparable. Certainly, at some early stage, attention needs to be drawn towards the 'business end' of an object, even where an object may be novel. Whether the affordance musters attention towards the action interface, or whether attention for the affordance catalyses action representation is unknown. As mentioned earlier, good affordances are designed to bring attention to the action interface.

This experiment, using novel symmetrical primes, should proffer no attentional bias, or indeed affordance, to the untrained observer. As a primary aim, Experiment 10 proceeds, in a more controlled way, to investigate the idea of objects evoking action. Each of four subject groups are trained to interact with four novel objects in a unique manner. The effect of the acquired affordance is subsequently measured using two different tests. The Attentional-cueing test determines where, on the irrelevant prime object, attention is at the time of response to an imperative target. A second, Evoked-action test attempts to measure any performance advantage that may be attributable to hand and/or wrist correspondence between prime affordance and the hand-wrist configuration required to respond to an imperative target.

8.1.1. Method

General Methodology

The design of the experiment required that sixteen participants attend a short 'training' session, to become familiar and practiced at making unique speeded hand and wrist responses to individually presented pictures of four novel objects. This was followed up with the (counterbalanced) administration of two tests, designed to evaluate the effects of the training in the two different ways described in the previous section. The study addresses whether an object (through training) can develop a particular affordance for action.

Participants

A sample of sixteen undergraduate students took part in this experiment; all were registered as full time undergraduate students at the University of Wales, Bangor; each received cash payment or course credit for their participation. All reported having normal or corrected to normal vision, and were unaware of the precise purpose of the study.

Apparatus/Stimuli

The same apparatus was used for both the training and testing phases of the experiment. Stimuli consisted of four two-dimensional, drawings of symmetrical objects (named Jack, Cube, Slider, and Sign; see Figure 8.1), each with dimensions of approximately thirteen cm high and eight cm wide. Two of the four prime objects were designed in greyscale only whilst the other two had an additional one colour fill, blue or green. Designed onto each of the images (hereinafter named objects) were two, 2 cm square images of buttons, one towards the top of the object and one towards the base, thereby providing an 'upper' or 'lower' button on each object.

When responding to an object presented on a touch screen, these buttons mimicked the pressing of a real button, both visually and audibly. In addition, the stimuli for the training phase consisted of simple animations (approx. twenty frames over 1000 ms) for each of the four objects. The animations depicted a movement or temporary change within the object as a result of pressing the 'correct' object button; the object always returning to its natural 'resting' state with the last frame of the animation. The bottom image of Figure 8.1 shows a typical still frame sequence of the 'Jack' object. This sequence ran twice, at speed, giving the impression of a Jack-in-the-box type of effect when the correct object button was pressed.

All images were presented on a 12-inch 'AppleColor' hi-res RGB 'touch-screen' monitor with a refresh rate of 15.058 ms, connected to a PowerPC 8500/120 computer using TouchStar™ touch screen software. The experiment was run on PsyScope version 1.2.2 software (Cohen, MacWhinney, Flatt, and Provost, 1993). Responses and timings were processed and recorded by the computer, and made through either the touch screen (movement time and button selection control, or through one of two (left and right hand) custom-made response effectors (see Figure 8.3) for reaction time and hand selection control.

Response effectors, used throughout all training and testing, comprised two custom-made (Technical department, UWB) Teflon coated metal boxes (30 x 20 x 40 cm) attached (Velcro) to a wooden baseboard (see Figure 8.3). A plastic joystick type response handle protruded from each of the boxes, facing towards the subject and aligned along the vertical plane (resting state). On top of each vertical response effector was a red response button. A simultaneous press of the left and right buttons served to initiate a trial (in all phases of the experiment). In the Attentional-cueing test, a simultaneous depression was also used to effect a response. In addition to the button press facility, the response handles could each be turned on their axes to 45 degrees right or left of vertical, thereby allowing two directional responses per effector (Evoked-action test); see upper Figure 8.2. Each box was positioned on a desktop, at elbow height to a seated subject, and centrally placed in front and below of the raised touch screen, in front of the participant's left and right hands. Both boxes were laterally centralised so that they were equidistant from the touch screen. The touch-screen was elevated to subject head height at a viewing distance of approximately 50 cm. All RT timings were calculated and recorded by the computer, and responses made through the effector configuration as described earlier.

Additional stimuli & apparatus – Evoked-action test

In addition to the four prime objects previously described, the Evoked-action test also utilised a set of four small overlay images as targets. Each target was approximately 2.5 x 12 cm and visually represented the required effector response relating to hand and wrist movement. These targets were randomly superimposed upon any of the four random 'objects' (Figure 8.2).

Additional apparatus & stimuli – Attentional-cueing test

This test utilised targets consisting of digit strings of size 14 bold '000' (no response) or '888' (speeded response). These targets were superimposed onto the buttons of prime images, and indicated whether a participant should withhold a response, 'No-go', or respond 'Go', by simultaneously pressing the two response buttons.

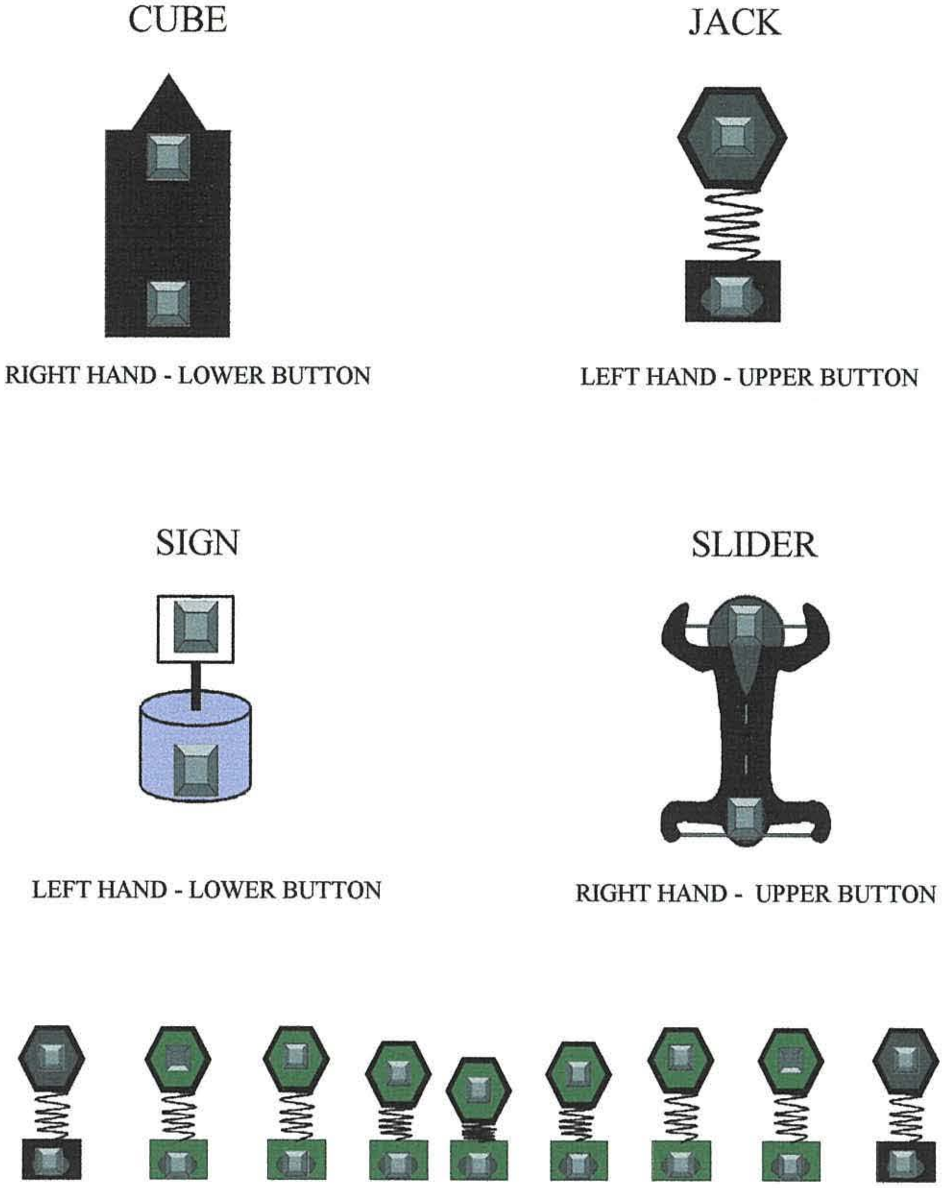


Figure 8.1. The top four images depict the objects used throughout all stages of the experiment. Each image carries two buttons. Only one of these buttons will be the 'correct' button for any one-subject group. The training phase instructs and practices the subject group on which button is the correct one for that group. The intention is that, for that subject, the object will develop a unique affordance, based on the hand and wrist configuration that is needed to make the button response during training. The wrist movement is interpreted as being the movement that achieves the Goal of the action (the button press). This same individual (by group) object-button mapping is subsequently used throughout both the Attentional cueing and Evoked action phases of the experiment, for each of the four groups. The lower part of the image depicts a sequence of animation for the 'Jack' object. Animation is used only in the training phase of this experiment.

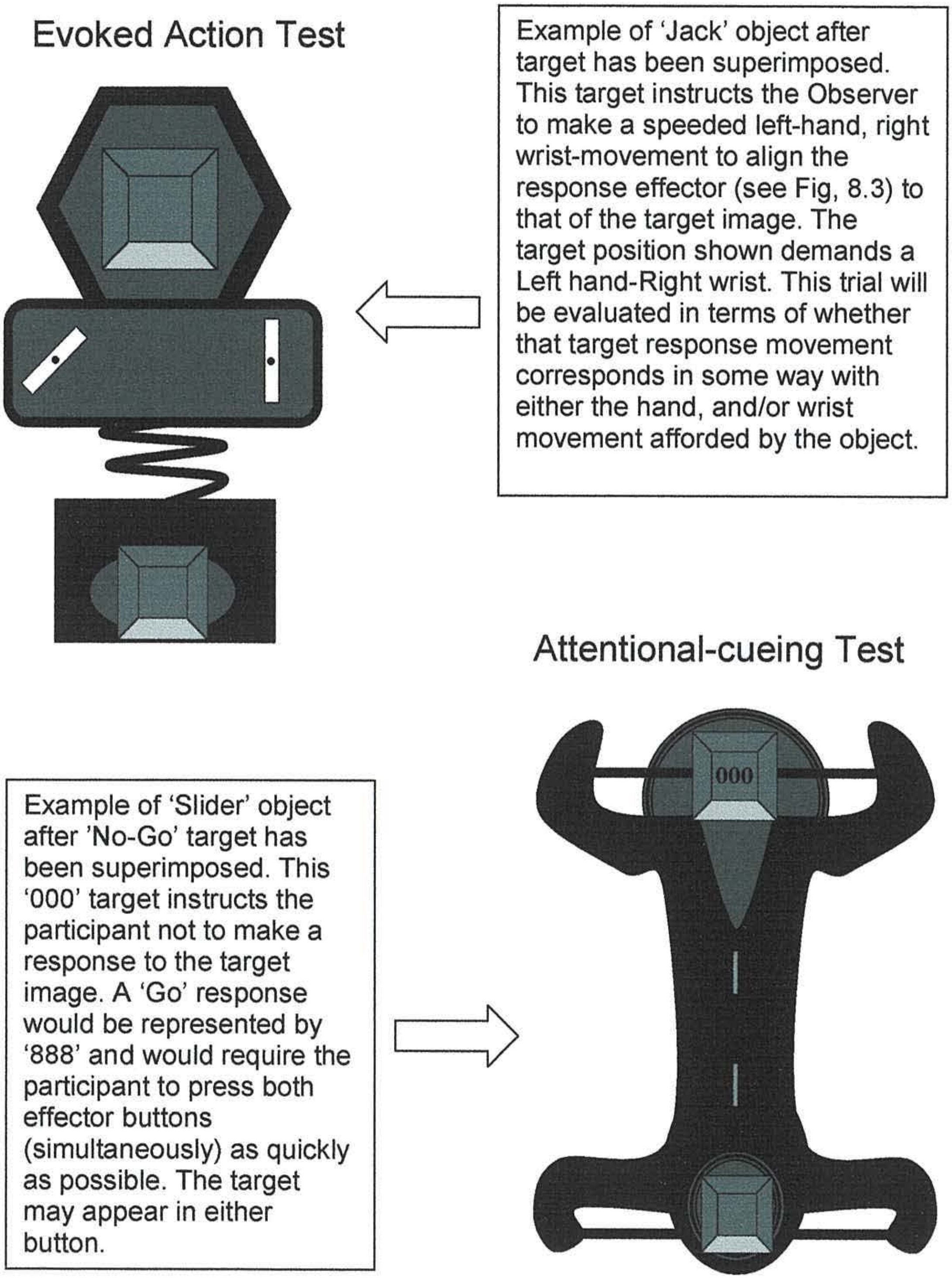


Figure 8.2 Examples of primes with superimposed targets for both the Evoked-action test (upper left) and the Attentional-cueing test (lower right). The shading on the button changes when the button is pressed, reverting to normal when released.

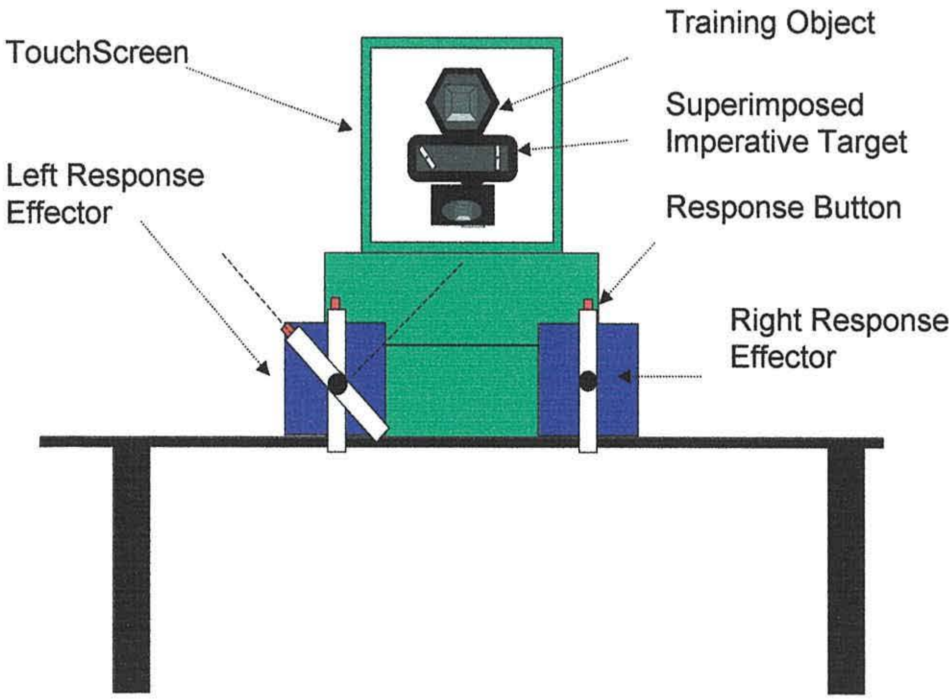


Figure 8.3. Experimental set up for training and testing. All images are displayed to a touch-screen. The resting position during training and testing is with left and right hands grasping the respective upright (white) handles. During training, RT is measured as the time to lift the responding hand from the red button, with movement time being the time to touch the screen in the correct place as defined by the object. Exactly the same response configuration is used in the Evoked-action test. The Attentional-cueing test requires participants to rapidly depress both red buttons when a 'GO' target is observed. The above screen display relates to a 'target' situation in the Evoked-action test. The superimposed target requires the participant to make a left hand, left wrist movement response. The 'extra' inclined white handle shows the position to which the participant is required to move the handle in order to effect a correct response. It is this movement that may have Correspondence (hand or goal) with the trained response to that particular (irrelevant) prime.

General design

Training – During training, a subject learned assigned responses to each of four novel objects over a forty-five minute training session. Correctly responding to a particular object was defined as using the correctly assigned hand (Left or Right) and pressing the assigned object button (upper or lower) on a touch screen. The sixteen subjects were assigned to one of four groups, each group being trained to respond to each object in a unique manner using either a left or right hand to press either a upper or lower button. Therefore, each object could be said to have a different affordance (hand-wrist configuration)[2] for each of the four groups.

Following the training session, both the Attentional-cueing and Evoked-action tests were administered, the order of testing, counterbalanced over participants.

Evoked action test design - The Evoked-action experiment was designed around a 2 x 2 x 2 within-subjects design, the dependant variable always being reaction time. The independent variables were a) responding Hand

[2] To avoid confusion, the description of the experiment for the training section refer to the hand action as "pressing the assigned button"; the evoked action experiment refers to the way that hand and wrist action used in response relates to the hand and wrist action used in training with that object, and interprets the wrist action in terms of achieving an end Goal. The attentional cueing experiment refers to within which button the target appears and whether this button was the same as that for which the participant was trained to respond to for that object; this trial then being interpreted in terms of correspondence with the Goal of the trained action.

(left or right); b) response Goal (left or right wrist action); and c) SOA[3] with two levels, either 200 or 800 ms. There were thus a total of 8 equiprobable experimental conditions. The method consisted of a screen centre presentation of one of the four "to be ignored" (random) prime objects. Following a random SOA, the imperative target appeared centrally superimposed onto the prime. Participants made a speeded response to this target with the hand and wrist movement depicted by the target configuration.

As all responses required a specific combination of hand and wrist movements, these movements could be interpreted according to their degree of correspondence with that afforded by the irrelevant prime for that trial. For example, where the prime afforded a top button, right hand response, this was the same as affording a right hand, left wrist response. In the same manner this response configuration directed by the target, was interpreted in terms of correspondence with the afforded Hand, the afforded Goal (wrist action), or a combination of both.

[3] Note that although the PsyScope timings for SOAs of 200, 400 800, and 1200 ms are reported throughout Experiments 10 and 11, in order to account for the touch-screen refresh rate of 15.058 ms., the actual timings should be read as 196, 392, 798, and 1190 ms., respectively. The SOAs reported in the text have been used to maintain continuity and be consistent with the timings for the previous experiments in the thesis.

Attentional-cueing test design – The Attentional-cueing test incorporated a 2 x 2 x 2 within-subjects design with RT as the dependant variable. The independent variables were a) target Button x 2; Upper or lower; c) Target type x 2, either '888' (respond), or '000' (don't respond); and d) SOA x 2; either 200 or 800 ms.; a total of 8 equiprobable conditions. There was an equal probability of 'go' and 'no go' trials. Again, participants were required to ignore the prime image and only respond to an imperative target by making a simple speeded button press with both hands in those 'go' conditions

Procedure

Training - Participants were shown an A4 card upon which was printed each of the prime images and instructions on how to respond to each. They were talked through the responses and told to study the card in an attempt to memorise the correct response to each object. Participants were required to sit, facing the eye level touch screen at a distance of approximately 50 cm, with left and right hands lightly grasping the left and right response effectors (respectively), causing the hands to rest in a upright fist position with the thumbs uppermost. This 'ready' position is that from which both the training as well as the experimental trials began. See Figure 8.3 for experimental layout.

A trial was initiated from the 'ready' position when the subject depressed both left and right effector buttons simultaneously (using the thumbs). One of the four prime objects appeared centrally on the screen upon a white background. (Each object subtended 9^0 of horizontal visual angle and 15^0 vertical at a viewing distance of 50 cm; these stimulus values remaining consistent throughout all stages of training and testing for both this experiment and Experiment 11.) The participant then made a speeded response to the object by lifting the assigned hand from the effector and pressing the correct on-screen button with the thumb, keeping the flat of the hand either on the top surface of the touch screen monitor (upper button) or on the underside of the monitor (lower button). For example, a right hand, upper button response required a right hand, left wrist movement.

Each training session consisted of 320 trials and lasted for approximately forty-five minutes. During the first fifty trials, participants were allowed to refer to the training card if uncertain of the required response. All participants were reminded to respond as quickly as possible at all times, throughout all phases of the Experiment. Throughout all training sessions, correct hand and button responses were rewarded with a short and positive animated action sequence of the object. Incorrect responses elicited a beep (incorrect hand) or 'bang' (incorrect button).

Evoked-action test procedure - The experimental environment was exactly the same for testing as it was for training. Participants were asked to adopt the 'ready' position as in training, and to initiate a trial by depressing both effector buttons simultaneously. This caused one of the four object images to be displayed full size at screen centre. After a randomly selected period of either 200 or 800 ms, a target appeared, centrally superimposed upon the prime object. As explained, this target indicated (symbolically) the required response; see Figure 8.2 (upper panel). Dependant on this indication, the participant speedily twisted either the left or right response effector, to either the left or right 45 degree position. [4] Incorrect responses were subsequently recorded as errors. All participants completed 320 trials in each testing session.

Attentional-cueing test procedure - Participants adopted the ready position with each hand covering the respective effector buttons. A trial began by the participant simultaneously depressing and releasing both response buttons. This action caused a one cm square red cross to be displayed at screen centre for a period of 1500 ms. Participants fixated this cross and awaited

---

[4] As the button to be pressed is always the end Goal of any afforded action, analysis for the Evoked-action test would be in terms of correspondence between the hand-wrist response configuration dictated by the imperative target, and how this configuration relates to the Hand and the Wrist action (upper or lower button press) afforded by the prime. This wrist action is therefore referred to in terms of correspondence with the action Goal (pressing the button).

the target. After 1500 ms one of the four random prime images appeared at screen centre. Following an SOA of 200 or 800 ms, a target appeared, superimposed onto either the Upper or Lower object button (see Figure 8.2 (lower panel). If the stimulus appeared as '888', the participant responded as quickly as possible by depressing and releasing both effector buttons simultaneously. Where the stimulus appeared as '000", participants made no response; the trial automatically timing out after 1500 ms.

8.1.2. Results

Training - All RTs greater than 5000 ms and response errors were removed from the dataset (0.4% of all trials). Five seconds was considered adequate time in which to make a simple touch-response to a target. Errors accounted for approximately 8% of training trials; within this error, approximately 76% were due to responses using the incorrect hand. The remaining 24% of error occurred where trainees responded with the assigned hand, but pressed the incorrect button. Figure 8.3 below illustrates response error during training, by type and by quartile. As might be expected, the largest decrease in error occurs after the first quartile where participants have become more confident in their responses. This trend is also reflected in Figure 8.4, where the largest effect of training appears in the first quartile.

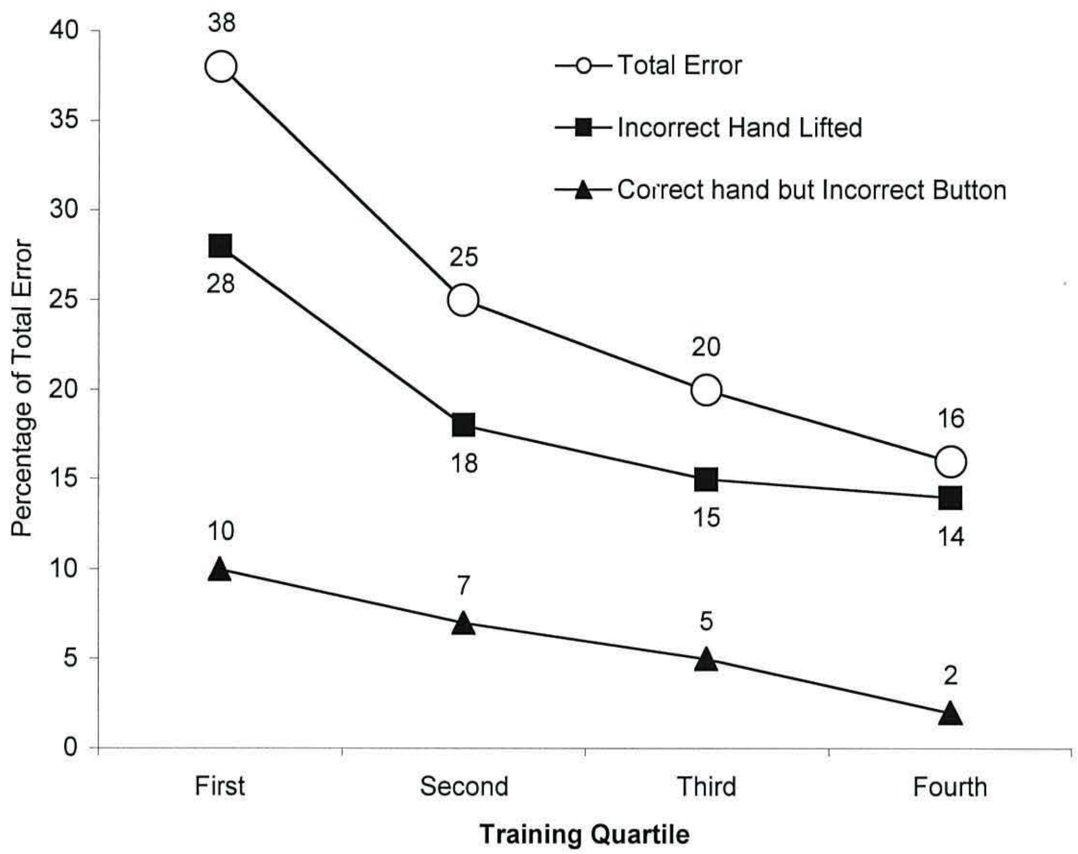


Figure 8.3. Error trials during training showing error types and frequency over time.

Further analysis only necessitated the production of Figure 8.4 showing the gradual improvement in response times as a function of training. A feature of this data is the large improvement during the first training quarter, and the levelling out thereafter - probably reflecting the ease at which the task could be learnt.

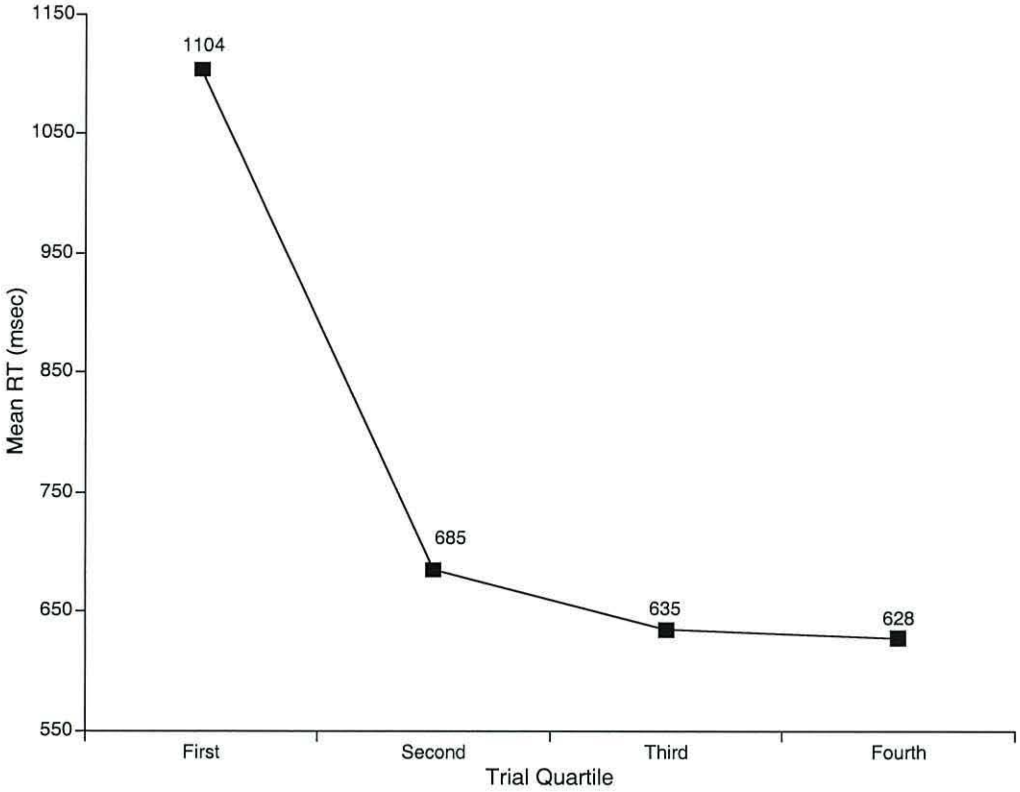


Figure 8.4. Mean RT data from training sessions by quartile. Each quartile represents 80 trials. There were no breaks between quartiles.

Evoked action test data - Anticipations (those responses less than 200 ms); those RTs greater than 1000 ms (3.6%of all trials) were excluded; as were those due to the iterative (3 standard deviation) process described earlier.

Evoked-action error data – response errors (86) represented 1.6% of all trials. Due to the relatively small number of errors, these were categorised by and Goal correspondence and are shown in Figure 8.4a below.

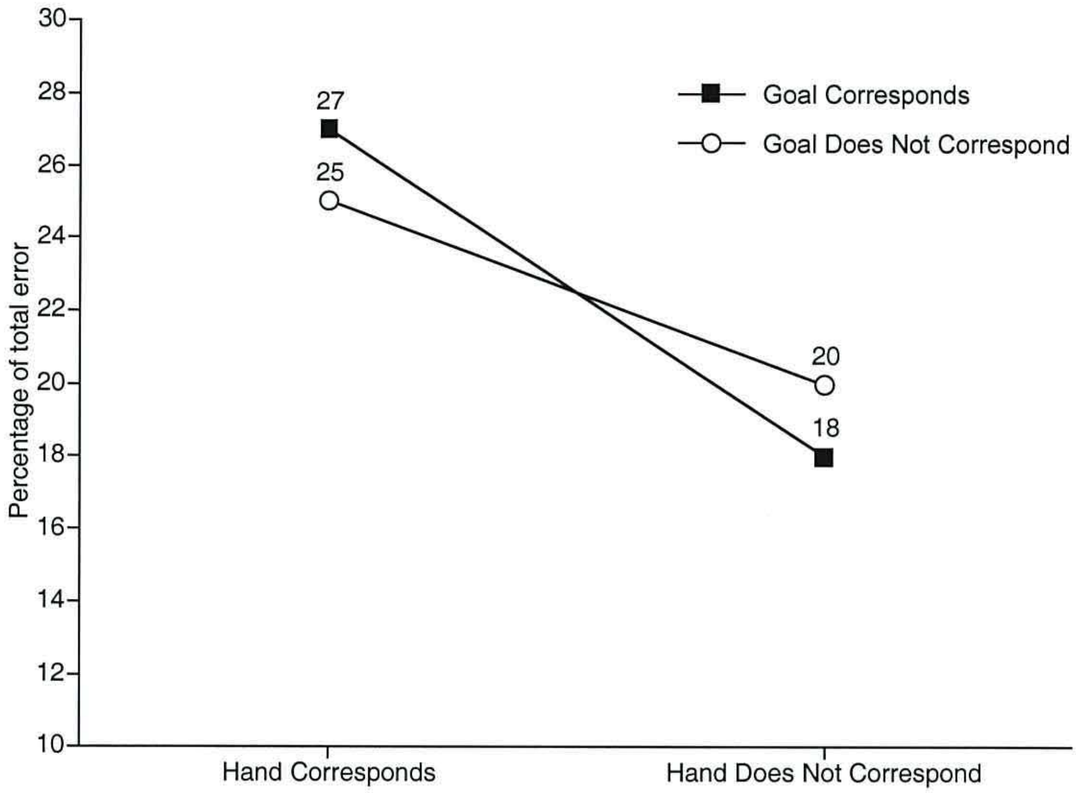


Figure 8.4a Illustrating percentage of evoked-action response errors over Hand and Goal correspondence.

The above figure shows generally less errors for trials where the responding hand does *not* correspond to the action afforded by the object, with slightly less error where the Goal does correspond. Most errors occur where both Hand and Goal correspond. Note that the differences between percentage error for the conditions represent only a very few actual trials. For this reason, further statistical analysis appeared neither useful nor informative.

Evoked action reaction time analysis – The remaining correct data was arranged in terms of levels of Correspondence between the response configuration directed by the target, and the response configuration afforded by the prime[5]. Analysis of the data showed practically no difference in mean RTs for those trials where the responding Hand corresponded (to the Prime) with all other conditions collapsed (*M*=565: *SD*=70.9), compared to those Non-Corresponding trials (*M*=566: *SD*=69.2). Similarly equivalent RTs were obtained for those trials where the Goal (button) Corresponded (*M*=566: *SD*=70.9), compared to when it did not (*M*=565: *SD*=68.2). Overall, responses at SOAs of 200 (*M*=573.8: *SD*=67.56) were considerably slower than at 800 (*M*=557.7: *SD*=70.59), but within correspondence, this difference remained relative. For this reason, and for clarity, the levels of SOA have been consolidated in Figure 8.5 below.

Figure 8.5., showing mean RTs for Hand and Goal correspondence, illustrates the slight facilitation in RTs for those trials where both the responding Hand and the Goal corresponded (*M*=563), with that afforded by the prime, over those times where only the Hand corresponded (*M*=567).

---

[5] As a reminder; a trial with a target that required a right hand, right wrist (lower button) action, where the prime *afforded* (through training) a right hand, lower button press, this would result in Correspondence for the factor of Hand, and Correspondence for the Factor of Goal.

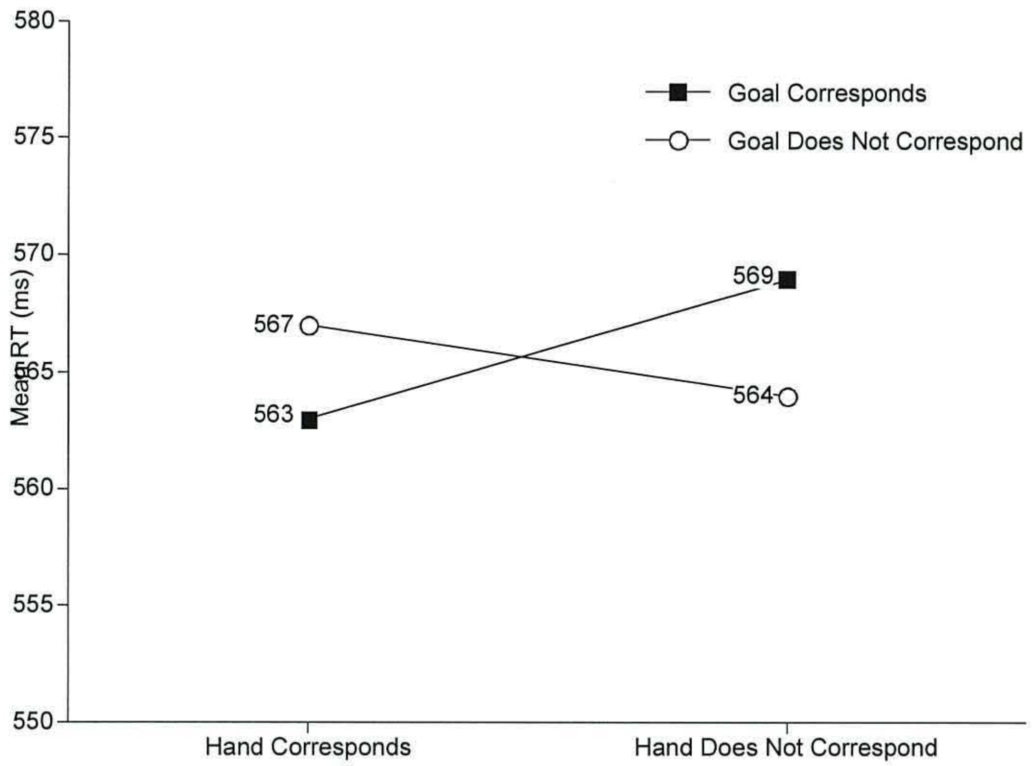


Figure 8.5. The figure shows the interaction between Hand and Goal Correspondence collapsed over SOA.

Overall times for 'Hand and Goal' correspondence differed little from those times for 'Hand and Goal' non-correspondence.

Data was subsequently processed using a 2 x 2 x 2 within-subjects ANOVA, examining the factors of correspondence for Hand, Goal, and SOA. Results showed a significant main effect of SOA; F (1,15)=15.38, p =.001, with overall, faster responses at SOA of 800 ms. There where no main effects for Hand; $F(1,15)=26.74$, $p=.747$; or Goal; $F(1,15)=9.77$, $p=.844$. There were no significant interactions.

Attentional-cueing results – Those responses greater than 1000 ms and less than 200 ms (anticipations) were removed from the data set (1.5%). Data was organised in terms of Goal correspondence, and response errors representing 2% of all trials, were removed. Response errors (104) accounted for 2% of trials. Initial analysis showed these errors to be evenly distributed over SOA and Goal correspondence. However, 73% of errors were for Lower button responses compared to 27% for Upper responses; equivalence of error for Goal correspondence and SOA was maintained across button position (see Figure 8.5 below).

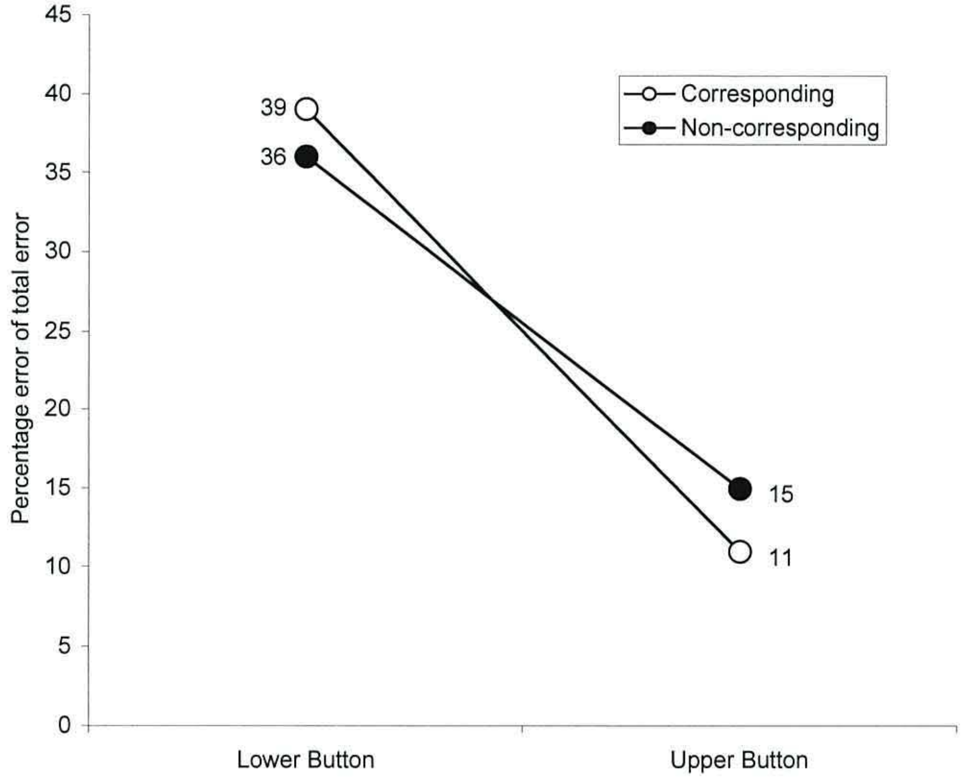


Figure 8.5. Illustrating response *error* over Goal correspondence and Button; there was no bias for SOA over Goal or Button, therefore not shown.

Reaction-time analysis - Responses to Goal corresponding Buttons were faster (*M*=435: *SD*=55.5) than to non-corresponding Buttons (*M*=441: *SD*=57.7). Responses to Upper Buttons (regardless of correspondence) were faster (and more accurate; *M*=423: *SD*=48.7) than to Lower Buttons (*M*=453: *SD*=59.8). Trials at SOAs of 800 (*M*=428: *SD*=55.3) produced faster response times than those of 200, (*M*=448: *SD*=56.2).

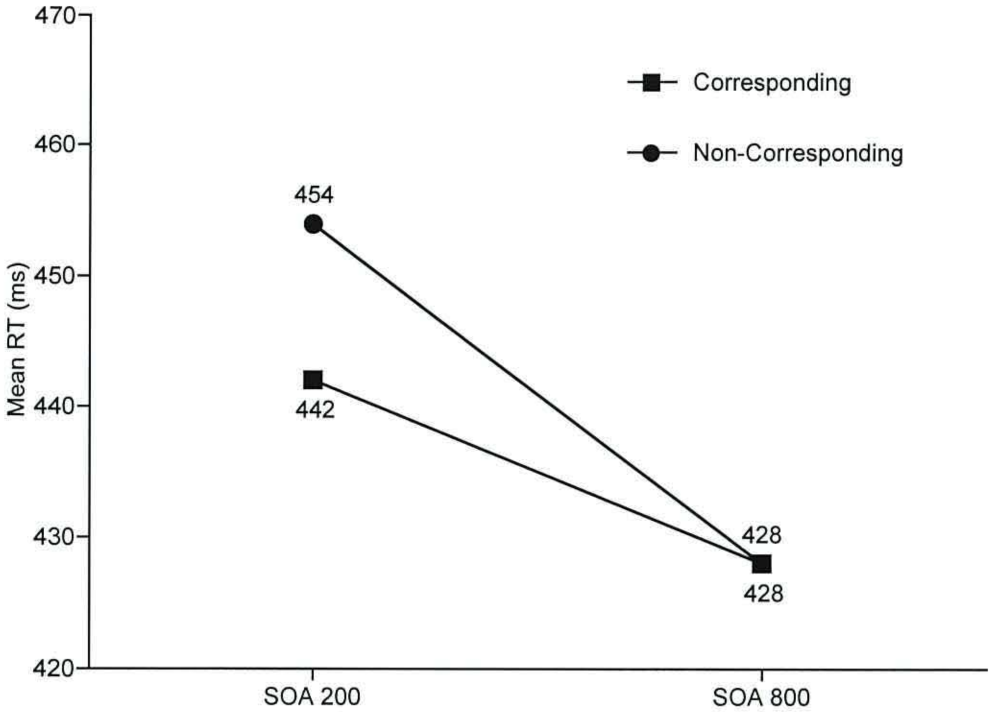


Figure 8.6. Mean RTs by Correspondence and SOA

Figure 8.6 shows the integration of the effects of Goal correspondence and SOA. A further sub-analysis is shown in Figure 8.7 on the following page, where the trials are re-classified in terms of Upper or Lower Button response.

A three-way within subjects ANOVA investigated the factors of Goal correspondence (Corresponding Vs. Non-corresponding), Button (Upper Vs. Lower), and SOA (200 Vs. 800 ms). The analysis revealed significant main effects for SOA; $F(1,15)=21.78$, $p<.001$, and Button; $F(1,15)=12.31$, $p=.003$. The effect for Goal correspondence was not significant, $F(1,15)=2.14, p=0.16$. There was a significant interaction between Goal correspondence and SOA; $F(1,15)=6.13$, $p=.026$. A three-way interaction between Goal correspondence, SOA, and Button was just short of significance at the .05 level; $F(1,15)=3.10$, $p=.09$.

The interaction between Goal correspondence and SOA was further investigated using paired t-tests. These showed no significant difference between Goal corresponding ($M=428$) and Goal non-corresponding ($M=428$) trials at 800 SOA, $t(15)=0.16$, $p=.872$ (see Figure 8.6). However, at 200 SOA, there were significantly faster RTs for Goal corresponding ($M=442$) over Goal non-corresponding trials ($M=454$), $t(15) = -2.51$, $p=.024$.

Figure 8.7 illustrates the difference between Goal corresponding and Goal non-corresponding trials for Button, grouped by SOA. RTs for targets appearing in the Upper buttons were overall faster that those for the Lower Buttons. Upper Button Goal corresponding trials were overall faster than Upper Button Goal non-corresponding trials, but this difference did not attain significance in either SOA [$t(15) = -.41$, $p = 0.686$, $t(15)= -.62$, $p = 0.545$, respectively for SOAs of 200 and 800 ms].

Lower Button trials showed differing trends between SOAs. That is, at 200 ms SOA, Lower Button Corresponding trials ($M=456$) were faster than Lower Button non-corresponding trials ($M=474$), this difference not quite reaching significance, $t(15) = -1.76$, p=.098.

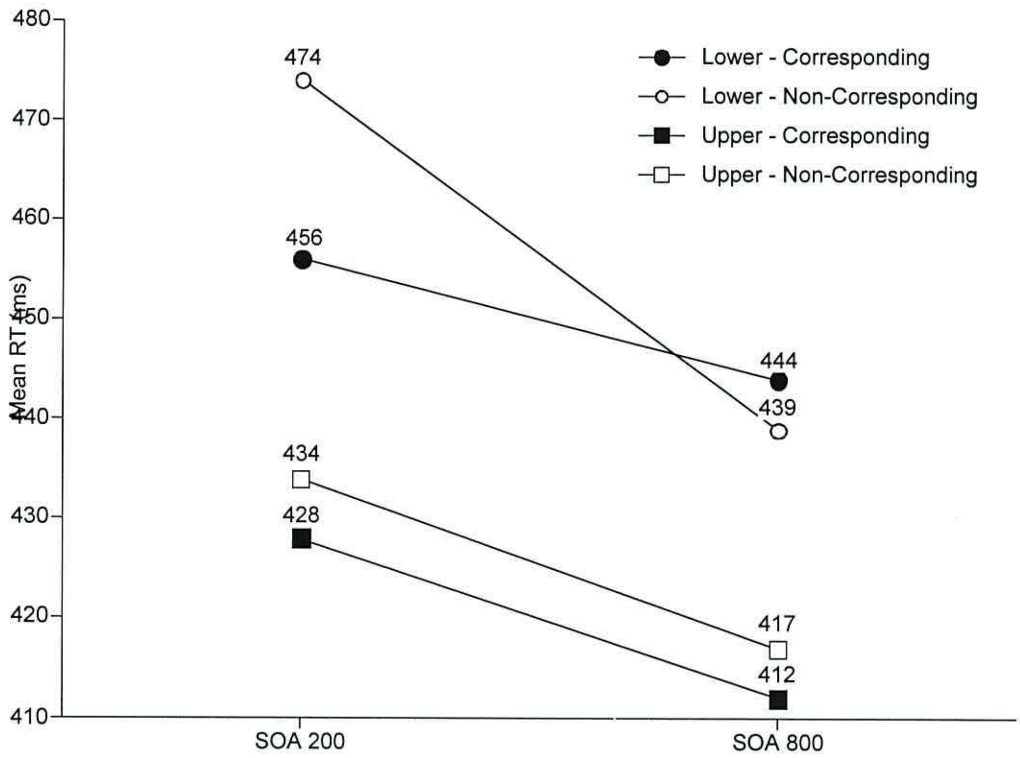


Figure 8.7 Mean RT for Upper and Lower targets by Goal correspondence and SOA

On the other hand, at SOAs of 800 ms, Lower button Corresponding trials (*M*=444) were slower than Lower button Non-Corresponding trials (M=439) this difference not being significant $t(15) = 0.8$, $p=.436$. The indication is that some form of inhibition may be operating at the longer SOAs of 800 ms for those targets appearing in the lower visual field, resulting in slower (non-significant) responses for Goal corresponding over

Goal non-corresponding trials. This is an interesting result inasmuch as it suggests that attention is being drawn to the affordance, in the form of facilitation at 200 ms, and possible inhibition at the longer SOA of 800 ms.

8.1.3. Discussion

This experiment was designed to overcome various methodological shortcomings highlighted in the previous experiments, whilst still retaining an experimental platform upon which effects of object affordance could be investigated. A major issue addressed by the present design is that of neutralising the potentially confounding, left-right asymmetry inherent in the prime objects. A second issue was the possible effect of the frame of reference between a prime object and the imperative target. These two issues were addressed by the design and use of novel symmetrical objects as primes. However, the above effects were shown to confound the results of Experiments 3, 4, and 5, and were specifically explored in the previous Experiment 9. The objects used in this experiment not only met the criteria for perceptual balance and centred prime-target reference frames, but also necessitated a form of human interaction in order to acquire affordance for action.

The hypothesis was that, if affordances, as conceptualised in the introduction, were the product of human interaction with the object, and not solely a product of attention, then these novel objects would, through training, acquire and demonstrate effects of affordance-based correspondence. This hypothesis was only partially supported. The training was shown to be effective inasmuch as overall performance improved significantly.

In the Evoked-action test, it was expected that, where the response required the same hand-wrist movement as that afforded by the prime object, there would be significant effects of Correspondence. Results did show a slight (4 ms) facilitation for those trials where the hand and goal corresponded but a similar amount of facilitation was also observed where the hand did not correspond, but the wrist did. In this light, the Evoked-action test failed to produce any strong evidence for affordance-based correspondence effects through training.

In contrast, the Attentional-cueing test produced more encouraging results. Again, whilst there was little difference in frequency of errors between corresponding and non-corresponding trials, there was a substantial improvement in response times for trials where the target appeared in an afforded (through training) location; this being interpreted in terms of correspondence for the goal of the afforded action. Further analysis identified differing patterns of correspondence effect dependant upon whether the target appeared in a lower or upper button (visual field) and the

SOA. Responses to targets appearing in the upper fields produced overall facilitation for correspondence over both SOAs. However, responses to lower targets, showed facilitation for correspondence only at 200 ms SOA. At 800 ms, SOA there appeared a reversal of effect, similar to that of inhibition of return.

The inhibitory pattern, although non-significant, suggests that attention goes to the affordance. Generally, when the cue-target SOA is shorter than 150-200 ms. (as in the shorter SOA here), responses are faster for targets appearing at the cued (corresponding) location than for targets appearing at the uncued (non-corresponding) location. This performance enhancement on corresponding 200 ms SOA trials indicates that the cue (affordance) summoned attention to its location. However, when the SOA was 800 ms, responses were slower for targets appearing at the cued (corresponding) location than for targets appearing at the uncued (non-corresponding) location. This time course is consistent with the time course of the typical IOR effect (e.g. Maylor & Hockey, 1985). The possibility of inhibition of return operating for targets appearing in the lower button also falls in with the idea that the lower visual field is more involved or biased towards visuo-motor operations in peri-personal space (action based), those upper field operations more biased to visual search and orienting type tasks (e.g. Previc, 1998).

In summary, the Evoked-action test produced no significant differences in response performance as a function of correspondence between the action afforded by the prime and the target directed hand-wrist configurations required to effect a response. It is considered probable that the training administered to participants may have been inadequate, in terms of duration, complexity, and perhaps method of application. Although the training was sufficient to significantly improve task performance to the objects, perhaps it was insufficient to produce a habituated response, considered to form the basis of an affordance.

Thus, one issue arising from comparisons of results between the two tests is why the same training should produce an effect in one and not the other. Perhaps the Evoked-action test (involving action planning) may have required a longer SOA for the effects of correspondence to build up, as in the earlier Experiments 3,4, 5, and 9. In support of this is the difference in the mean RTs between the two tests, approximately 100 ms faster for the Attentional-cueing test.

In summary, affordances may operate both at an early stage, to capture attention; and at a later stage, in order to facilitate action execution. It is possible that under the present experimental conditions (very short training) the affordance of these novel objects was of insufficient 'strength' to facilitate the motor implementation of the action.

In a final attempt to better demonstrate affordance acquisition through training with novel objects, the next experiment utilised a longitudinal methodology, where participants were trained over a longer period of eight training sessions. It was anticipated that more extensive training with the objects would enhance effects of correspondence in both the Evoked-action and the Attentional-cueing tests.

8.2. Experiment 11 – Introduction

This experiment follows on, mainly as a result of inconclusive Evoked-action results in the previous Experiment 10. It will also provide an opportunity to replicate and consolidate the Attentional-cueing effects of this same experiment. The design is very similar to that of Experiment 10, but is now longitudinal, to allow for extended training and testing over a period of time. In this way, it is hoped to mimic the way that object affordance is established in the more natural environment.

8.2.1. Method

Participants

A sample of four postgraduate students took part in this experiment; all were registered as full time Ph.D. students at the University of Wales, Bangor, and each received cash payment for their participation. All reported having normal or corrected to normal vision, and were unaware of the precise purpose of the study.

Apparatus/Stimuli

Stimuli - As in Experiment 10, the experiment was partitioned into a training phase and a testing phase; the equipment used was common to both. Stimuli consisted of the same four two-dimensional, drawings of symmetrical objects (named Jack, Cube, Slider, and Sign) as used in the previous experiment. All apparatus and stimuli were identical to that used in Experiment 10.

Design

This was a longitudinal study consisting of three testing phases interspersed with two (four session) training phases. The design incorporated the following sequence of training/testing;

- Friday pre-training test session where each of the four Subjects completed the Evoked-action, and Attentional-cueing tests.
- A block of training sessions administered on each day Monday to Thursday followed, with another Friday test session for the same Evoked-action and Attentional-cueing tests.
- Another Monday to Thursday block of daily training sessions, with a final Evoked-action, and Attentional-cueing test on Friday.

The whole experiment therefore, spanned fourteen days, with average session length being twenty minutes. Training was administered in the same manner as Experiment 10, the only difference being in phasing eight sessions over a period of fourteen days, rather than one. All other elements of training presentation, application, and data collection, remained the same.

The Evoked-action and Attentional-cueing tests remained identical to those described in the previous experiment.

Procedure

The procedure for each phase of the experiment was identical to that of the single phase Experiment 10.

8.2.2. Results

Training - All RTs greater than 2000 ms and response errors were removed from the dataset. This stage of the analysis did not require the training data to be analysed further than the production of Figure 8.8 showing the gradual improvement in response times as a function of training. A feature of this data is the steady improvement in performance over the eight sessions. This can be compared to the sudden increase in performance during the first quartile of training in Experiment 10.

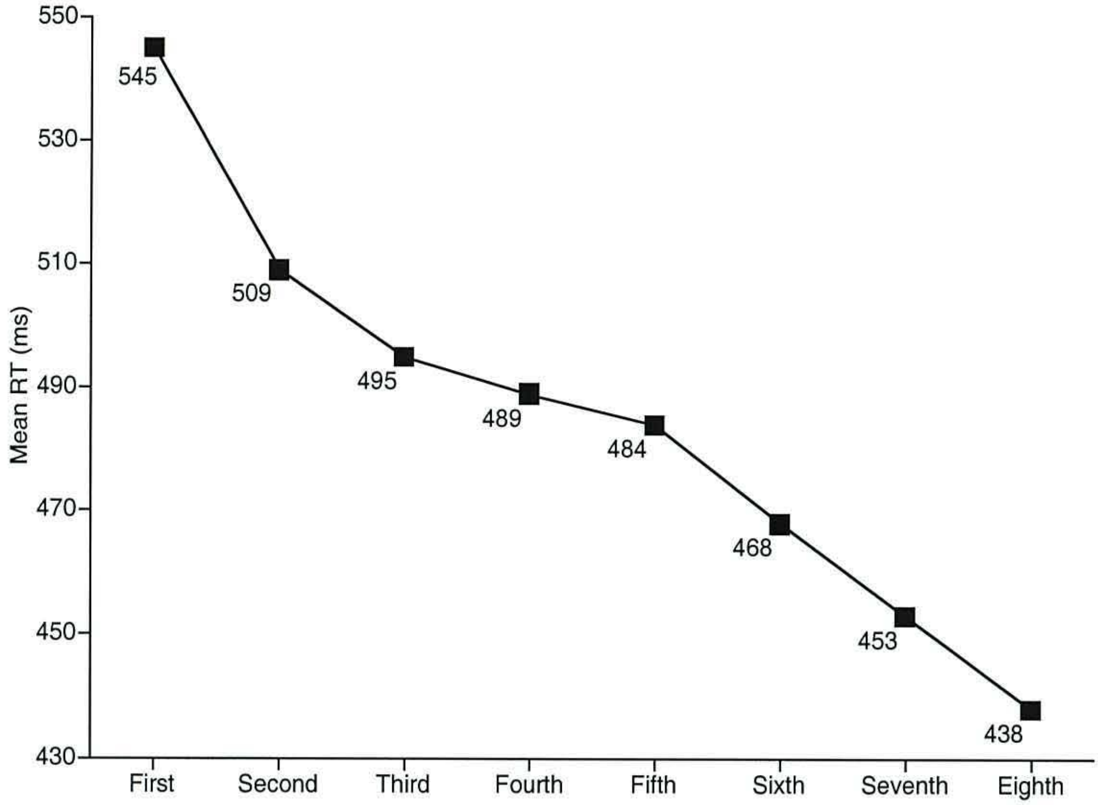


Figure 8.8. Mean RTs for each training session over eight days

Evoked-action test - Anticipations (RTs less than 200ms), RTs greater than 1000 ms, and response errors were removed from the dataset. These exclusions represented approximately 4% of all trials. The remaining data was rearranged in terms of Hand correspondence and Goal correspondence, in a similar manner to that of Experiment 10.

Evoked-action error data – Error data alone accounted for 2.5% of all trials. Errors relating to testing carried out in the period prior to any training accounted for 52% of these errors. As these errors were made in the pre-training period, this 52% (amounting to 52 actual errors) does not lend itself to any useful analysis relating to the experimental hypothesis, and are therefore excluded. The spread of the remaining 48% are shown in Figure 8.8a.

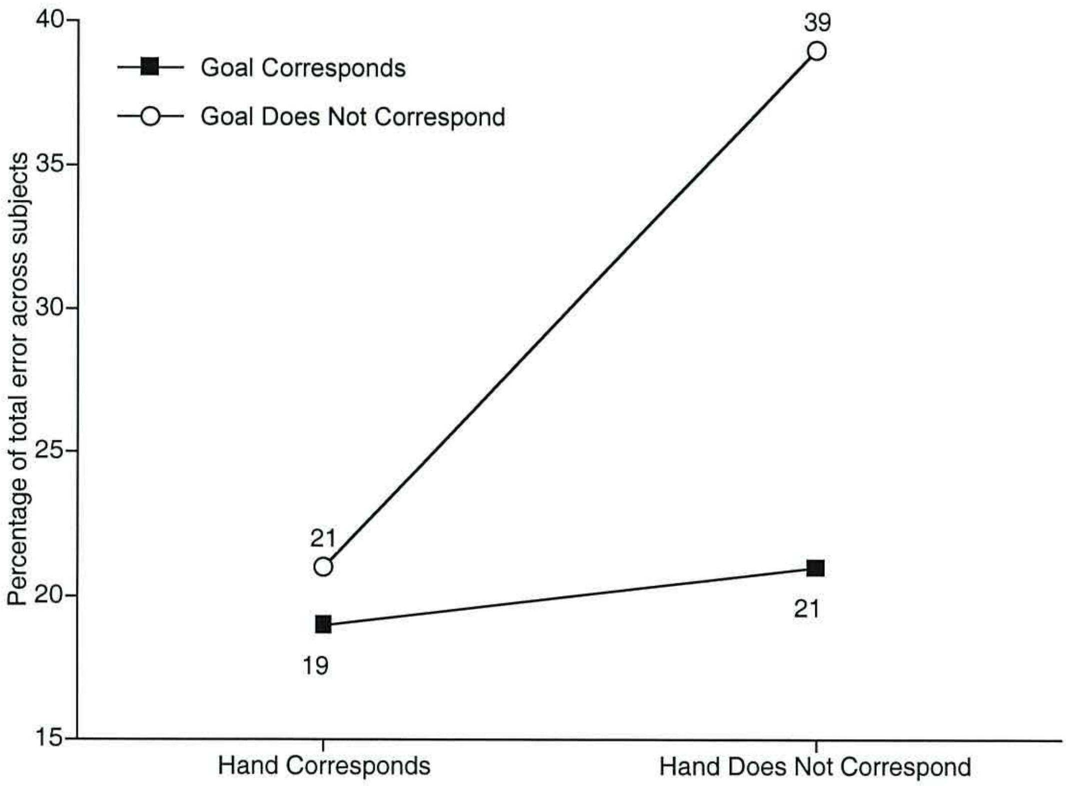


Figure 8.8a Showing Evoked-action errors collapsed over subject; post training runs only.

Figure 8.8a shows a lower frequency of error where both the responding Hand and Goal both correspond, and where the Hand corresponds but not the Goal. Errors increase considerably in those trials where neither the responding Hand nor Goal corresponds. In should be noted that the 18% increase in error for Hand and Goal non-correspondence only represents an absolute value of 8 actual errors. For this reason, an analysis of error by participant is not processed; suffice to state that over the four participants, percentage of total errors were calculated as 15%, 60%. 17%, and 8%. All errors were evenly spread across SOA.

A WS analysis of error by Hand correspondence, Goal correspondence, and SOA, failed to show any significant main effects or interactions for either Hand correspondence [$F(1,3) = 1.822$, p=.270], Goal correspondence [$F(1,3) = 1.238$, p=.347], or SOA[$F(1,3)$ =.601, p=.495].

Evoked-action RT data - Figure 8.9 below shows the arrangement of reaction time data by Correspondence for Hand and Goal with the factor of SOA collapsed down. As per Experiment 10, RTs for SOAs of 800 ms were considerably faster (M=517.8: SD=94.48) than for SOAs of 200 ms (M=539.2: SD=104.7). However, this difference was evenly distributed over Correspondence, resulting in no real difference in Correspondence effects over SOA.

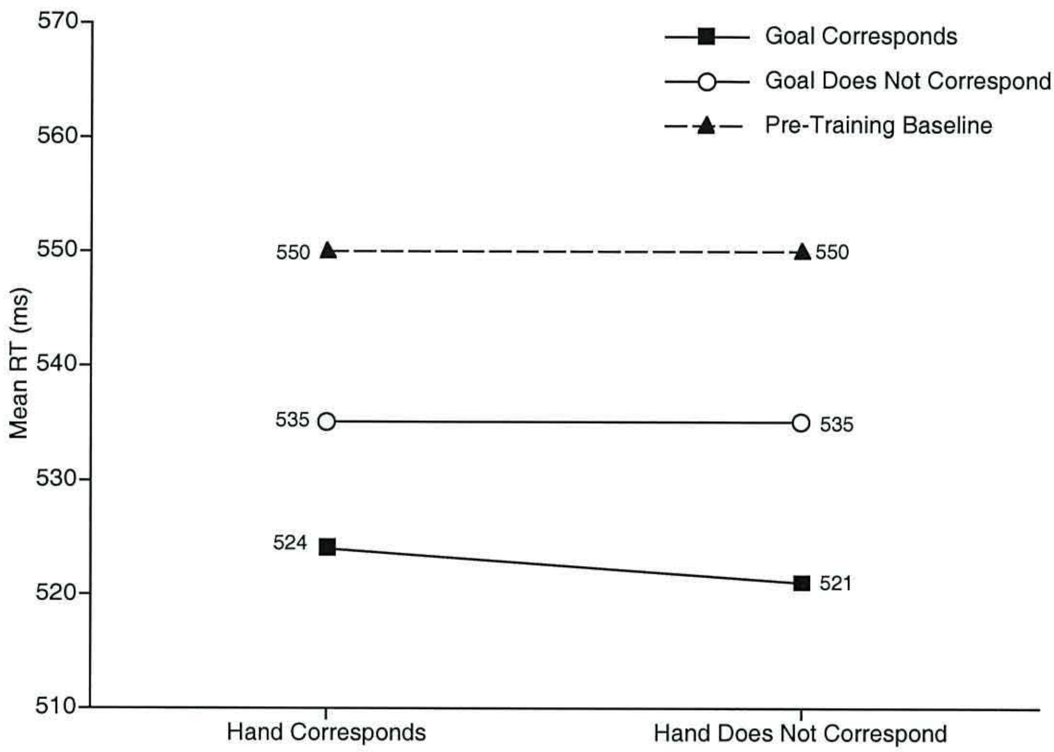


Figure 8.9 The figure shows the interaction between Hand and Goal Correspondence collapsed over SOA. The data shown is from combined results of both testing sessions mid and post training.

Figure 8.9 shows mean RTs for Pre-training trials to be considerably slower than the same trials after training. After training there is seen to be a major reversal of the pre-training results, particularly for those trials where the afforded Goal corresponds to the response configuration directed by the target. In the post-training sessions there is facilitation for trials where the action Goal Corresponds, irrespective of Hand Correspondence. In trials where the responding hand Corresponds with the afforded action then responses are faster when the Goal also Corresponds (*M* = 524), than when it does not (*M* = 535). This facilitation in response times due to Corresponding Goal is maintained even over conditions of Hand Non-Correspondence.

A 2 x 2 x 2 within subjects ANOVA investigating factors of Hand x 2, Goal x 2, and SOA x 2 (200 or 800 ms), showed a significant main effect for Goal, $F(1,3) = 11.20$, $p=.044$, reaction times to those trials where the action Goal corresponded being significantly faster than when they did not, irrespective of responding Hand. There was no main effect of Hand; $F(1,3) = 23.40$, $p=.560$; or SOA, $F(1, 3) = 5.41$, $p=.102$. There were no other main effects or interactions.

Attentional-cueing results - Anticipations (RTs less than 200ms), RTs greater than 1000 ms (representing 0.3% of all trials), and response errors (2%) were removed from the dataset. Data was then processed using the previous iterative process to remove outliers.

Attentional-cueing error data - Error data (2%) was negligible with 50% of these errors derived from one participant, compared to 5% from another. 62% of errors were responses to for Corresponding trials compared to 38% for Non-Corresponding, spread equally across SOAs and objects. Figure

8.9a below shows the distribution of error across participants, Correspondence and SOA.

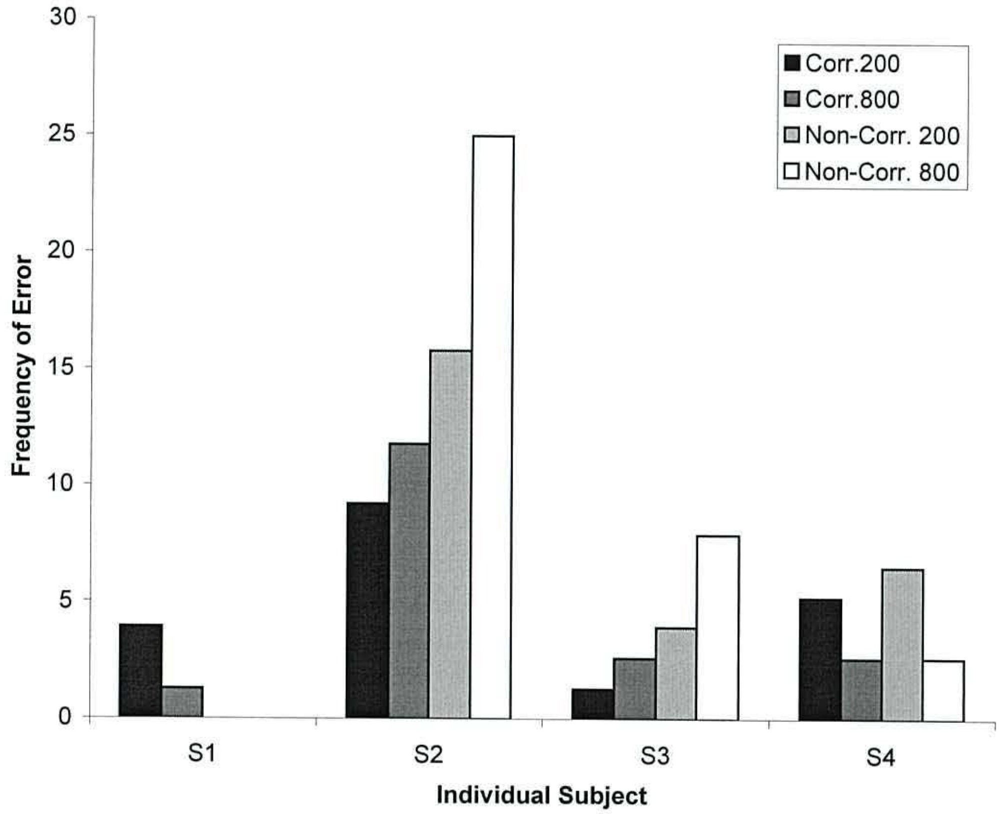


Figure 8.9a. Frequency and spread of errors across participant for the Attentional-cueing task.

The remaining data was rearranged in terms of correspondence between the response afforded by the Prime, (the Goal of the afforded action), and the imperative target location, i.e. Upper or Lower Button. Figure

8.10 shows the data for each testing session before, during and post-training.

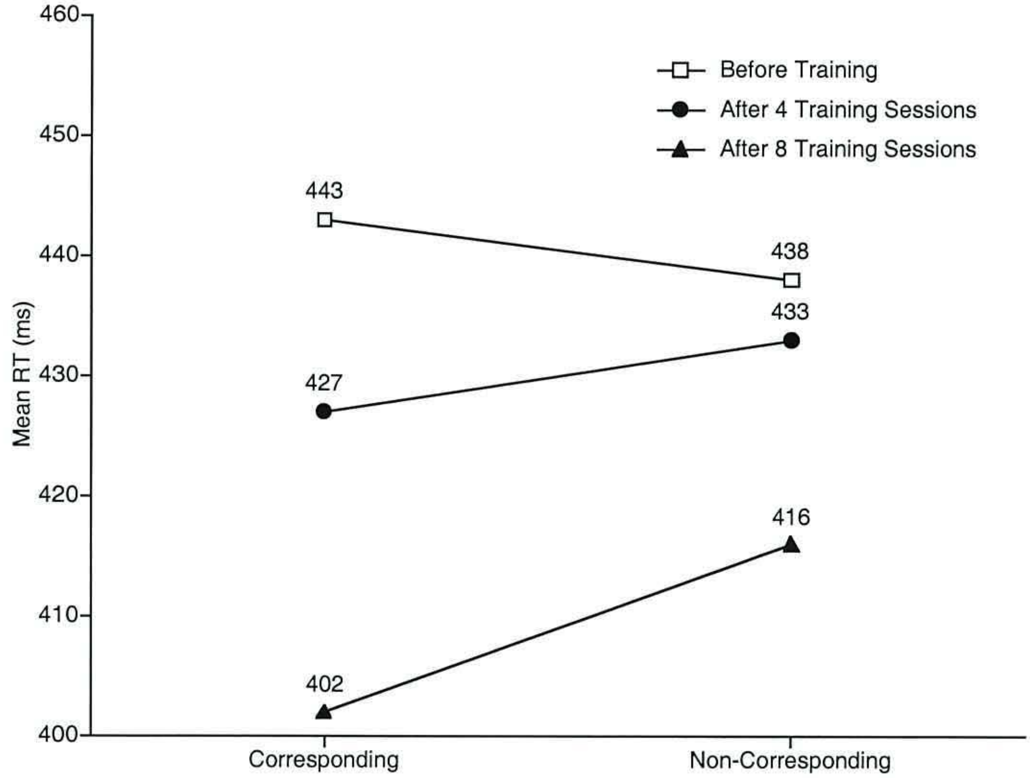


Figure 8.10. Attentional-cueing task: Mean RTs - Goal correspondence over training.

The mean RTs for the pre-training trials, are used as a baseline for indicating the effects of training on general response times. The first block of four training sessions reversed the baseline trend, introduced, and maintained facilitation for those trials where the target appeared in a Button location that Corresponded with the afforded action Goal. A further block of four training sessions decreased latencies over both conditions of Correspondence also increasing the effect of Correspondence. Mean RT performance for the two post-training sessions (Runs 2 and 3) are shown in Figure 8.11 below, where a trend of facilitation for Corresponding over Non-Corresponding trials is evident over both SOAs of 200 and 800 ms.

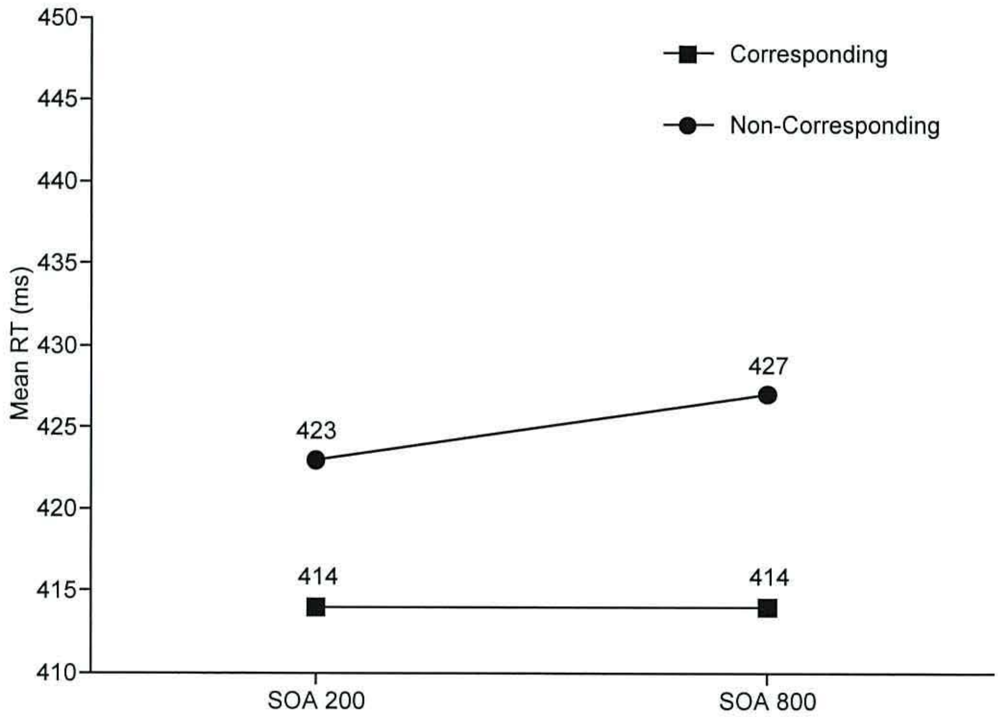


Fig 8.11 Mean RTs by Correspondence and SOA for Attentional-cueing task. (mid and post training only)

Data was re-organised to include Correspondence within Button over all participants; the results shown in Figure 8.12a below.

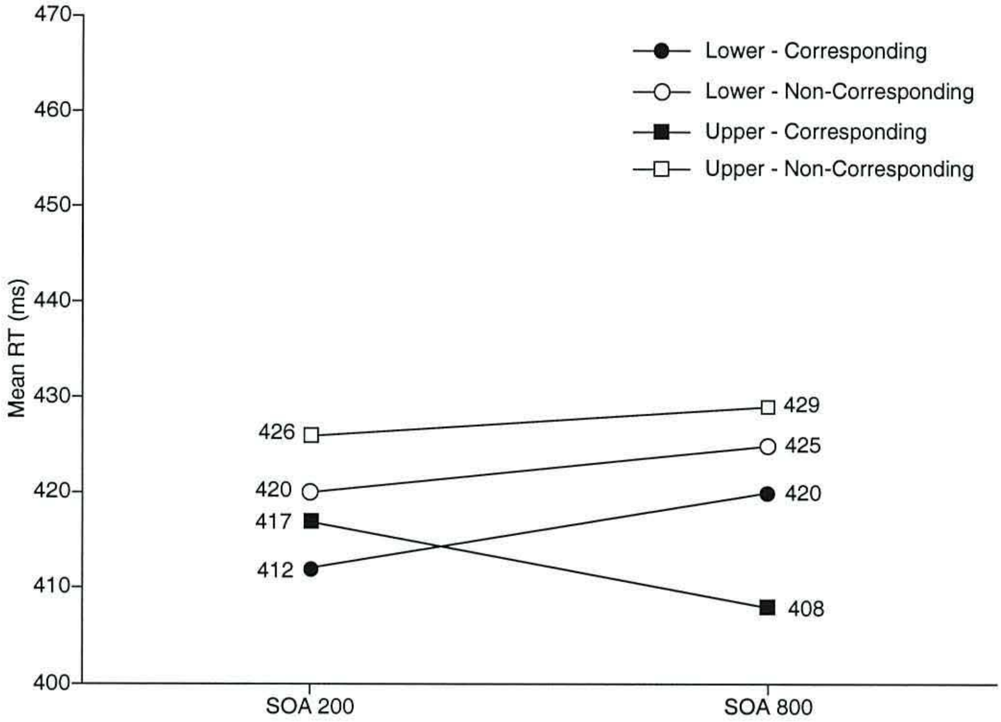


Figure 8.12a Illustrating performance by Goal correspondence for Upper and Lower buttons, across SOA.

A four-way within-subjects analysis of variance was carried out to investigate the factors of Testing Phase (1, 2, or 3); SOA (200 and 800 ms), Button (Upper or Lower) and Goal correspondence (Corresponding or Non-corresponding). There were no main effects for Testing Phase; $F(2,6)=2.184$, $p=.194$; SOA; $F(1,3)=.079$, $p=.797$; Button, $F(1,3)=.033$, $p=.866$; or Goal correspondence $F(1,3)=2.63$, $p=.203$. As illustrated in Figure 8.11, although there were no significant main effects or interactions, the trend was that responses to Corresponding trials over both SOAs were faster than to Non-Corresponding. Further examination of results over each subject are shown in Figure 8.12b. below.

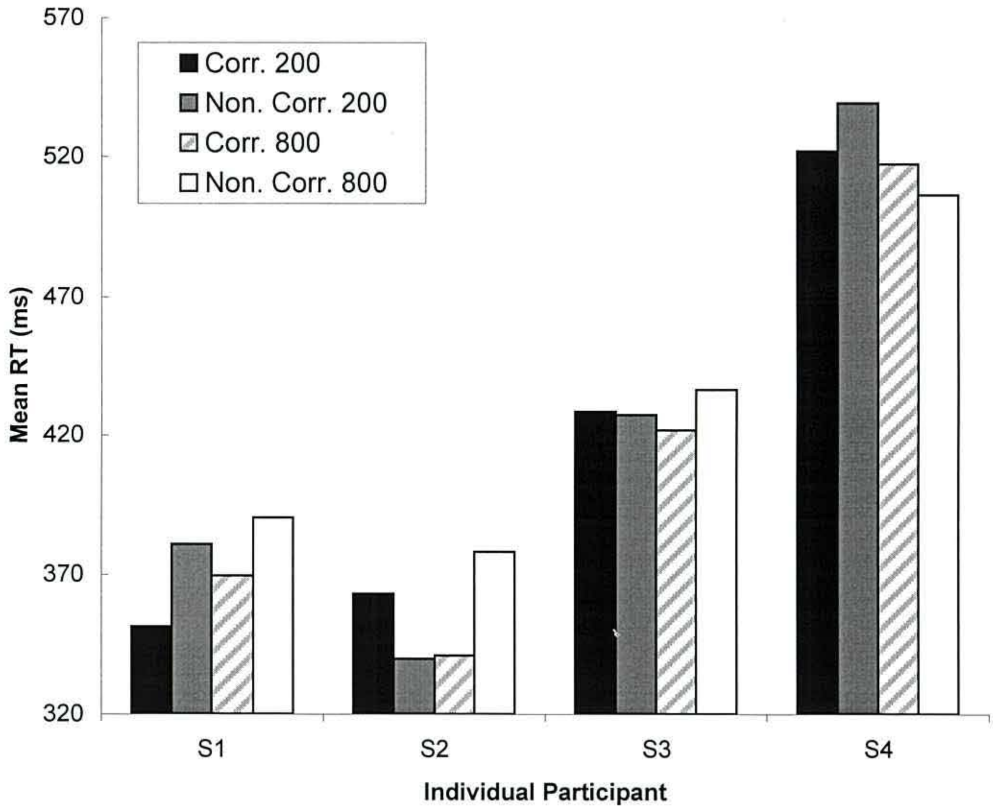


Figure 8.12b Illustrating Mean RTs for Goal correspondence and SOA for each participant.

Figure 8.12b shows a slightly puzzling pattern of performance across subjects for Correspondence over Non-correspondence, at both SOAs. At 800 ms SOA S1 to S3 show good facilitation for Correspondence over Non-correspondence; (+21,+37,and +11 ms respectively) the situation for S4 at 800 ms is reversed (-11 ms). At SOAs of 200 ms, S1 and S4 show facilitation for correspondence (+29 and +18 ms), while the reverse is true for S2 and S3; (-23 and –1 ms). Further investigations into whether the Goal correspondence factor for the Upper or Lower buttons independently followed similar trends of Correspondence over SOAs are presented in Figures 8.13 and 8.14 below; the figures reflect performance at SOAs of 200 ms and 800 ms respectively.

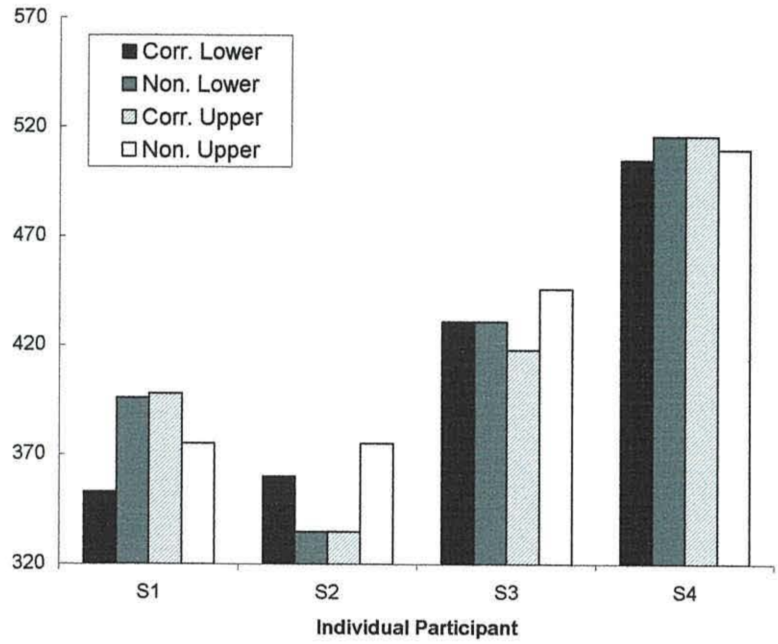


Figure 8.13. Goal correspondence by Button at SOA of **200** ms.

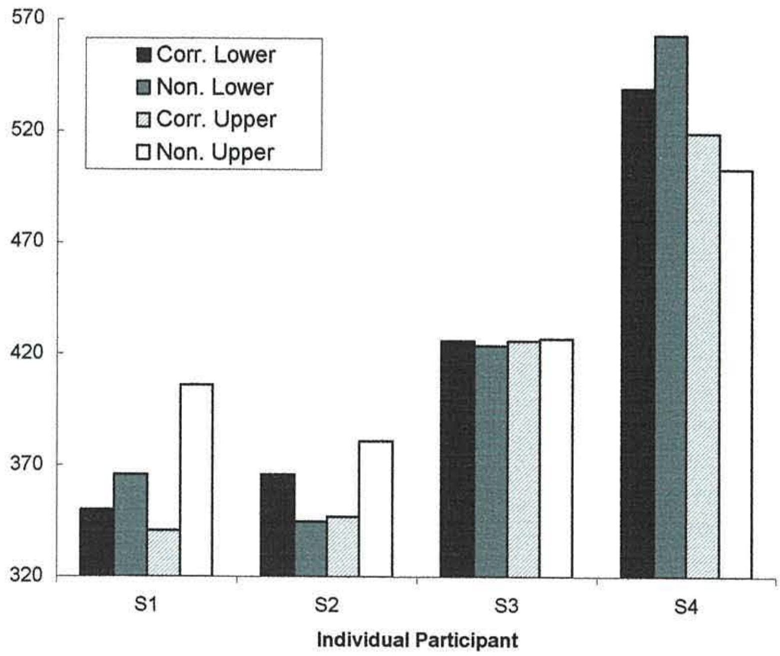


Figure 8.14. Goal correspondence by Button at SOA of **800** ms.

Figure 8.13 depicts the patterns of performance at 200 ms SOA, for Goal correspondence, by Subject, for Upper and Lower buttons. At 200 ms SOA, facilitation for Goal correspondence for the Lower buttons is observed for S1 and S4; (+43 and+11 ms respectively); the reverse being true for S2, (-25 ms) with no effect of Correspondence for S3. For the Upper buttons at 200 ms, S1 and S4 are slower in the corresponding condition (-23 and –6 ms respectively, with S2 and S3 being faster, (+40 and +24 ms).

Figure 8.14 depicts a reverse pattern for SOAs of 800 ms. With S1 and S4 faster for corresponding trials in the Lower buttons (+16 and +24 ms respectively) whilst S2 and S3 are slower (-21 and –2 ms). For the Upper buttons at 800 ms, S1, S2, and S3 are all faster for Correspondence (+65, +34, and +1 ms respectively), whilst S4 is slower (-16 ms). Although some of the differences are of considerable magnitude, none of these differences elicited a significant main effect of Correspondence; therefore little can be made of the curious trends at this stage.

8.2.3. Discussion

This experiment employed a longitudinal design in order to expand on the findings of Experiment 10, relating to the acquisition of affordance and its subsequent influence on attention, action planning, and action execution. Both Experiments 10 and 11 employed a more perceptually balanced testing environment than was possible in the earlier experiments. The difference between these two 'training' experiments lay in the method of application of affordance training and testing. The design used here was longitudinal, in the hope that the elongated (over time) application of the training might more closely mimic that used in the normal human acquisition of object affordance, thus giving results that are more reliable. Although the overall hypothesis that object affordance primes (evokes) action is not statistically supported, there remain some interesting results and indications.

Firstly, regarding the training method, whether the difference in design had any more effect than that administered in the previous experiment is open to question. A quick glance at the improvement in task performance on training over time shows a more gradual overall benefit over time than that achieved in Experiment 10.

The Evoked-action test in the earlier Experiment 10 showed that most benefit in response performance was gained in those trials where the (response directed) Hand and Wrist configuration corresponded to that Hand/Goal target configuration mapped through training. In contrast, although the Evoked-action results in this latest experiment produced a considerable performance benefit (albeit non-significant) for these 'Hand and Goal' corresponding trials, the effect was more a function of Goal, than Hand correspondence. The significant effect of Goal correspondence in the

Evoked-action test implies that the action Goal is of more relevance than the Hand required for mediating the action. The implications of this makes more feasible the idea that these correspondence effects were based on a priming of the action system for the end action of the afforded task. That is, the wrist action that would finally cause the button to be pressed, was more salient to the action (overall) than which hand was used.

Some recent neuropsychological findings are consistent with this notion of the importance of the end goal in interactions with objects. For example, Humphreys and Riddoch (2001) reported a neglect patient who could only perform visual search tasks in his affected visual field when the target object was defined in terms of the action associated with it; for example, find the object from which we can drink. Furthermore, his performance was best when the target's handle was oriented towards him and was defined in terms of its associated action. This finding led Humphreys and Riddoch (2001) to suggest that the perceptual properties of the object alone (in this case, its affordance to the perceiver) are only sufficient to facilitate search when they are combined with the intended action, that is, the end goal.

The Attentional-cueing tasks of both Experiments 10 and 11, produced a difference in Goal correspondence effects between Upper and Lower buttons. This difference was more evident at SOA 800 ms. At that

SOA, Experiment 10 showed a facilitatory effect for Goal corresponding trials for the Upper buttons, and a trend for inhibition for Lower button, Goal corresponding trials. Experiment 11 produced a more random set of results, although overall, a similar trend was evident. This trend, despite non-significance through perhaps lack of power, lend support to the idea that attention is being automatically drawn to the most salient part of the prime object, in readiness for action. When results from the two experiments are taken together, we may conclude that in these simple experimental tasks, the action system is best primed for the end point or task Goal, and that attention is initially and automatically drawn to this 'action' point. With this perspective, it takes no great stretch of the imagination to see the potential for irrelevant objects in every-day environments to catalyse such phenomena as action slips.

Chapter 9

9. General Discussion and Conclusions

The primary aim of this thesis is to provide converging evidence for the nature of object affordance in relation to the human action system, and further, to examine the influence of affordance on human response performance. The empirical question addressed by this work is whether the affordance of objects can automatically evoke mental representations for their most strongly associated actions.

In this chapter, the main findings of the experiments within the thesis are presented and discussed in terms of two major issues relating to affordance-based phenomena; 1) the time course of the affordance-based effects, and 2) the role of attention for such effects to occur.

9.1. Overview

Using the stimulus-response compatibility paradigm, Tucker and Ellis (1998) found effects of correspondence between functional characteristics of (pictures of) every-day objects, and elements of an observer's response. They attributed these effects to the object having an affordance for human action, this affordance being potentiated in those situations where the orientation of the presented object offered a preferential grasp to an observers responding hand. The speed of response towards the affording object was subsequently evaluated in terms of correspondence between the responding hand and the orientation (thus affordance) of the presented object.

The present set of experiments provides new evidence and further insight into the way object affordance can result in action potentiation. The objective of Experiment 1 was to replicate, and examine further, the affordance-based effects found by Tucker and Ellis. In a simple reaching task, using images of common everyday objects, presented at varying orientations, Experiment 1 failed to reveal any facilitation in response performance for trials where orientation and responding hand corresponded. Various explanations for this null effect were discussed; the foremost being the possibility that any correspondence effect may need time to develop, in a similar manner to that found by Kornblum et al. (1999) using a Stroop type task.

Experiment 2 addressed this issue by increasing the complexity of the task thus extending the response time to the presented objects. Using the same objects as those in Experiment 1, a simple judgement task was included. This time, the objects were presented either slightly above or below the horizontal midline of the screen. The task was to make an upper or lower judgement, and to respond with the (upper or lower) assigned hand. The judgement task had the effect of increasing response times by around fifty milliseconds overall, elevating the mean RT to that achieved in the Tucker and Ellis (1998) experiment. This extended exposure time resulted in a significant trend of facilitation for corresponding over non-corresponding trials, the effect of correspondence influencing both reaction time and error rates.

Experiments 3, 4, and 5 constituted the first part of the investigation into the time-course and response specificity of the correspondence effects found in Experiment 2. The method employed in these experiments employed an everyday object, in this case a frying pan, as a prime. The general design was similar to that of Tucker and Ellis, but differed inasmuch as the pan object was completely irrelevant to the imperative task. If, as hypothesised, the effect of affordance is automatic, then an object's visual presence within the stimulus environment should be sufficient to afford action. The object was presented at varying SOAs, and orientations, prior to presentation of an imperative target that signalled either a left-hand or a right-hand response using a left side or a right side (of body mid-line) response effector.

In summary, across three experiments, it was found that similar correspondence effects were generated for the ipsilateral hand (Experiment 3); the contralateral hand, when positioned to correspond with the response effector on the affordance side, (Experiment 4), and the ipsilateral foot (Experiment 5). The pattern of results was equivalent in all three experiments, showing a gradually developing and long-lasting effect of correspondence with time. The observation that correspondence effects occurred irrespective of response modality was seen to have serious implications for the idea that an affordance might preferentially activate a 'best afforded' limb. At this stage of the investigation, the finding that the orientation of an object produced a bias to responding to that side of space was clear; the cause of the effect was not.

Experiment 6 addressed the possibility that attention to the affordance is an important contributor to effects of correspondence. The hypothesis investigated was that attention is directed or captured by the object's affordance. The design incorporated the use of a prime, but with an imperative 'go-no go' target appearing in one of the upper or lower prime quadrants, in left or right space. This experiment showed an effect of correspondence where the target and handle appeared in the same hemi-space. Further analysis showed that the effect was confined to where the target and handle appeared in the same (lower) quadrants; in these situations, at SOAs of 800 ms, corresponding trials were significantly slower than non-corresponding trials.

These results indicated that attention was indeed being drawn to the object's handle, rather than to the whole side of space, this drawing of attention resulting in an IOR type effect when handle and target appeared at the same location. Whether the drawing of attention was due to the object evoking semantic mechanisms based on perceived utility, thus directing attention to its action interface, or the perceptual qualities of the handle simply cueing or directing attention (exogenously or endogenously) remained unclear.

Experiment 7 attempted to answer these questions by employing a simple cueing paradigm, where the pan-prime would be replaced by a non-affording, geometric, exogenous cue, the target remaining central. The experiment failed to show any effect of exogenous cueing, indicating either that the previous results where primarily due to affordance based mechanisms, or that the handle served to direct attention to a side of space, or possibly, that the current experiment failed to successfully parallel the visual effects of the pan's handle.

Experiment 8 heralded a new line of investigation to the pan task. It was realised that in Experiments 3, 4, 5, and 6, a slight perceptual asymmetry existed between the pan object and the imperative target. In order to investigate any confounding effects of this perceptual asymmetry, Experiment 8 was designed as a pilot to test for any frame of reference effects between target and prime. It was subsequently shown that when the asymmetry was corrected the effects of any correspondence were greatly reduced. However, the cost of eliminating the prime-target asymmetry also resulted in absence of perceived transition between trials, that is, the *base* of the pan appeared in exactly the same position in every trial, whilst the handle appeared on its left or right side. To the centrally fixated observer, it seemed that the prime and its orientation could very easily be ignored. Not only was the 'frame of reference' effect eliminated, but also the opportunity to observe any affordance based effects.

Experiment 9 provided a fuller investigation of target and prime frame of reference by slightly exaggerating the asymmetry. All targets would continue to be presented at screen centre, but the prime would now be presented slightly shifted to left or right of centre. Therefore, the frame of reference was manipulated, whilst the potential for affordance was maintained. Results showed a very similar trend of results to those found in the earlier experiments, and that these results could be separated out into those due to frame of reference effects and those due to effects of prime orientation, due to the difference in the way the effects developed over time (discussed later). Although the effects of correspondence for affordance remains significant in their own right, these findings do have implications for results achieved in the earlier experiments, especially 3,4, and 5; essentially relating to the magnitude of the effects that can be attributable to affordance. The main conclusion from Experiments 3-5 was that the pan's handle facilitated action for the side of space on which it appeared. More importantly, the effect was considered to be the product of abstract spatial coding mediated by the salience (possible both perceptual, and action-based). However, the correspondence effects of Chapter 7 were predominantly due to the spatial code created by the prime-target relationship. Whilst the frame of reference (FOR) effect is a significant finding, there remain two important considerations; 1) the prime-target relationship in the frame of reference was purposely, slightly exaggerated, and 2) the FOR findings should not detract from the fact that the object's orientation produced significant effects of correspondence, independent and separable from those due to FOR. Only further experiments would help clarify the true contribution of the FOR effect to those results of Experiments 3-5.

The question remains of whether correspondence effects of object orientation were due to abstract spatial coding, as must have been the case with the foot Experiment 4; or were they more due to affordance for action as could have been the case with the other experiments. The fact that the foot experiment elicited a correspondence effect of a similar magnitude to that of the hands would suggest that an abstract spatial code (along with a frame of reference effect) was the source of correspondence effects for both hands and feet.

As mentioned above, the design of the 'frame of reference' experiment slightly exaggerated the prime-target offset in such a way as to discourage ambiguity in the interpretation, and therefore the magnitude of the frame of reference effect would almost certainly have been less for the pan experiments, 3-5.

Experiments 10 and 11 attempted to reduce the potential for perceptual confound by introducing the concept of novel and symmetrical objects as primes. The concept of object novelty provided a situation in which any effects of correspondence could only be attributable to an observer's *acquired* knowledge of the object's function.

These experiments provided an important set of findings for the investigation of object affordance, inasmuch as they indicated that the motor coding to achieve the end goal of an action sequence, for example, pressing an upper or lower button was a stronger contributor to correspondence effects than those processes involved at *arriving* at the end goal, for example, hand selection.

Both Experiments 10 and 11 provided results of a similar trend on the attentional cueing tests, lending support to previous findings that attention is drawn to the affording action interface of the object. In the evoked-action tests, responses to targets requiring a corresponding wrist movement to that now afforded by the prime were much faster than when not afforded. This

Goal (or wrist) correspondence effect was observed irrespective of responding hand.

9.2. Specificity of Response Activation

Central to determining the origin of the observed correspondence effects is the issue of response specificity. For example, Tucker and Ellis (1998) found that correspondence effects between the object's orientation and the responding side were only observed in their first experiment where each hand was assigned to a left and a right response. When, however, left-right responses were assigned to two fingers of the same hand, no compatibility effect was observed. Based on this finding, Tucker and Ellis concluded that the object's orientation gives rise to action potentiation for a particular hand (right or left).

Within this thesis, it has been shown that effects of correspondence are typically observed between the (irrelevant) prime orientation of an object and the side of response to an (imperative) target. Are the correspondence effects due to the affordance of an object operating in such a manner as to generate, within the observer, some form of abstract response code, or, can these effects be interpreted in terms of an action specificity account, the orientation of the object (for example, right) evoking a response from the corresponding (right) hand?

The experiments in Chapter 5, however, do not fully support this action specificity account. Experiment 4 approached this issue by manipulating a factor of the response set. Results clearly indicated that the correspondence was *not* between the orientation and the corresponding hand, but rather between the orientation of the prime object, and the response effector's location. Alternatively, the response that may have been activated by an affordance may have been for the hand situated 'nearest' to the object's affordance, that is, action specificity for the *nearest* hand.

This idea was discounted when results from Experiment 5 showed similar patterns and magnitude of correspondence effects using left and right foot responses, leading to the conclusion that correspondence effects were due to the generation of a more abstract response code.

Evidently, the prime affordance in these experiments can potentiate a range of responses that correspond with its orientation, consistent with an account of abstract response coding. Clearly, an affordance does *not* necessarily activate *only* the specific motor program best suited for manipulation of the affordance, i.e. specific hand. This is inconsistent with the account by Tucker and Ellis (1998) that affordance-based effects come about through coding the relation between the object's orientation and the hands. Further support comes from the observation that there was no effect of whether the affordance was presented as facing towards or away from the observer. The absence of depth effects in Experiment 3, 4, and 5 provided motivation to investigate alternative accounts of action potentiation arising from orientation of affordance.

Experiments 8 and 9 provided a set of informative findings in relation to the source of correspondence effects. The design allowed the separation of effects of prime orientation from the confounding effects of frame of reference. In short, very similar correspondence effects to those of the previous experiments were produced, but based both on the spatial relationship between the position of target and prime, *and* on the actual orientation of the prime.

Experiments 10 and 11 provided a further breakthrough in the investigation of action specificity in terms of the observed ability of the action *goal* to prime action, although no evidence of limb specific potentiation was found for earlier stages of the action sequence involved in reaching that goal. In this light, perhaps the affordance better serves action planning based primarily on the end goal, rather than the specific motor implementation of the action. The implications of the finding may not be as counter-intuitive as they first seem. The purpose of the affordance is to inform and prepare the observer for the object's possible usage, whilst the orientation may cause representation of the best or most convenient way of handling the object; however this representation need not exclude other possible uses of the affordance. What is most important when interacting with an object is the representation of the whole action sequence rather than just the initial stage. Having the end goal foremost will facilitate individual steps of the whole action sequence; for instance, the position in which the hand needs to be to perform the end goal will affect the hand grip chosen in performing the initial step. In this light, the end goal of an action should be the prime candidate upon which influences of affordance should be observed.

In summary, the present data suggest that an object's perceived functional component can evoke mental representations for action, even in the absence of any intention to act upon that object. The present set of data has exposed the presence of affordance operating in two ways. Firstly, through the formation of an abstract *spatial code* between the object's perceptual affordance and the response side (Experiments 2, 3, 4, and 5), serving to orient attention to the business end of the object; and secondly, through a goal-based representation formed by the perceiver's knowledge of an object's *utility* (Experiments 10 and 11). The two accounts need not be mutually exclusive.

9.3. Time Course of Affordance-Based Effects

In the SRC literature the idea of the time course along which compatibility effects occur is well established. The effects of irrelevant stimulus dimensions (Simon effects) have been shown to develop rapidly (within 50 to 100 ms) and to be short-lived (e.g. Hommel, 1993b; Kornblum et al., 1999).

In contrast, the results from Experiment 2 provided new evidence to show that the effect of an irrelevant property (affordance) of an irrelevant stimulus took time to appear. The main conclusion from this experiment was that time course was an extremely important factor in observing this type of correspondence effect. The implications of this early finding are an important indicator that these correspondence effects may *not* have been due to the same processes underlying typical Simon type effects. If the object orientation (affordance) produced a left-right code that corresponded (or not) with the response side, then the resulting pattern might resemble a Simon type effect. However, the correspondence effect was only observed when response latencies were increased to around 500 ms (by increasing task difficulty).

In Experiments 3,4, and 5, a controlled method of time delay was used to map out the time course of correspondence effects over a time scale of between 0 and 1200 ms SOA. Results from Experiment 3 provide the first set of data that show significant effects of correspondence between the irrelevant object's orientation (affordance) and the responding hand building over time. Of greatest interest was the observation that these effects, whilst minor at 0 ms SOA, built over time to significance at 800 and 1200 ms. As previously discussed, this building over time did not fit in with the type of time course of effect shown to be evident with other Stroop and Simon type tasks where response activation was a result of irrelevant stimulus attributes (see Hommel, 1994; Kornblum et al, 1999). For example, one account of these results, as well as those of Tucker & Ellis (1998), would be that perceptual segmentation of the affording object results in the handle itself acting as a lateralized stimulus. If so, the handle in the prime image might produce response activation similar to that of lateralized objects in the Simon paradigm; however, this is not a likely account for the correspondence effects observed here, as the long-lasting and gradual development of these effects is in sharp contrast to the transient response activation found by lateralized stimuli in the Simon paradigm.

The time course of these correspondence effects is also different from the time course of the frame of reference effects observed in Experiment 9. In that experiment the two correspondence effects, whilst similar in trend, developed over a different time course. Whilst the FOR effects developed between 0 and 400 ms SOA and were maintained through to 1200 ms SOA, the time course of the orientation-based effects only built up between 800 and 1200 ms. If the correspondence effects of prime orientation were solely due to the spatial coding that underlies the FOR effects, they would develop over the same time course. In this light, the effects of orientation must originate based on some other element of the stimulus set, such as the affordance of the prime. Therefore although it remains likely that the correspondence effects of experiments 3,4,and 5, were to a degree due to frame of reference effects, it is considered that FOR contribution would have been proportionately less than in the actual frame of reference experiments where the target-prime offset was slightly exaggerated.

As a final note, the slow build up of the affordance effect still appears to be inconsistent with the proposal of a 'direct route' to action put forward and elaborated upon by Riddoch, Humphreys, and their colleagues (e.g. Riddoch & Humphreys, 1987; Riddoch, Humphreys & Price, 1989; Rumiati & Humphreys, 1998). Riddoch and Humphreys proposed the operation of a 'direct' route to action that is independent from semantic information about the object.

The idea behind this proposal is that the object's stored visual structure can be mapped directly against the motor patterns for actions associated with that object. Provided that the idea behind such a direct route ensures speed and efficiency, then the idea of a 'gradual' build up of affordance over time seems inconsistent, although directness of route need not necessarily be equated with speed of action, rather efficiency of processing. Perhaps the need to make a correct or calculated response is more important than the need to make a quick one, and perhaps the role of automaticity and 'direct action' routes, may be more pertinent in facilitating action planning rather than direct action per se.

In this light, future research might employ a more varied spread of dependant measures, such as investigating the influence of affordance on action planning, on intention, or choice. The ability to respond quickly, whilst important, is barely the prime pre-requisite of human action. The ability to evaluate appropriateness of action, timing, and plan action sequences are also major components. In this sense, the information carried in an affordance probably benefits many action-related processes promoting smooth transitions within the whole perception-action process.

9.4. The Role of Attention

Attention research has recently provided evidence concerning the action-based representations available for attentional selection (e.g. Tipper, Lortie, & Baylis, 1992). Well-known attentional phenomena, such as negative priming (e.g. Neill, 1977; Tipper, 1985) have been shown to be influenced by representations that take the object's use into account, that is, action-centred representations. For example, participants in the Tipper et al. (1992) study were slower to respond to targets whose location in the previous trial was occupied by a distractor (negative priming effect); most importantly the negative priming effect was greater for distractors that were closer to the participant's responding hand.

A major consideration in the early stages of the thesis was the possibility that a shift of attention towards the affordance may have been generating a spatial code that would be processed in terms of correspondence with the code for response side, thus creating the observed effects. The possibility of the effect originating from this 'attentional shift' process (see Nicoletti and Umilta, 1994; Stoffer, 1991; Umilta and Nicoletti, 1992) was very unlikely for two reasons. First, the time course of the effect bore little resemblance to that expected of a Simon type effect. Secondly, in the case that attention was initially being shifted from central fixation to the object's handle, the upcoming central target would then shift attention *away* from the object's handle, thus generating an *incongruent* spatial code to that generated by the first attention shift. Consequently, the attentional-shift hypothesis is not thought to play a role in explaining the present correspondence effects, although attention itself may still be a critical element.

One issue of concern arising from the results of Experiments 3, 4 and 5 was the effect of the *perceptual* salience *of the* handle, as opposed to the effects of what may be termed salience through *affordance for action.* An important issue in examining action potentiation from real-life objects (or images of these objects) is that object affordance will often be confounded with other perceptual factors. For example, a handle oriented to one side of space not only offers an affordance to one hand or the other, but also creates perceptual asymmetry or segmentation in the object's appearance. In fact, many or most artefacts are designed in such a way in order to *attract* attention to their functional parts and thus offer clues to their interaction possibilities.

Handles invariably either project in some fashion, or are designed to draw attention using different colours or textures. Doorbells and buttons are designed to invite pressing with a finger, and many objects are intended to fit a grip or hand in a specific manner. This 'good' design makes life difficult for the experimenter. Any facilitative or inhibitory elements of S-R effects in these ecologically valid experimental conditions become very difficult to isolate. Thus, of particular interest is the effect, or contribution of attentional factors in obtaining the correspondence effect, that is, the handle of the pan behaving like a lateralized cue.

One major issue described in Chapter 6 was how can the effects of an 'affordance generated' abstract code be differentiated from that of a purely attention capturing effect of the pan's handle. Experiment 6 employed a variant of a spatial cueing task; manipulating the spatial relations between areas of the prime object and the location of the imperative target.

Results showed that longer prime-target delays of 800 ms produced faster responses to non-corresponding, than to corresponding trials. That is, when the imperative target appeared in the same location as the prime handle, responses were slower than when it appeared elsewhere in the same hemi-field. This pattern of performance resembled that of inhibition of return (IOR) of visual attention (Posner & Cohen, 1980). This result lent support to the idea that the affordance was capturing attention to itself rather than to the whole hemi-field in which the affordance appeared.

This finding is consistent with recent evidence on attentional capture and its modulation by semantic properties of the capturing stimulus. Work by Yantis and colleagues (i.e. Yantis and Jonides, 1990; Yantis and Hillstrom, 1994) have shown that properties of the stimulus itself, as well as the intention of the perceiver can modulate attentional capture. This has been termed the object-based theory of attentional capture (Yantis and Hillstrom, 1994), according to which attention is captured by the onset of a *new* perceptual stimulus. Following the same line of argument, the pan handle in the set-up of Experiment 6, albeit irrelevant to the task, may have acted as an endogenous cue, capturing attention via its representation as a functional feature of the object. The question of whether the physical handle of the object results in these type of attentional effects of perceptual segmentation, or whether effects are due to association for action was addressed in Experiments 10 and 11.

Experiment 7 utilised a simple cueing task to estimate the contribution of any lateralized cueing type effect of the handle; the experimental task designed to be physically and temporally analogous to the configurations used in Experiments 3,4, and 5. Not only did the experiment failed to show any significant attentional cueing effect regardless of cue-target configuration and SOA, it also failed to produce evidence of any attentional-shift processes at work. This result indicates that the perceptual characteristics of the handle may not be such an important factor as the ability of the handle to draw attention to itself through its affordance for action.

This proposal was reinforced by the results of Experiments 10 and 11, particularly in the attentional cueing task, where a pattern of facilitation (at SOA 200 ms) and inhibition (at SOA 800 ms) can be explained only if the button acted as an attentional cue, cueing attention to the object and to the location it occupied. Taken together the results lend support to the idea that attention is initially being automatically drawn to the action interface of the object, thus potentiating action. Why should this be? Future hypotheses might predict that this drawing and/or capturing of attention is both necessary and implicit in the idea that an object can evoke representations for, and thus potentiate action.

References

Bradshaw, J., Willmot, C., Umilta, C., & Phillips, J.G. (1994). Handemisphere spatial compatibility, precueing, and stimulus-onset asynchrony. *Psychological Research/Psychologische Forschung, 56*, 170-178.

Brust, J.C.M. (1986). Lesions of the supplementary motor area. In H.O. Luders (Eds.) *Advances in Neurology: Supplementary motor area.* Philadelphia, PA: Lippincott-Raven Publishers.

Cohen, J.D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioural Research Methods, Instruments and Computers, 25*, 257-271.

Craft, J.L., & Simon, J.R. (1970). Processing symbolic information from a visual display: Interference from an irrelevant directional cue. *Journal of Experimental Psychology, 83,* 415-420.

Craighero, L., Fadiga, L., Rizzolatti, G., & Umilta, C. (1998). Visuomotor priming. *Visual Cognition, l5*, 109-125.

Craighero, L., Fadiga, L., Umilta, C. & Rizzolatti, G., (1999). Action for perception: A motor-visual attentional effect. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 1673-1692.

Danziger, S., Kingstone, A., & Ward, R. (2001). Environmentally defined frames of reference: Their time course and sensitivity to spatial cues and attention. *Journal of Experimental Psychology: Human Perception and Performance. Special Issue, 27*, 494-503.

De Jong, R., Liang, C-C., & Lauber, E. (1994). Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus-response correspondence. *Journal of Experimental Psychology: Human Perception and Performance, 20*,731-750.

Della Sala, S., Marchetti, C., & Spinnler, H. (1991). Right-sided anarchic (alien) hand: A longitudinal study. *Neuropsychologia, 29*, 1113-1127.

Della Sala, S., Marchetti, C., & Spinnler, H. (1994). The anarchic hand: A fronto-mesial sign. In F. Boller & J. Grafman (Eds.), *Handbook of Neuropsychology*. Amsterdam: Elsevier.

Duncan, J., Humphreys, G.W. & Ward, R. (1997). Competitive brain activity in visual attention. *Current Opinion in Neurobiology, 7*, 255-261.

Duncan, J. (1999). Converging levels of analysis in the cognitive neuroscience of visual attention. In G.W. Humphreys, J. Duncan and A.Treisman (Eds.), *Attention, Space and Action*. Oxford University Press.

Edelman, S. & Bulthoff, H.H. (1992). Orientation dependence in the recognition of familiar and novel views of three-dimensional objects. *Vision Research, 32*, 2385-2400.

Eimer, Hommel & Prinz (1995). S-R compatibility and response selection. *Acta Psychologica, 90*, 301-313.

Ellis, R. & Tucker, M. (2000). Micro-affordance: The potentiation of components of action by seen objects. British Journal of Psychology, 91(4), 451-471.

Faugier-Grimaud, S., Frenois, C. & Stein, D.G. (1978). Effects of posterior parietal lesions on visually guided behaviour in monkeys. *Neuropsychologia, 16*, 151-168.

Fitts, P.M. & Seeger, C.M (1953). S-R compatibility: Spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology, 46,* 199-210.

Folk, C.L., Remington, R.W. & Johnston, J.C. (1992). Involuntary covert orienting is contigent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 1030-1044.

Gibson, J.J., (1979). *The ecological approach to visual perception.* Boston: Houghton Mifflin.

Goodale, M.A. (1995). The cortical organisation of visual perception and visuomotor control. In S. Kosslyn (Ed), *An invitation to Cognitive Science (Volume 2): Visual Cognition and Action*. Cambridge, Mass: MIT Press, pp. 167-213.

Goodale, M.A. & Milner, A.D. (1992). Separate pathways for perception and action. *Trends in Neurosciences, 15*, 20-25.

Goodale, M.A., Jacobson, L.S., Milner, A.D., Perrett, D.I., Benson, P.J. & Hietanen, J.K. (1994). The nature and limitations of orientation and pattern processing supporting visuomotor control in a visual form agnosic. *Journal of Cognitive Neuroscience, 6*, 578-585.

Goodale, M.A., Milner, A.D., Jacobson, L.S. & Carey, D.P. (1991). A neurological dissociation between perceiving objects and grasping them. *Nature, 349*, 154-156.

Hasbroucq, T., & Guiard, Y. (1991). Stimulus-response compatibility and the Simon effect: Toward a conceptual clarification. *Journal of Experimental Psychology: Human Perception and Performance,5*,246-266.

Hedge, A. & Marsh, N.W.A. (1975). The effect of irrelevant spatial correspondence on two-choice response-time. *Acta Psychologica, 39*, 427-439.

Hillstrom, A. P. & Yantis, S. (1994). Visual motion and attentional capture. *Perception & Psychophysics, 55*, 399-411.

Hommel, B. (1993a). The role of attention for the Simon effect. *Psychological Research, 56*, 179-184.

Hommel, B. (1993b). Inverting the Simon effect by intention: Determinants of direction and extent of effects of irrelevant spatial information. *Psychological Research, 55*, 270-279.

Hommel, B. (1994). Spontaneous decay of response-code activation. *Psychological Research/Psychologische Forschung, 56*, 261-268.

Hommel, B. (1995). Stimulus-response compatibility and the Simon effect: Toward an empirical clarification. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 764-775.

Humphreys, G.W. & Riddoch, M.J. (2001). Detection by action: Neuropsychological evidence for action-defined templates in search. *Nature Neuroscience, 4*, 84-89.

Jacobson, L.S., Archibald, Y.M., Carey, D.P. & Goodale, M.A. (1991). A kinematic analysis of reaching an grasping movements in a patient recovering from optic ataxia. *Neuropsychologia, 29*, 803-809.

Jonides, J. & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics, 43*, 346-385.

Joseph, R. (1990). Critical Issues in Neuropsychology: Neuropsychology, Neuropsychiatry, and Behavioural Neurology. New York: Plenum Press.

Kornblum, S., & Lee, J. (1995). Stimulus-response compatibility with relevant and irrelevant stimulus dimensions that do and do not overlap with the response. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 855-875.

Kornblum, S., Hasbroucq, T. & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus-response compatibility – A model and a taxonomy. *Psychological Review, 97*, 253-270.

Kornblum, S., Stevens, G.T., Whipple, A., & Requin, J. (1999). The effects of irrelevant stimuli: The time course of stimulus-stimulus and stimulus-response consistency effects with Stroop-like stimuli, Simon-like tasks, and their factorial combinations. *Journal of Experimental Psychology: Human Perception & Performance, 25*, 688-714.

Lhermitte, F. (1983). Utilisation behaviour and its relations to lesions of the frontal lobes. *Brain, 106*, 237-255.

Lu, C.-H. & Proctor, R.W. (1994). Processing of an irrelevant location dimension a function of the relevant stimulus dimension. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 286-298.

Lynch, J.C., Mountcastle, V.B., Talbot, W.H., & Yin, T.C. (1977). Parietal lobe mechanisms for directed visual attention. *Journal of Neurophysiology, 40*, 362-389.

MacKay, H.A. (1985). Stimulus equivalence in rudimentary reading and spelling. *Analysis and Intervention in Developmental Disabilities 5*, 373-387.

Marr, D. (1982). *Vision*. Freeman, San Francisco.

Maylor, E., & Hockey, R. (1985). Inhibitory component of externally controlled covert orienting in visual space. *Journal of Experimental Psychology: Human Perception and Performance, 11*, 777-787.

McNabb, A W, Carroll, W M & Mastaglia, F.L. (1988). "Alien hand" and loss of bimanual coordination after dominant anterior cerebral artery territory infarction. *Journal of Neurology, Neurosurgery and Psychiatry, 51*, 218-222.

Michaels, C.F. (1988). SRC between response position and destination of apparent motion: Evidence of the detection of affordances. *Journal of Experimental Psychology: Human Perception and Performance, 14*, 231-240.

Michaels, C.F. (1989). S-R compatibilities depend on eccentricities of responding hand. *Quarterly Journal of Experimental Psychology, 41*, 263-272

Michaels, C.F. & Schilder, S. (1991). Stimulus-response compatibilities between vertically oriented stimuli and horizontally oriented responses: The effects of hand position and posture. *Perception and Psychophysics, 49*, 342-348.

Michaels, C.F. & Stins, J.F. (1997). An ecological approach to S-R compatibility. In B. Hommel & W. Prinz (Eds.), *Theoretical issues in stimulus-response compatibility* (pp. 330-360). Amsterdam: North-Holland.

Milner, A.D. & Goodale, M.A. (1993). Visual pathways to perception and action. *Progress in brain research, 95* (Ed. T.P. Hicks, S. Molotchnikoff, & T. Ono). Elsevier, Amsterdam.

Milner, A.D., Perrett, D.I., Johnston, R.S., Benson, P.J., Jordan, T.R., Heeley, D.W. et al. (1991). Perception and action in "visual form agnosia". *Brain, 114*, 405-428.

Milner, A.D. & Goodale, M.A. (1995). *The visual brain in action*. Oxford University Press Inc., New York.

Mountcastle, V.B., Lynch, J.C., Georgopoulos, A., Sakata, H. & Acuna, C. (1975). Posterior parietal association cortex of the monkey: command functions for operations within extrapersonal space. *Journal of Neurophysiology, 38*, 871-908.

Neil, W.T (1977). Inhibition and facilitation processes in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 444-450.

Nicoletti, R., & Umilta, C. (1989). Splitting visual space with attention. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 164-169.

Nicoletti, R., & Umilta, C. (1994). Attention shifts produce spatial stimulus codes. *Psychological Research, 56*,144-150.

Nicoletti, R., Umilta, C., & Ladavas, E. (1984). Compatibility due to the coding of the relative position of the effectors. *Acta Psychologica, 57*, 133-143

Norman, D.A. (1981). Categorisation of action slips. *Psychological Review, 88*, 1-15.

Perrett, D.I., Smith, P.A.J., Potter, D.D., Mistlin, A.J., Head, A.S., Milner, A.D., & Jeeves, M.A. (1984). Neurons responsive to faces in the temporal cortex: Studies of functional organisation, sensitivity to identity and relation to perception. *Human Neurobiology, 3*, 197-208.

Perenin, M.T. & Vighetto, A. (1988). Optic ataxia: a specific disruption in visuomotor mechanisms. Different aspects of the deficit in reaching for objects. *Brain, 111*, 643-674.

Pierrot-Deseillingy, C., Rivaud, S., Gaymard, B. & Agid, Y. (1991). Cortical control of reflexive visually-guided saccades. *Brain, 114*, 1473-1485.

Pohl, W. (1973). Dissociation of spatial discrimination deficits following frontal and parietal lesions in monkeys. *Journal of Comparative Physiology and Psychology, 82*, 227-239.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25

Posner, M.I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. Bouwhuis (Eds.), *Attention and Performance X: Control of language Processes* , 531-556. London: Erlbaum

Previc, F.H. (1998). Neuropsychology of 3D space. *Psychological Bulletin, 124* , 123-164.

Proctor, R.W., Van Zandt, T., Lu, C.-H., Weeks, D.J. (1993). Stimulus-response compatibility for moving stimuli: Perception of affordances or directional coding. *Journal of Experimental Psychology: Human Perception and Performance, 19*, 81-91.

Proctor, R.W., & Lu, C.-H. (1994). Referential coding and attention-shifting accounts of the Simon effect. *Psychological Research, 56*, 185-195.

Reason, J.T. (1990). The contribution of latent human failures to the breakdown of complex systems. In D.E. Broadbent, D. E. & J.T. Reason et al. (Eds.). *Human factors in hazardous situations* (pp. 27-36). New York, Clarendon Press/Oxford University Press.

Riddoch, M.J., Edwards, M.G., Humphreys, G.W., West, R., & Heafield, T. (1998). Visual affordances direct action. Neuropsychological evidence from manual interference. *Cognitive Neuropsychology. Special Issue: Perception and Action, 15*, 645-683.

Riddoch, M.J. & Humphreys, G.W. (1987). Visual object processing in optic aphasia: A case of semantic access agnosia. *Cognitive Neuropsychology, 4*, 131-185.

Riddoch, M..J., Humphreys, G.W. & Price, C. J. (1989). Routes to action: Evidence from apraxia. *Cognitive Neuropsychology 6*, 437-454

Roswarski, T.E., & Proctor, R.W. (1996). Multiple spatial codes and temporal overlap in choice-reaction tasks. *Psychological Research, 59*, 196-211.

Rumiati, R.I. & Humphreys, G.W. (1998). Recognition by action: Dissociating visual and semantic routes to action in normal observers. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 631-647.

Sakata, H., Taira, M., Murata, A., & Mine, S. (1995). Neural mechanisms of visual guidance of hand action in the parietal cortex of the monkey. *Cerebral Cortex. Special Issue: Spatial vision and movement in the parietal lobe. 5*, 429-438.

Shulman, H.G., & McConkie, G.W. (1973). S-R compatibility, response discriminability, and response codes in choice reaction time. *Journal of Experimental Psychology, 98*, 375-378.

Simon, J.R., & Rudell, A.P. (1967). Auditory S-R compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology, 51*, 300-304.

Simon, J.R. (1969). Reaction toward the source of stimulation. *Journal of Experimental Psychology, 81*, 174-176.

Simon, J.R., Hinrichs, J.V., & Craft. (1970). Auditory S-R compatibility: Reaction time as a function of ear-hand correspondence and ear-response-location correspondence. *Journal of Experimental Psychology, 86*, 97-102.

Stein, J.F. (1991). Space and the parietal association areas. In J. Paillard (Ed.) Brain and space, p. 185-222. Oxford University Press, Oxford. Taira, M., Mine, S., Georgopoulos, A., Murata, A. & Sakata, H. (1990). Parietal cortex neurons of the monkey related to the visual guidance of hand movements. *Experimental Brain Research, 83*, 29-36.

Stoffer, T.H. (1991). Attentional focussing and spatial stimulus-response compatibility. *Psychological Research, 53*, 127-135.

Stoffer, T.H. & Umilta, C. (1997). Spatial coding with reference to the focus of attention in S-R compatibility and the Simon effect. In B. Hommel & W. Prinz (Eds.), *Theoretical Issues in S-R Compatibility* (pp. 181-208). Amsterdam: North-Holland.

Stroop, J.R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662.

Taira, M., Mine, S., Georgopoulos, A.P., Murata, A., & Sakata, H. (1990). Parietal cortex neurons of the monkey related to the visual guidance of hand movements. *Experimental Brain Research, 83*, 29-36.

Tarr, M. J. & Bulthoff, H. H. (1993). Is human object recognition better described by geon structural descriptions or by multiple views? Comment on Biederman & Gerhardstein (1993). *Journal of Experimental Psychology: Human Perception and Performance, 21*, 1494-1505.

Tipper, S. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology, 37*, 571-590.

Tipper, S.P., Lortie, C., & Bayliss, G. (1992). Selective reaching: Evidence for action-centred attention. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 891-905

Tucker, M. & Ellis, R. (1998). On the relations between seen objects and components of potential actions. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 830-846

Umilta, C., & Liotti, M. (1987). Egocentric and relative spatial codes in S-R compatibility. *Psychological Research, 49*, 81-90.

Umilta, C., & Nicoletti, R. (1985). Attention and coding effects in S-R compatibility due to irrelevant spatial cues. In M.I. Posner & O.S.M. Marin (Eds.). *Attention and Performance XI*, (p. 457-471). Hillsdale, NJ: Erlbaum.

Umilta, C., & Nicoletti, R. (1992). An integrated model of the Simon effect. In J. Alegria, D. Holender, J. Junca de Morais, & M. Radeau (Eds.), *Analytic approaches to human cognition*, (p. 331-350). Amsterdam: Elsevier.

Ungerleider, L.G. & Brody, B.A. (1977). Extrapersonal spatial orientation: the role of posterior parietal, anterior frontal, and inferotemporal cortex. *Experimental Neurology, 56*, 265-280.

Ungerleider, L.G. & Mishkin, M. (1982). Two cortical visual systems: In D.J. Ingle, M.A. Goodale, R.J.W. Mansfield (Eds.) *Analysis of visual behaviour*, (p. 549-586). MIT Press: Cambridge, MA.

Wallace, R.J. (1971). S-R compatibility and the idea of a response code. *Journal of Experimental Psychology, 88*, 354-360

Yantis, S. & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception & Performance, 10*, 601-621.