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MICRO-AFFORDANCES IN VISUAL MENTAL IMAGERY AND VISUAL SHORT-TERM MEMORY

by

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Micro-affordances in Visual Mental Imagery and Visual Short-term Memory by Noreen Derbyshire

Abstract

Micro-affordance effects have been reported for several different components of the reach-to-grasp action during on-line visual processing (Tucker and Ellis, 1998; Ellis and Tucker, 2000; and Tucker and Ellis, 2001). One property of these effects is that they have been shown to terminate once an object is removed from view (Tucker and Ellis, 2001). This thesis describes eight experiments that examine the presence of micro-affordance effects during off-line visual processing. All eight experiments employ a stimulus-response compatibility paradigm. Three different experimental designs were employed to examine the presence of micro-affordance effects arising from the relationship between: (a) the power and precision component of the reach-to-grasp action and the compatibility of an object for grasping with either a power or precision grasp, and (b) the orientation of an object for grasping and hand of response.

The results of the experiments suggest that: (a) the representations utilised during off-line visual processing can potentiate actions arising from the two components of the reach-to-grasp action investigated; (b) the representations utilised during off-line visual processing can also inhibit micro-affordance effects; (c) main effects of object orientation (faster response times to either left or right-oriented objects) in those experiments examining the relationship between the orientation of an object for grasping and hand of response can be used to support a theory for the existence of prototype object representations, held in long term memory, for the process of object recognition, and (d) due to differences in the object properties thought to give rise to micro-affordance effects, and the existence of different off-line visual processes, different experimental designs are required to elicit micro-affordance effects arising from the two types of micro-affordance effects investigated in this thesis.

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Signed ....

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Chapter One

1.1 Introduction

This thesis is concerned with representational theories of mind as they relate to the field of visual perception and visual mental imagery. Before the development of psychology as a discipline, philosophers argued over the problem of how the human eye and brain were able to create the phenomenological sensation we know as visual perception. For centuries it has been recognised that information contained in the retinal image lacks many of the qualities associated with visual perception. For example, retinal images are flat, static and meaningless whereas perception is three-dimensional, dynamic and meaningful. It has therefore been concluded that some sort of processing of the retinal image must occur after it has left the eye. The assumption that intervening processing of visual information must occur between the retinal image and visual perception underlies most models in cognitive psychology today. With the advent of the information-processing paradigm in psychology and the introduction of the computing metaphor, this assumption has become clearly expressed. According to this paradigm all cognitive processes can be explained in terms of a series of symbols (representations) that are transformed through a series of processes or rules. The most notable theory of visual perception to arise within this paradigm is Marr's computational theory of vision (1982).

Importantly, Marr also set out a general 'computational' framework for investigative research in visual perception and other areas of cognition. This framework sets out three levels of description at which it is proposed all cognitive processes should be understood: the computational level; the algorithmic and representational level; and the implementational level. The computational level of description comprises a theory of the computational problems that any system has to solve. Whereas, the representational/algorithm level comprises a description of how the processes employed in solving the problem are to be achieved (algorithms) and what form the input and output (representations) to the system is to take. Finally the third level, the implementational level of description, provides a description of the 'hardware' of a system, which in the case of the human brain is details of its neuro-circuitry. Although, Marr states that the computational level of description is the most important level of description, he also emphasises that a full understanding of any cognitive system requires explanation at all three levels. The reasons for this are illustrated clearly when we see how the computational framework has been applied to Marr's theory of visual perception.

Marr identifies the main computational problem to be solved by the visual system as one of an organism's need to identify the "real" properties of the external world. He notes however that the properties to be identified will depend on the purposes for which the visual system has evolved. Accordingly, Marr describes vision as:

"a process that produces from images of the external world a description that is useful to the viewer and not cluttered with irrelevant information." (1982, p31).

How images of the external world are constructed by the visual system, and what form they take, are problems for the algorithmic/ representational level of description. Although theoretically there are numerous forms that a visual representation could take, and an infinite number of processes for creating a visual representation, both these factors will be constrained by an organism's neuro-circuity (level of implementation) and by the purposes for which the visual system developed in the first place (computational level). For example, representations utilised by the human visual system are likely to differ widely from those used by some animals as the neuro-circuitry is different from those animals and the purposes for which the visual system evolved is likely to be different to those animals. However, representations utilised by the human visual system might be similar to those used by closely related animals, e.g. primates, because the neuro-circuitry is more similar. A detailed description of the representations and algorithms put forward by Marr to explain human visual perception will not be given here, however the reader can refer to Marr (1982).

Marr's theory of perception represents a prototypical example of a representational theory. Although the theory's contribution to the field of vision is indisputable and Marr's work continues to guide research today, like other computational theories, it suffers from a number of limitations. Two of these limitations are: 1) the absence of a role for action in visual perception and, 2) the symbol grounding problem.

The first of these limitations arises from an assumption underlying Marr's theory. According to Marr, the visual system is a system designed to extract information from the environment in order to construct the three-dimensional representations necessary to guide behaviour. These representations are seen as providing a purely visual description of the layout of the environment. Although Marr's theory utilises movement of the viewer in construction of visual representations, for example, motion parallax to aid depth perception, the role of action in the theory is limited. Recent evidence however suggests that this is not the case and that action has a major role to play in the visual process. In section three of this chapter some evidence for the role of action in visual perception will be reviewed together with an alternative theory of visual perception that does provide a central role for action.

The second limitation of Marr's theory, the problem of symbol grounding, is a problem for all representational theories and relates to the question of how internal representations constructed by the visual system (or any cognitive system) acquire meaning (Harnad, 1990). As we will see in section three of this chapter, an important claim to arise from evidence supporting the role of action in visual perception, is the assertion that actions are encoded in representations underlying the visual perception of objects. It will be shown that this assertion is important as it helps provide a partial solution to the problem of symbol grounding.

Having reviewed the evidence in this chapter for the role of action in visual perception, chapter two will examine the role of action in visual mental imagery. Due to the phenomenological similarities that exist between visual perception and visual mental imagery much research has concentrated on establishing which physiological and cognitive structures are shared between the two systems. However, despite findings that many systems are shared, visual perception and visual mental imagery are not the same, and as such each field of research has focused its attention on a number of research questions not relevant to the other field or simply not addressed in that other field. In reviewing the literature on the relationship between visual mental imagery and action the differences in research-focus between the two fields will become apparent. Of particular interest to this thesis will be matters concerning the nature of representations underlying visual mental images. As mentioned above, in the vision literature there is evidence to suggest that representations underlying visual processes contain action encodings and it is these action encodings which help ground representations in the external world. In the main body of this thesis evidence from a series of experiments will be presented to support similar claims about the nature of representations underlying off-line visual processing, in particular visual mental imagery and short-term visual memory.

1.2 Vision and Action

In this section theoretical and empirical perspectives on the relationship between action and vision will be discussed. The section is divided into four sub-sections. In the first sub-section an alternative theory to Marr's theory of visual perception is presented. Unlike Marr's computational theory of visual perception, Gibson' 'ecological' theory of vision (1979) provides a central role for action in visual perception. However, as we will see, serious theoretical criticisms have meant that for many years some researchers have overlooked a number of important ideas presented in the theory. In sub-sections 2-4 some evidence that has led to a re-examination of Gibson's theory will be reviewed together with theories that have attempted to reconcile the Gibsonian approach to vision with the more traditional computational approach.

The literature presented in sub-sections 2-4, is divided into three areas of interest: neurophysiological, neuropsychological and behavioural. This division roughly reflects the three levels of description purported necessary for a true understanding of cognitive processes, as proposed in Marr's computational framework. Although the main focus of research undertaken for this thesis aims to provide better understanding at the representational level of description, any claims made in relation to the nature of representations in visual perception and visual mental imagery should, as we saw above, take into account explanations at the other two levels. The division of literature into these three areas is not clear-cut however, as the researchers themselves have recognised the need to draw on different research methodologies.

1.2.1 Ecological Theory of Vision (Gibson, 1979)

Like Marr, Gibson argued that a true understanding of visual perception could only come about by first understanding what the visual system was for and why it had evolved as it did.

The most controversial idea put forward by Gibson was the notion of 'Affordances'. According to Gibson the mere sight of an object can 'afford' action in the viewer if the physiology of the viewer is consistent with the afforded action. Importantly, Gibson argued that it was the object itself that afforded the action and the viewer could 'directly' perceive this 'affordance'. For example, chairs afford sitting (to adult humans) and fruit affords eating (to many organisms), etc. However, when applying the idea to all objects in the environment, the theory has been shown to have some obvious limitations. For instance, how can a post box in the Amazon Jungle afford 'posting', unless this relationship has first been learned? If a post box does afford 'posting' because of a learned association then the affordance is not an intrinsic property of the object (post box) but arises from an associative relationship between the individual doing the posting and the post box. However, it is still possible to argue that a post box affords a lower level association such as 'object insertion'.

The above problem also serves to highlight the main criticism that has been cited against Gibson's theory, that of its status as a 'direct' theory of vision. In purporting that vision is a 'direct' process Gibson rejected the idea of internal representations and instead proposed that visual perception could be understood at two levels of description. The first of these levels, which is equivalent to Marr's third level of description, is a description of the physiology of the visual system, whereas the second level relates to an understanding of the structure of sensory input, which he considered to be the optical array of light entering the eye.

Gibson argued that the physical system had developed in such a way to 'pick-up' invariant patterns of information contained in the optic array, thereby rejecting the need for an intermediate level of description. As discussed in the introduction, representational theories have dominated psychology and cognitive science and, as such, Gibson's direct theory of vision has attracted much criticism (Ullman, 1980). Given the seriousness of many of these criticisms Gibson's theory attracted little mainstream support although several researchers have continued to pursue a Gibsonian approach to the problem of visual perception.

For example, Warren (1984) provided evidence to suggest that stairs possess a 'climbability' affordance. Participants in the study were asked to judge whether or not differently proportioned steps were climbable or not. The results showed a statistical difference between judgements made by the tallest and shortest participants. It was found that 'climbability' judgements could be determined by a ratio between the viewer's leg length and the height of each step. The results were therefore interpreted as showing that participants were sensitive to the 'climbability' of the steps by merely viewing them. Several other studies based on participant judgements or participants' ability to carry out a task have been used to support the existence of other affordances – intercepting a projectile (Todd, 1981) – where to step for optimal leaping (Lee, Lishman and Thomson, 1982) and running (Warren, Young, and Lee, 1986). However, such results do not necessarily mean that an affordance is directly detected; it is always possible than some sort of calculation is carried out by the visual system based on object size, distance from the viewer and limb proportions.

As well as seeking evidence for specific affordances, the theory of affordances has been put forward to explain the existence of well documented stimulus-response compatibility effects (Michaels, 1988; 1989; Michaels and Schilder,1991). Stimulus response compatibility effects typically occur when some combination of a stimulus dimension and an organism's response results in faster reaction times than an alternate combination. For example, pressing a red key in response to a red visual stimulus results in faster response times than pressing a green key in response to a red visual stimulus. In sub-section four of this chapter S-R compatibility effects will be reviewed in greater detail. The Gibsonian explanation of the effects will then be contrasted with more traditional explanations that have been put forward to explain the effects.

In spite of the controversy that still exists in regard to the Gibsonian notion of 'direct' vision, there has been a rekindling of mainstream interest in the theory. Several reasons can be identified for this re-emergence of interest.

Firstly, developments within the field of machine vision have found that understanding all the behaviours that a whole system is engaged in is necessary to reduce the computational load to be handled by the visual system. In the case of humans and many other animals this would include eye movements, head movements and whole body movements. When these factors are taken into account it has been found that often the visual system does not require a detailed three-dimensional visual description of the environment to carry out its tasks (Ballard, 1990). Secondly, embodiment theorists have identified many examples of organism behaviour that can be better understood by reference to the whole organism's interaction with the environment than by reference to a set of complicated algorithms (Clark, 1997). Perhaps, most importantly, as we will in the next sub-section of this chapter, there is now an abundance of evidence to suggest that action plays a crucial role in visual perception.

1.2.2 Neurophysiological Evidence for the Role of Action in Visual Perception

Due to obvious ethical problems much of the neurophysiological research in this field has been carried out on non-human primates. Although some caution is required when generalising from monkeys to humans, support for some of these generalisations have been found following the development of new brain imaging techniques coupled with clinical observations of brain damaged individuals.

It is generally agreed that more is known about low level visual abilities than high level visual abilities. The areas commonly associated with low-level vision are those brain structures running from the retina to the primary visual cortex, together with the extrastriate cortex which is a belt of association cortex surrounding the primary visual cortex. The areas running from the retina to the primary visual cortex are generally thought to be responsible for providing 'local' information about each point of light hitting the retina – wavelength, motion, orientation etc - whereas areas contained within the extrastriate cortex are thought to be primarily responsible for combining this information to produce global aspects of an image such as object shape, figure ground separation etc. Beyond the extrastriate cortex the function of various visual areas is less well known, however it is these areas that are thought to be primarily responsible for high-level visual abilities such as: object recognition; spatial localisation of objects using frames of reference not based on the retina; and of primary concern for this thesis, visual mental imagery.

Research into the function of brain areas associated with high level vision have identified several areas which cannot be associated with purely visual processing but instead exhibit dual processing properties, in particular action and vision properties. Similarly, studies of the motor cortex, an area of the brain one would primarily associate with motor action, have identified cells that exhibit both sensory and motor properties (Kalaska and Crammond, 1992). For example, the dual function of motor cells has also been observed in relation to the 'observation' of actions. Cell activity in the rostral part of the ventral premotor cortex of monkeys has been observed both when they grasp or manipulate an object and when they see the experimenter carrying out similar actions (Rizzolatti and Arbib, 1998). The ability of such cells to fire both when actions are performed and when actions are observed has led these cells to be dubbed 'mirror' cells. Several authors suggest that a mirror system for gesture recognition also exists in humans (Fadiga , Fogassi, Pavesi and Rizzolatti, 1995). Cells associated solely with muscle control have been found to make up only about one third of those contained in the Primary Motor Cortex (Georgopoulos, 1991).

Returning to the visual system, the main body of neurophysiological evidence to suggest that actions have an integral role to play in visual perception arise from identification of two distinct processing streams in the visual cortex. The first of these, the ventral pathway, projects from the primary visual cortex to the inferotemporal cortex, whereas the second, the dorsal pathway, projects from the primary visual cortex to the posterior parietal cortex.

Initial investigations into the function of these two pathways suggested that the ventral pathway was primarily responsible for object recognition, and the dorsal pathway was primarily responsible for location of objects in space. Studies of non-human primates found that lesions to the ventral system would affect object recognition whereas lesions to the dorsal system produced disturbances in object localisation (Ungerleider and Mishkin, 1982). The functional differences exhibited by these two pathways led to them being dubbed the 'what' and 'where' pathways.

The division of labour between the ventral and dorsal systems was at first thought to reflect a similar division of labour observed earlier in the visual pathway. Investigation into the function of cells in the retina, LGN and Primary visual cortex reveal the presence of two distinct types of cells 'magnocelluar' and 'parvocellular' cells (Reid, 1999). It has been found that magnocellular cells display properties that equip them well for perception of motion and detection of sudden stimulus onsets – properties that are spatio-temporal in nature. In contrast, parvocellular cells have been found to display properties that equip them well for detecting colour, pattern and texture variations, which are important in object recognition. However, in the light of more recent research it has become clear that the ventral and dorsal systems receive inputs from both parvo and magnocellur cells. Nonetheless, there are cells within each of these two regions that exhibit unique properties not found in the other region. For example, neurones found in the posterior parietal cortex have been found to respond to both sensory-related and movement-related activity. Separate subsets of cells within this region are active during eye-hand coordination, visually guided reaching movements and saccadic eye movements (Andersen, 1987), while others are sensitive to the visual qualities of an object that determine the posture of the hand and fingers during a grasping movement (Taira, Mine, Georgopoulos, Murata, Sakata, 1990). Similarly, neurones in the inferotemporal cortex have been found to be sensitive to form, pattern and colour. Also in both this, and neighbouring temporal lobe areas, cells have been identified that respond selectively to particular objects (Miyashita, Date and Okuno, 1993), faces (Bayliss, Rolls and Leonard, 1985; Desimone, 1991) and hands (Gross, Rocha-Miranda and Bender, 1972).

Neuroimaging studies of non-brain damaged humans suggest that similar functions to those identified in the single cell studies of non-primates can be attributed to equivalent areas of the human brain. Brain imaging studies have revealed that the posterior parietal cortex is activated when participants are engaged in visually guided actions, such as reaching movements, grasping movements, and eye saccades (Matsumura, Kawashima, Naito, Satoh, Takahashi, Yanagisawa, and Fukuda, 1996). Similarly, imaging studies of the occipitotemproal region show that it is selectively activated when processing colour, texture and differences in object form (Puce, Allison, Asagari, Gore and McCarthy, 1996; Price, Moore, Humphresy, Frackowiak and Friston, 1996; Malach, Reppas, Bension, Kwong, Jiang, Kennedy Leddedn, Brady, Rosen and Tootell, 1995; and Kanwisher, Chun, McDermott and Ledden,1996).

The above evidence together with neuropsychological evidence, to be presented in the next section, has led to a re-assessment of the "what" and "where" descriptions given to the ventral and dorsal pathways. Instead of "what" and "where", it is believed that the pathways are more aptly described as "what" and "how" pathways.

1.2.3 Neuropsychological Evidence for the Role of Action in Visual Perception

As indicated above, instead of 'what' and 'where' pathways, the ventral and dorsal pathways seem to be more accurately described as 'what' and 'how' pathways. The concept of 'what' and 'how' pathways was reported by Goodale and colleagues (Goodale, Milner, Jakobson and Carey 1991; Goodale and Milner, 1992; Goodale, 1993) following observations of a patient, D.F., who exhibited visual object agnosia caused by carbon monoxide-induced anoxia. Brain scans revealed that damage inflicted by the trauma was quite diffuse. However, whilst sparing the primary visual cortex, sizeable damage was observed in the ventrolateral regions of her occipital lobe. Clinical observations of D.F.'s disabilities revealed that she was unable to recognise objects from their visual contours and was unable to describe or distinguish different objects presented to her in a discrimination test. She could however use colour and other surface features to recognise objects (Humphrey, Goodale, Jakobson and Servos, 1994). Additionally, she was unable to purposely adjust her fingers to fit the size of a visually presented object. However, if given instructions to grasp the same object, she could accurately perform the correct prehension movements. A similar pattern of dissociation was also seen in her responses to orientation tasks. If asked to align her hand with the orientation of a slot positioned at a number of difference orientations, or verbally describe the orientations, she was unable to perform the tasks but if asked to post a card through the slots she performed almost as well as typical individuals.

A dissociation between vision for action and vision for recognition has also been observed in other patients. Riddoch and Humphreys (1987) cite the case of an optic aphasic patient, J.B., who suffered extensive left-sided brain damage following a road traffic accident. Clinical observations revealed that J.B. was poor at naming objects and accessing semantic information relating to those objects, but could make appropriate gestures towards those same objects when viewing them.

It can be noted that in order to either recognise an object or make appropriate actions and gestures towards an object, the visual system requires knowledge of that object's features. In the case of the two patients described above, D.F and J.B, these features were available to the visual system, as demonstrated by their ability to make appropriate actions and gestures towards the objects, yet they were unable to use these same features to describe or recognise the objects. Given the pattern of deficits exhibited by the two patients and the ostensibly ventral route brain damage diagnosed in these two patients, the studies support the neurophysiological evidence for two distinct visual systems, one which is predominately for visual recognition and one for visuomotor abilities.

In contrast to the above findings, Humphreys and Price (1989) cite the case of an apraxia patient who exhibited the opposite pattern of deficits. The patient, C.D., experienced a cerebral bleed caused by hypertension resulting in a left parietal lesion. Clinical observations revealed that C.D. had normal object recognition and object naming abilities, but was impaired at making the appropriate gestures to the same objects. Moreover, C.D.'s gesture impairment to seen objects was worse than his gesture impairment to the names of those objects. Interestingly, the observed deficits were restricted to his right hand.

The impairment observed in C.D. confirms much earlier reports of similar patterns of deficit in head wound patients during World War One. Several reports were made of patients who were unable to locate objects even though they were capable of recognising them (Holmes, 1919). For example, one report was of a patient who could correctly identify a pocket-knife but who could not grasp it. Attempts to do so resulted in a grasping action in the wrong direction.

Although the pattern of deficits exhibited by C.D (and presumably the WWI head injured patients, although complete details are unavailable) could be considered deficits in spatial abilities, this is thought not to be the case. It has been noted that often such individuals can describe the relative location of objects in the visual field contralateral to their brain lesion, although they cannot perform the appropriate action toward to the objects (Jeannerod, 1988). It seems more appropriate, therefore, to describe such deficits as 'visiomotor' impairments, hence once again the 'how' pathway instead of the 'where' pathway.

The observation of a disassociation between vision for action and vision for recognition in other patients has led some researchers to suggest that the processing carried out by the visiomotor pathway is analogous to a detection of affordances. For example, Riddoch, Edwards, Humphreys, West and Heafield (1998), and Riddoch, Humphreys and

Edwards (2000) describe the symptoms of a patient with anarchic hand syndrome (Della Sala, Marchetti, and Spinnler, 1991; 1994). Anarchic hand syndrome can be described as a collection of behaviours in which involuntary manual actions are made by a person who is aware that the actions are inappropriate.

The study was carried out on a patient, E.S., a 59 year-old, right-handed ex-nursing assistant who reported a gradual onset of symptoms but no precipitating head injury. MRI and CT scans carried out on the patient revealed a range of abnormalities. Behavioural analysis of the symptoms revealed the existence of two major categories of 'interference' effects[1] when the patient was required to either pick-up or point at an everyday object such as a cup. One category of effects was shown to be determined by the nature of the patient's response, for example more interference effects were observed when ES was asked to pick-up a cup than when she was required to point at a cup. However, of interest here, the other category of interference effects was found to be dependent on the stimulus properties. In one experiment ES was given the rule to pick up a cup, positioned in front of her, with her left hand if it was positioned on the left-hand side of her body's midline, and with her right hand if it was positioned on the right-hand side of her body's midline. The results revealed inference effects for both hands when the handle of the cup was oriented toward the hand displaying the effect. For example, a right-hand interference effect would be observed if a cup positioned on the left-hand side of the patients mid-line had its handle pointing to the right-hand side, but not if the handle was pointing to the left-hand side. As these interference effects have been shown to be dependent on stimulus properties it has been suggested that the involuntary actions arise due to affordances offered by the stimuli for action.

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[1] Riddoch et al, 1998, describe interference effects as "instances in which inappropriate responses were made with the one hand when responses are meant to be made with the other hand" (p.648)

Although the emphasis in this and the previous sub-section has been to provide evidence for separate 'what' and 'how' pathways, it is important to note that the ventral and dorsal pathways exhibit complex interconnectivity (Goodale, Jakabson and Servos, 2000). Caution is therefore required when describing the ventral pathway as purely for object recognition and the dorsal system as purely for spatial and visiomotor activity. For example, Baylis and Driver (1993) note that the term 'what' carries a tacit implication that 'identity' information is non-spatial. They note however that object identity is usually given by shape information that depends on the relative location of the contours of an object. Therefore 'what' information also includes spatial information. Although Baylis and Driver do not argue against the 'what' and 'where/how' systems, they do suggest a distinction between two types of spatial information. One type of spatial information they describe as 'object' based and one as 'frame' based. Similar arguments for two types of spatial information in vision have also been put forward by Kosslyn (1996). The two types of spatial relations described by Kosslyn are 'categorical' spatial relations which include classes of position (above below etc), size (small, medium and large) and orientations, and 'co-ordinate' spatial relations which are more comparable with the 'where/how' concept. According to Baylis et al's distinction, 'categorical' spatial relations would be equivalent to 'object' based spatial relations, and 'co-ordinate' spatial relations would be equivalent to 'frame' based spatial relations.

It can be seen that the dissociation between vision for action and vision for object recognition displayed by brain damaged individuals supports the neurophysiological findings for two distinct visual pathways, although the function of each pathway appears to be more complicated than earlier investigations suggested.

In the next section behavioural evidence for the role of action in visual perception will be presented. Once again it will be demonstrated that this evidence is consistent with the idea of two visual processing streams, one for visual recognition and one for visio-motor activity.

1.2.4 Behavioural Evidence for the Role of Action in Visual Perception

The idea of a separate direct visual route to action has also been tested in a population of non-brain damaged individuals. In an experiment carried out by Rumiati and Humphreys (1998), participants were asked to either name line drawings of objects or, make appropriate gestures toward line drawings of objects, under time pressure. Analysis of the errors revealed a marked difference in the types of error made depending on whether or not the participants were naming the objects or making gestures toward the objects. Under both task conditions participants made both "visual" and "semantic" errors. Visual errors were defined as those in which the participant made a:

> "response to another item that was similar in shape to the target but was neither associated with the target nor from the same functional category (e.g., razor - hammer)" (p.634).

Whereas semantic errors were defined as those in which the participant made a:

> "response to another item that was associated with the target or from the same functional but not visually related to the target (e.g. hammer - saw)" (p.634).

Analysis of the errors revealed that more visual errors were made during gesturing than during naming, but more semantic errors were made during naming than during gesturing. In a second experiment participants were again asked to either name or make gestures to a series line drawings, but this time also to a series of written words (of objects). Once again it was observed that more visual errors were made during gesturing than during naming, and more semantic errors during naming than during gesturing. However, in addition it was observed that no visual errors occurred during gesturing to words – only semantic errors. Taken together, the investigators interpret the results of these experiments as evidence for dual, independent routes to action from vision. The observation that more semantic errors were made during the naming of object pictures and during the gesturing of written words was argued to provide evidence for the activation of a visual route mediated by semantic-functional knowledge about objects. In contrast, the observation that visual errors occurred during gesturing to pictures of objects but not to their written names provides evidence for a direct route between visual information and action, which is not mediated by semantic-functional knowledge.

Another study which provides behavioural evidence consistent with the idea of two separate visual processing streams was carried out by Aglioti, DeSouza and Goodale (1995). The study consisted of a three-dimensional version of the Ebbinghause Illusion. (See Figure 1. for an example of the standard two-dimensional version of the illusion).

On each trial participants were presented with two 'target' discs - one on the participants' right field of view and one on the participants left field of view - one of which was surrounded by discs larger than itself and one which was surrounded by discs smaller than itself (standard illusion). Trials were then randomly alternated so that on some trials the target discs were physically different in size to each other but appeared perceptually identical, while on the other trials the target discs were physically the same size but appeared perceptually different. During the experiment participants were asked to pick-up the target disc on the right if they thought the discs were the same size, and pick up the target disc on the left if they thought they were different. Consistent with the standard two-dimensional version, the results revealed that participants were sensitive to the illusion.

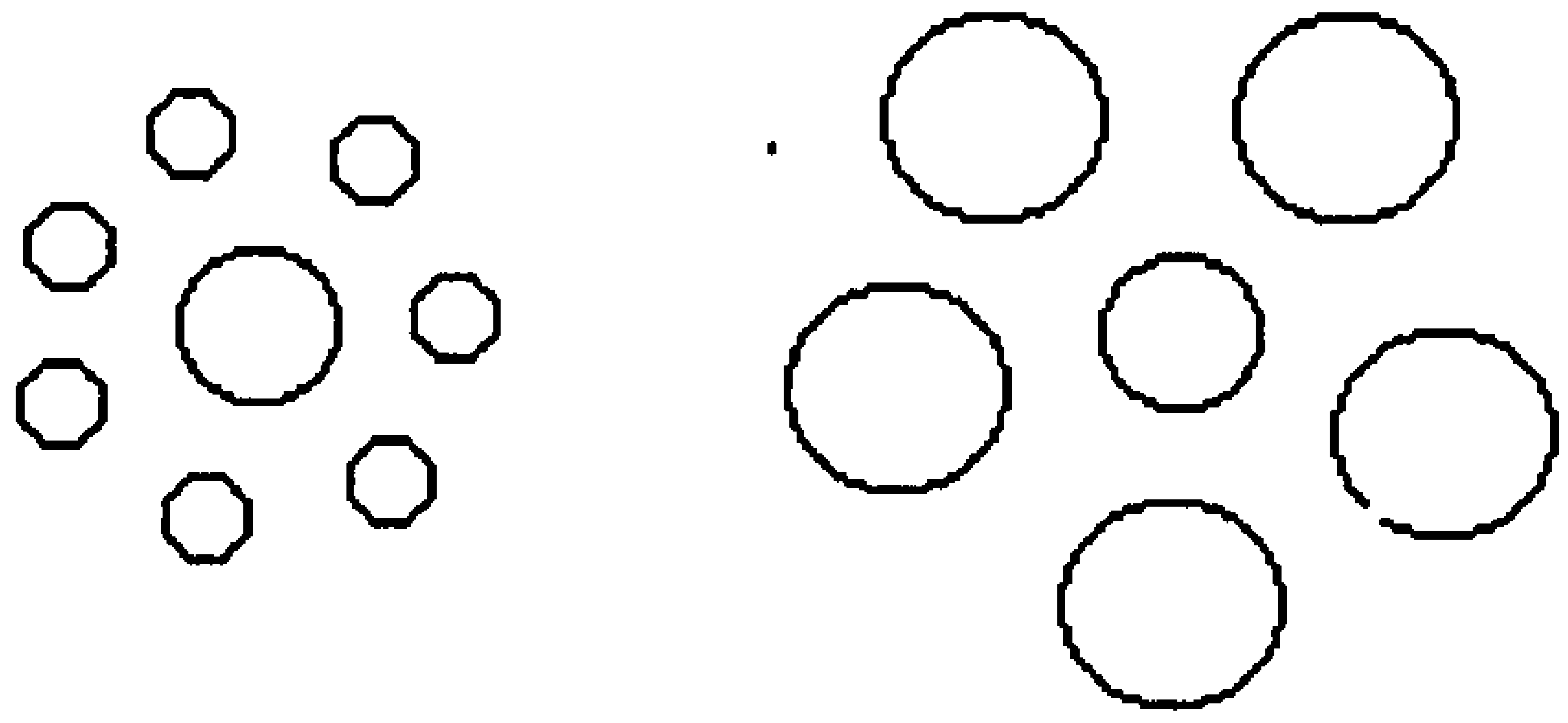

Figure 1
The Ebbinghaus Illusion
(The two target circles at the centre of each circular array appear to be different sizes but *are in fact identical)*

However, as well as observing participant's susceptibility to the illusion, measurements were carried out on the aperture of the participants' grasp (between thumb and index finger) during the task. The results of the analysis on this data revealed that the maximum aperture recorded when participants went to pick up a target disc was solely determined by the actual size of the target disc and not its perceived size. These results are interpreted as showing vision for action is not sensitive to the size contrast illusion, whereas vision for recognition and visual comparison is. Once again, this interpretation of the results is consistent with a dissociation between vision for action and vision for recognition. Although similar results have been reported by Haffenden and Goodale (1989) and Westwood, Heath and Roy, (2000), it should be noted that other researchers report conflicting results (Franz, Gegenfürtner, Bülthoff, and Fahle, 2000; Pavani, Boscagli, Benvenuti, Rabuffetti and Farnè, 1999). Franz et al argue that the absence of a positive result in their study is due to the fact that in the earlier studies perceptual judgements were carried out by comparing the two target circles, whereas manual responses were made towards only one of the target circles. In their studies single-circle presentations of the illusion showed no differences between the two types of response. Haffenden and Goodale however believe that the difference in results is due to the size of the gaps between the target and surrounding circles used in the two studies not reporting the dissociation. Experiments utilising a variety of other visual illusions to compare judgements and motor responses (both grip aperture and force used to lift the stimuli) also report conflicting results (Gentilucci, Chieffi, Daprati, Saitti and Toni, 1996; Daprati and Gentilucci, 1997, Brenner and Smeets, 1996 and Jackson and Shaw, 2000). A study carried out by Vishton, Rea, Cutting and Nunez, (1999) together with a review of previous findings have led these authors to suggest that different findings between the various studies can still be interpreted with reference to the separate dorsal and ventral systems. They note that the findings can be attributed to a dissociation between relative and absolute size perception rather than a dissociation between perception and action. This claim is consistent with the finding that the dorsal system's response to visual size is normally based on absolute size whereas the ventral system's response to size is normally based on relative size.

Other behavioural evidence to suggest a dissociation between vision and action comes from a series of studies carried out by Tucker and Ellis, (1998); Ellis and Tucker, (2000); and Tucker and Ellis, (2001). The studies, which comprise a series of reaction time experiments, demonstrate that 'seen' objects can facilitate actions in the viewer when the stimulus property producing the facilitatory effect is not goal relevant. To explain these effects it has been suggested that representations underlying the perception of 'seen' objects contain encodings of the actions that can be carried out on those objects. These potentiation effects have been termed 'micro-affordances'.

All the studies demonstrating these effects employ a stimulus response compatibility (SRC) paradigm. As already stated in the introduction above, the rationale behind this paradigm is that specific mappings between particular stimuli dimensions and compatible response actions lead to quicker response latencies in the respondent. To recap on the example already given, a typical SRC effect would be the finding that pressing a red key in response to a red stimulus results in faster reaction times than pressing a red key in response to a green stimulus. As can be seen from this example the stimulus dimension responsible for the effect (colour) is goal relevant. In contrast, as we will see below, the effects observed in the SRC experiments carried out by Tucker and Ellis occur when there is a compatibility between a response and a stimulus dimension that is not goal relevant. The facilitatory effects observed in these studies are not a wholly new phenomenon however. The ability of a stimulus dimension to effect a viewer's response when the stimulus dimension is not goal relevant is a well documented SRC effect and has been named the 'Simon Effect' (Simon, 1969). However, the application of this approach to the study of visual processes is new, as is the explanation put forward to explain the effects.

One of the most widely investigated instances of the Simon Effect, is the spatial Simon Effect (Alluisi and Warm, 1990). It has been found that right and left hand responses to stimuli in the compatible visual field (left and right) are faster than left and right hand responses to stimuli in the incompatible visual field, even when this stimulus dimension is irrelevant to the task at hand. For example, if participants are asked to respond differentially to two different coloured stimuli one placed on the right side of a visual display and one on the left, response latencies will be faster if the stimulus shares the same spatial dimension (left or right) with the hand making the response (left or right). Further, Anzola Bertoloni, Buchtel and Rizzolatti (1977) have found evidence that spatial compatibility effects occur whether participants perform a similar task with crossed or uncrossed hands. In the crossed hands condition, a right hand response (hand on the left side of the body) was faster to a stimulus in the left visual field than to one in the right visual field, and vice versa.

In the 'micro-affordance' studies, the design of experiments were such that participants were shown either pictures of objects or the objects themselves and asked to make manual actions in response to a categorisation decision. For example, in one experiment (Tucker and Ellis, 1998) participants were shown pictures of everyday 'graspable' objects, e.g. saucepans, teapots, hammers etc. The objects were presented either in their correct orientation (the right way up) or upside down. Participants were asked to categorise the objects according to this distinction by pressing either a pedal with their right hand or a pedal with their left hand. Half the participants received one response mapping, e.g. left hand pedal for objects in their correct orientation and right hand pedal for objects upside down, and the other half of the participants received the reverse mapping. Analysis of the reaction time data revealed that response times to the categorisation task were significantly faster on trials where the observed object was optimally positioned for a grasping action by the hand making the response – in other words a compatibility effect was observed between hand of response and object orientation. In addition, analysis of the error data revealed that responses were more accurate when there was a compatibility between object orientation and hand of response.

The compatibility effects observed in all micro-affordance studies are illustrated clearly in the reaction time data by an interaction between the response made and the stimulus dimension under investigation. Figure 2 illustrates a typical interaction observed in the data. In this graph it can be seen that right hand responses to right oriented objects are executed faster than right-hand responses to left oriented objects, and vice versa. Similarly, Figure 3 illustrates an interaction in the error data in which right-hand responses to right oriented objects are more accurate (less errors) than right-hand responses to left-oriented objects, and vice versa.

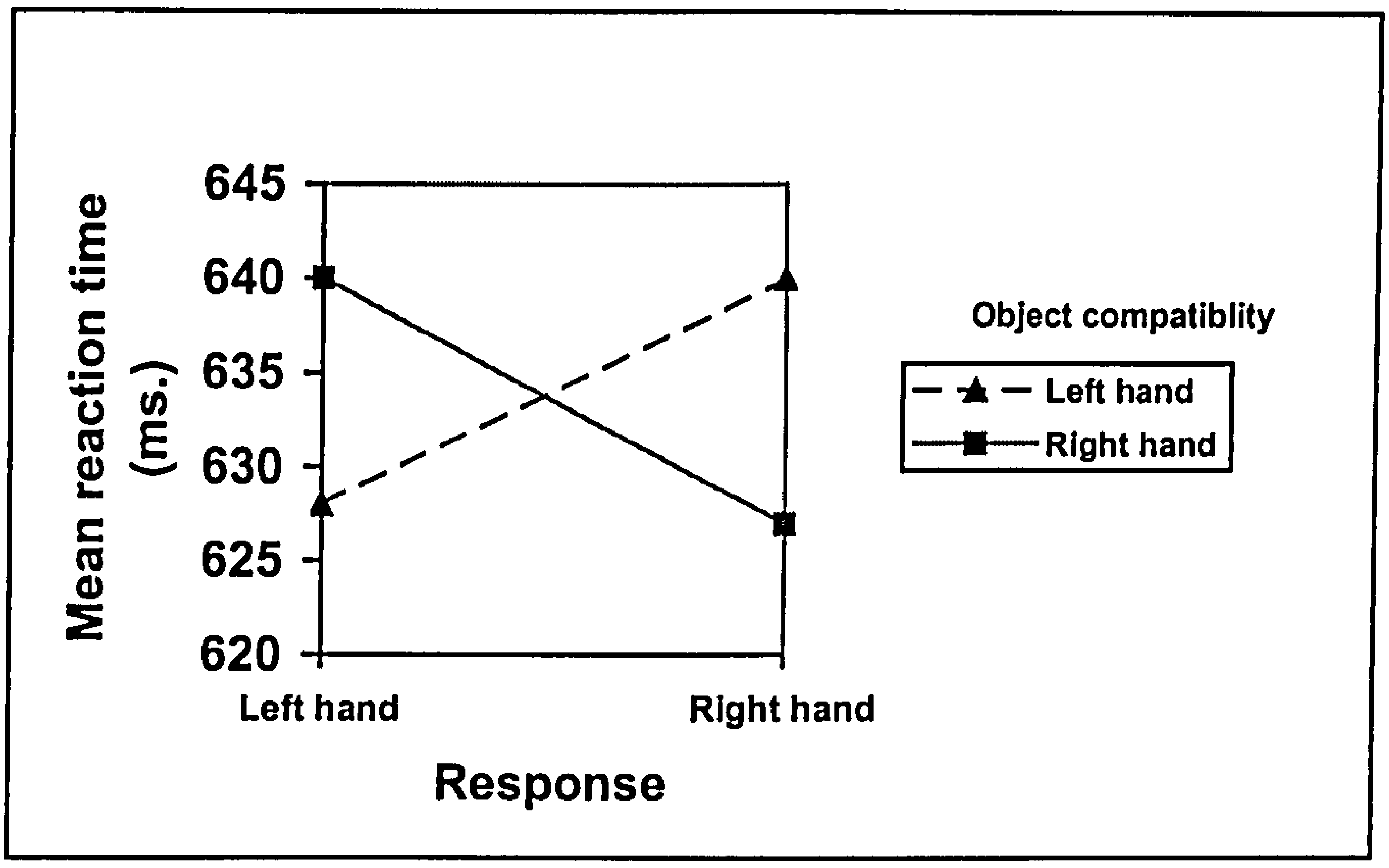

Figure 2
Mean Response Times for Left and Right-hand responses to Left and Right-oriented Objects

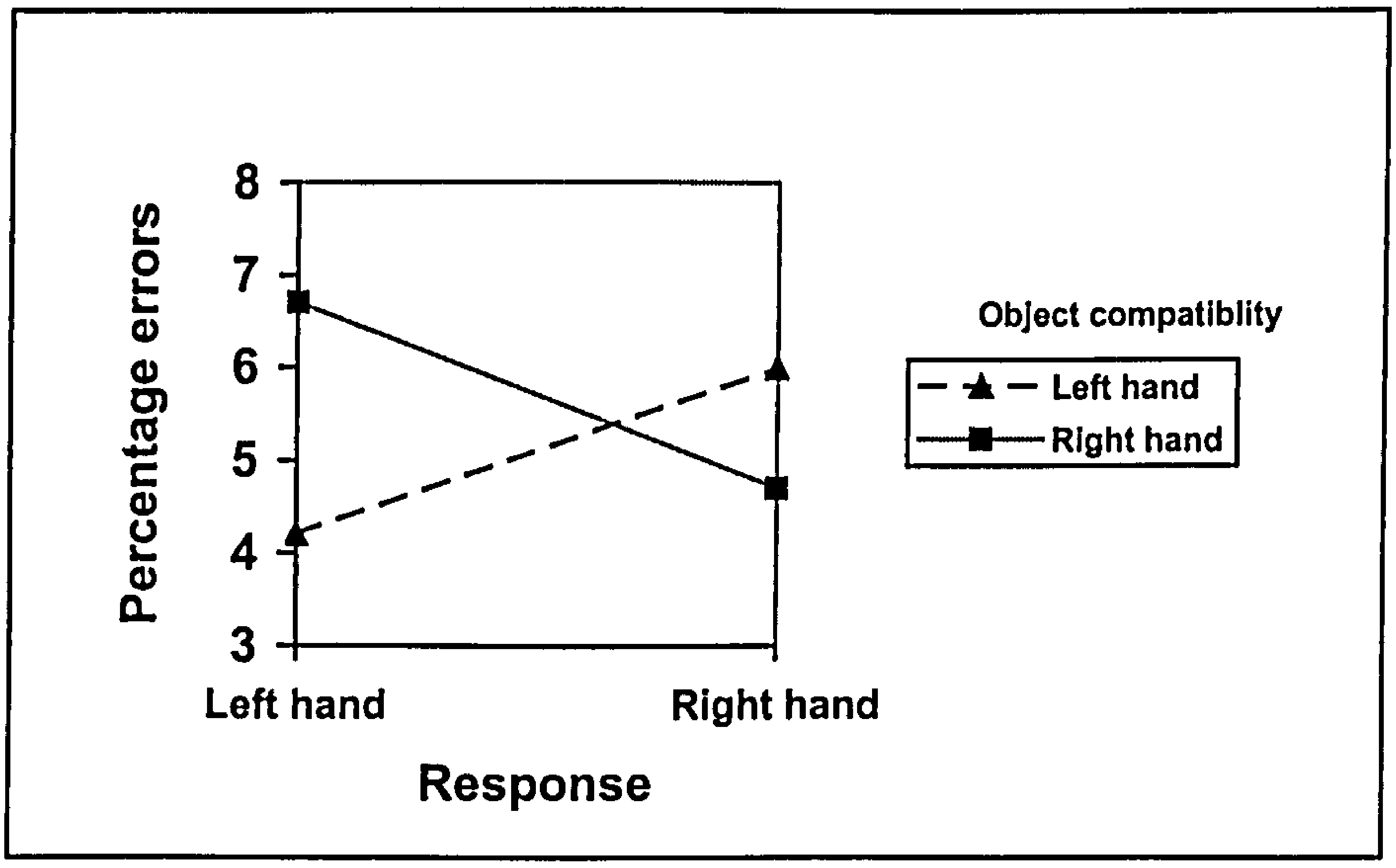

Figure 3
Mean Number of Errors for Left and Right-hand responses to Left and Right-oriented Objects

The compatibility effects observed in these experiments have been interpreted as demonstrating that 'seen' objects can facilitate components of a grasping action in the viewer. Moreover, the actions are facilitated by a stimulus property not relevant to the categorisation task - the positioning of objects in terms of their left-right orientation was irrelevant to the task at hand in the above study.

Later ‘micro-affordance’ studies employing the same paradigm have revealed facilitation for several other actions (Ellis & Tucker, 2000). For example, it has also been found that a precision grasp (between thumb and index finger) is quicker than a power grasp (whole hand) if the object being viewed is optimally compatible with such a grasp. This compatibility effect was observed in a study in which participants were shown a series of objects and asked to categorise them as either organic or manufactured using either a power or precision grasp action. The results revealed that responses were significantly faster if there was a compatibility between the response made (a power or precision grasp) and the compatibility of that object for grasping by that particular grip. For example, a precision grasp in response to a peanut, coin or pencil (small objects that are normally picked up using a precision grasp) and a power grasp in response to a hammer teapot, or banana (larger objects that are normally picked up with a power grasp).

An important feature of all these effects is that they have been found to terminate once an object is removed from view. This was demonstrated in a study (Tucker and Ellis; 2001) in which participants were asked to view pictures of objects which again differed in terms of they compatibility for grasping by a power or precision grasp. Participants were asked to make their responses when they heard a high or low pitched tone. In this study the categorising task (manufactured or organic) was used to determine whether or not participants would respond to the object or withhold their response (a go, no-go paradigm). The three experiments undertaken in this study all differed in terms of timing between presentation of the stimulus and the tone signalling the response. Participants either responded while the objects were in view, immediately the objects were removed from view or 300 msecs after the objects had been removed from view.

The results revealed that if the tone indicating a response occurred while objects were in view a compatibility effect could be observed in both the reaction time data and the error data. This was consistent with the earlier studies. However, if the tone sounded 300 milliseconds after the objects were removed from view no compatibility effects were observed in any of the data. For the experiment in which the tone sounded immediately the objects were removed from view, the compatibility effect was observable only in the reaction time data and not for the error data.

Given that these effects occur only when viewing objects, it has been proposed that the representations utilised during the visual processing of objects contain encodings for both the visual description of objects and for the actions that can be carried out on objects.

As already mentioned, the components of action identified in these studies have been termed 'micro-affordances'. As the name suggests there is some similarity between the term 'affordance' used in this context, and that used by Gibson in his ecological theory of vision. Both uses of the term imply that objects afford or facilitate actions. However as discussed above, Gibson rejected the notion of internal representations and viewed affordances as a property of the object. Micro-affordances by contrast are seen as a property of the viewer's nervous system, and are thought to form an integral part of the representations used in visual processing. In addition, the term micro-affordance refers only to particular components of action – hand shapes, wrist actions etc., and not to gross actions such as reaching or sitting.

Traditional 'information processing' explanations put forward to explain SRC effects, including the 'Simon' Effect are based on the assumption that abstract codes are created automatically during visual processing. It is thought that these codes can then either facilitate or interfere with responses depending on the congruence between stimulus and response. One idea for the causes of these congruent and incongruent effects is that 'Dimensional Overlap' occurs between stimulus and response (Kornblum, Hasbroucq and Osman, 1990; Kornblum, 1994). For example, right hand responses to stimuli in the right visual field are faster than right hand response to stimuli in the left visual field because the stimulus and response each share the 'right' spatial dimension.

This account can be contrasted with the ecological explanation put forward to explain SRC effects. According to this account, the reaction time measurements collected in SRC experiments can be interpreted as reflecting the degree to which a viewer's action is afforded by the environment (the stimulus). For example, the spatial Simon Effect can be explained with reference to affordances arising from the position of an object, affordances such as

> "orienting toward, pointing at, reaching for, grasping, and so forth"
> (Michaels, 1988, p. 233).

It is argued that all these affordances favour responses in the direction of the stimulus, therefore reactions toward a stimulus, as occur in 'Simon Effect experiments unsurprisingly report faster response times. Like all ecological theories of vision, this account of the SRC effects rejects the notion of internal representations instead arguing that affordances are a property of the environment and can be directly perceived by the viewer.

The account of the effects offered by the authors of the micro-affordance studies differs from both the above explanations. As reported above, the effects in micro-affordance studies have been interpreted as providing evidence for the assertion that representations underlying seen objects contain encodings both of the visual descriptions of objects and of the actions that can be carried out on objects. Like traditional explanations for SRC effects this alternative account is firmly situated within a information processing framework. However, the compatibility effects observed in these studies are seen as arising from a direct association between the response code and the code for the relevant stimulus property without the need for a further level of abstract coding. These associations between objects (stimuli) and actions (responses) are argued to have arisen either during the life-time of the person, or over an evolutionary time-scale, and therefore reflect the importance of the viewer's interaction with their environment.

Interestingly, in trying to differentiate between the traditional explanation for compatibility effects and the micro-affordance account, there appears to be evidence to support both explanations. According to the dimensional overlap explanation, facilitation should occur where the stimulus and response share the same dimension, irrespective of the association between stimulus and response. In the Anzola et al (1977) study described above, this was the case. Right hand responses to stimuli in the compatible visual field were faster in both a crossed-hands and uncrossed-hands condition. However, some recent evidence suggests that the uncrossed hands condition may be fundamentally different from the crossed hands condition. As will be discussed later in this section, Simon Effects are observed to reduce overtime. However, this decaying effect only seems to occur in the uncrossed hands position and not in the crossed hands position (Wascher, Schatz, Kuder and Verleger, 2001).

Evidence to support predictions arising from the micro-affordance explanation was found in a follow-up experiment (Tucker and Ellis, 1998) to the first micro-affordance experiment described earlier. In this study participants were again presented with a series of graspable objects both in their correct orientation (the right-way up) and upside down. However this time, instead of responding to objects with left and right hand pedal presses, participants responded with key presses of the index and middle finger on the right hand. According to the dimensional overlap explanation, facilitation should still be observed as left and right abstract codes can be produced which correspond to the relative positions of the index and middle finger. However, no evidence of facilitation was observed – a finding that is consistent with the micro-affordance account.

Although at first sight the findings from the micro-affordance studies and the findings from the above SCR studies appear contradictory, a closer examination of the data suggests the effects observed in the two types of experiment are very different. Although each type of effect arises as the result of a stimulus dimension not relevant to the viewer's goal, two major differences have been observed. Firstly, inspection of the time course of the responses in a traditional spatial Simon Effect studies have revealed that the effects reduce overtime – the slower the response time the weaker the effect (Simon, Ascosta, Mewaldt and Speidel, 1976). However, a similar time course analysis of responses in the micro-affordance studies reveals an increase in effect size – the slower the response time the stronger the effect (Tucker and Ellis, 2001). The difference in the time course of the effects therefore suggests that different processes are involved in the two types of study.

A second difference between the two types of effects to suggest that different processes are involved concerns the use of colour as a response cue in the experiments. In the traditional Simon Effect experiments colour has often been used as the response cue and compatibility effects have been observed. This was the case in the experiment described above. However, when colour is used as a response cue in the micro-affordance studies, no compatibility effects are observed (Ellis, Symes and Tucker; under review).

It can be seen therefore that the explanation put forward to explain micro-affordance effects does not rule out standard 'abstract code' explanations but instead suggests that compatibility effects observed in the micro-affordance studies involve different processes.

In providing an explanation of SRC effects observed in the micro-affordance studies, the authors of these studies also suggest that the account offers a means of reconciliation between Marrian and Gibsonian approaches to the visual perception of objects. It can be observed that the explanation is able to offer a central role for action in visual processing whilst remaining firmly situated within a computational framework.

Other researchers have also suggested a means of reconciliation between the two theories, for example, Goodale and Humphrey (1998). However, the micro-affordance account differs in an important way from the Goodale and Humphrey account. According to Goodale and Humphrey the two theories are reconcilable on the grounds that those sympathetic to Gibsonian theory are concerned with visual abilities that are primarily under the remit of the dorsal stream, whereas those sympathetic to the Marrian approach to vision, the 'reconstructionists', are mainly concerned with visual abilities that are under the remit of the ventral system. As we saw in the last section, these authors argue that the two visual streams are relatively independent of each other. Importantly they also argue that the dorsal stream is important for visiomotor co-ordination – an 'on-line' property of visual processing. Goodale and Humphrey are therefore arguing that the Marrian and Gibsonian approaches are complementary. However the micro-affordance account emphasises the mutual dependence of the dorsal and ventral systems, arguing that visual object representation in the brain is the coupling or binding of visual responses with action related responses (Ellis and Tucker, 1998). It seems important therefore to distinguish these two cases.

The data from the micro-affordance studies is compatible with both the idea of visual representation necessarily including action properties and the idea that visual representation and affordance are relatively independent. In the latter case the compatibility effects would be explained by reference to the dorsal visual system. If, however, it is to be argued that, action facilitation results from the involvement of action encodings in visual object representation it might also be expected to be observed in the case of 'off-line' visual processing such as visual mental imagery and visual memory. In the next chapter a review of literature on visual mental imagery is undertaken in order to assess whether or not the study of representations underlying visual mental images and visual memory can indeed shed light on the role of action encodings underlying seen objects.

Chapter Two

2.1 Introduction

In Chapter One the role of action in visual perception was examined. Converging evidence from several research methodologies provided evidence for separate neural pathways for visual object representation and visio-motor co-ordination. Based on these findings several different researchers have suggested that the Marrian and Gibsonian approaches to visual perception can now be reconciled. However, as we saw at the end of the last chapter, two of the explanations put forward to reconcile the two approaches with reference to the functions of the ventral and dorsal systems differ with respect to the degree to which the two systems are thought to be dependent on one other. According to Goodale and Humphrey (1998) the two systems are relatively independent of one another. The dorsal system is believed to be important to 'on-line' motor co-ordination and the ventral system to object representation. Accordingly, it is proposed that the Marrian and Gibsonian approaches are reconcilable on the grounds that those sympathetic to the Marrian approach are mainly concerned with visual abilities under the control of the ventral system. Whereas, those sympathetic to the Gibsonian approach are mainly concerned with visual abilities under the remit of the dorsal system.

However, Ellis and Tucker (in submission) propose an alternative means of reconciliation for the two approaches. According to the argument put forward by these authors, object representation arises from the mutual dependence of the two visual pathways and possibly other brain systems. Consequently, it is proposed that object representation is dependent both on the visual properties of an object, the actions associated with an object and possibly other associations from other modalities.

Given that the former view put forward by Goodale and Humphrey (1998) emphasises the 'on-line' nature of the dorsal system then one may <u>not</u> expect to observe action effects arising from the presence of micro-affordances in 'off-line' vision, for example in the processing of visual mental images of objects. However, if the latter explanation put forward by Ellis and Tucker (1998) is correct, then one may expect to see micro-affordance effects for imagined as well as seen objects. In this chapter a review of some of the literature on 'off-line' visual processing is undertaken in order to examine this possibility.

The chapter is divided into six sections. In the next section the relationship between visual mental imagery and visual perception is examined in order to establish the degree to which visual perception and visual mental imagery share the same cognitive and physiological structures. In section three of the chapter Kosslyn's (1996) model of the imagery system is examined. This model, derived from high level theories of vision, is used to illustrate how the common assumption underlying computational theories of vision, i.e. that the sole purpose of the visual system is to produce visual descriptions for use by other cognitive systems, has been carried through from the field of visual perception to field of visual mental imagery.

In section four the literature review looks at the role of action in visual mental imagery. Evidence will be presented to suggest that as in the field of visual perception close links exist between the motor system and the visual imagery system. Particular attention is given in this section to a distinction that can be drawn between research into 'dynamic' action encodings and 'non-dynamic' action encodings in visual mental imagery.

As visual mental imagery is only one topic of interest within the field of 'off-line' vision, section five of the chapter includes a short review of literature from the field of visual memory, including short-term visual memory visuo-spatial working memory and visual long-term memory. Although there is little doubt that the phenomena under investigation in each of these individual fields are highly related, each field has developed its own set of theoretical questions and methodologies. Particular attention will be paid in this section to the visual spatial component of Baddeley's (1986) working memory model in order to highlight conceptual and methodological differences that exist between the study of visual memory and the study of visual mental imagery.

Finally, the chapter concludes by setting out the research methodology and hypotheses to be addressed in the main body of the thesis.

2.2 Visual Mental Imagery and Visual Perception

The term Visual Mental Imagery refers to the phenomenological experience of seeing with the 'mind's eye'. In psychology interest in visual mental imagery is primarily focused on its role in information processing rather than on the phenomenological experience itself. However, given the phenomenological similarities that exist between visual perception and visual mental imagery it is not surprising that researchers have for many years sought to identify the degree to which the two processes share the same cognitive and physiological structures. Some of the earliest studies to find support for a 'shared cognitive resources' hypothesis employed a dual task paradigm. By demonstrating that two concurrent cognitive tasks can either interfere or facilitate each other it is suggested that the same underlying cognitive structures are involved in each task. In one of the earliest experiments of this kind (Perky, 1910), participants were asked to mentally visualise objects while looking at pictures. Reports from the participants indicated that the mental imagery task would interfere with their visual perception abilities. Later studies employing the necessary controls missing from this early study have confirmed the findings. For example, Craver-Lemely and Reeves (1987) asked participants to form mental images (imagery task) whilst trying to decide whether or not two line segments were perfectly aligned (perceptual task). The results revealed that participants were significantly impaired in their ability to carry out the perceptual task when forming an image compared to when they did not form a mental image, or when they carried out another concurrent task not involving imagery. Similar conclusions have also been drawn from studies demonstrating facilitation effects. In a priming study carried out by Farah

(1985) participants were asked to form the image of a shape prior to carrying out a signal detection task. If the primed image (the shape) and the task image in the signal detection task were the same, participant response times were significantly faster than when the primed image and task image were different. Other behavioural studies involving a range of visual phenomena have drawn similar conclusions (Peterson and Graham, 1974; Finke and Schmidt, 1977, 1978; Freyd and Finke, 1984)

Although behavioural studies of this kind are suggestive of shared cognitive resources, the field of visual imagery has been plagued with controversy over the nature of the representations underlying visual images. On one side of the argument researchers have argued that visual mental images are 'depictive' in nature (Kosslyn, 1996), whereas other researchers suggest that visual mental images are 'propositional' (Pylyshyn, 1973). Although this debate is not directly relevant to the aims of this thesis, the imagery debate and the degree to which visual mental imagery depends on visual perception are closely related topics as much of our understanding of visual perception is based on the assumption that the visual system utilises the 'depictive' quality of vision (Farah, 2000).

Notwithstanding these considerations, similar conclusions to those drawn from the behavioural studies, described above, concerning the relationship between visual perception and visual mental imagery can also be drawn from studies of brain damaged individuals who exhibit parallel deficits in their perceptual and imagery abilities.

Bisiach and colleagues (Bisiach and Luzzatti, 1978; Bisiach, Luzzatti and Perani, 1979) report the case of a patient with unilateral visual neglect. Patients presenting this syndrome are commonly found to have posterior parietal damage that results in perceptual impairments in the contralateral visual field to the brain lesion. This was the case with the patient described here. It was observed that when the patient was asked to describe what they could see in front of them they would always ignore the objects on the left-hand side of their visual field. Similarly, when the patient was asked to imagine standing at one end of a well known piazza in Milan and describe what they could see in their 'mind's eye', they would again fail to describe those buildings and landmarks on the left hand-side of their visual field. However, when asked to imagine the same scene from a perspective in which they were looking back on their earlier vantage point (the opposite end of the piazza), they were able to describe all the buildings and landmarks left out in their earlier description. The inability to describe objects in the left visual field both when viewing a scene and when imagining a scene is suggestive that the same brain mechanisms are used in both imagery and visual perception.

However, the evidence for a 'shared resources' hypothesis arising from the study of brain damaged individuals is not as straight-forward as it first appears. In another study, Behrmann, Winocur and Moscovitch (1992) report the case of an agnosic patient, who had intact visual imagery abilities but was unable to recognise visual objects. At first sight this disassociation could suggest that imagery and vision draw on very different neural structures. However, Jeannerod (1993) suggests that the dissociation can be explained if one presumes a hierarchical organisation for the mechanisms used in processing visual representations. Under this proposal perception and imagery would share the same image generation system, but the input would be distinct for images built from perceptual materials and those built from memory. Farah (2000) provides a similar explanation for this dissociation, suggesting that the dissociation is a result of a disconnection syndrome (Geschwind, 1965) in which input from the on-line visual system is disrupted before object recognition takes place, whereas input from stored sensory information is unaffected.

Perhaps some of the strongest evidence for common underlying cognitive and physiological structures in visual imagery and visual perception come from studies employing brain-imaging techniques. Such studies have been able to confirm that many of the brain areas used in 'high-level' vision are also utilised in visual mental imagery. However, the evidence for the involvement of some areas, in particular the primary visual cortex, is mixed. Several studies have provided evidence for activation of this brain region during visual mental imagery (Kosslyn, Alpert, Thompson, Malijkovic, Weise, Chabris, Hamilton, Rauch and Buonanno,1993; Le Bihan, Turner, Zeffiro, Cuenod, Jezzard and Bonnertot, 1993) while others find no evidence (Mellet, Tzourio, Denis and Mazoyer, 1995; Mellet, Tzourio, Crivello, Joliot, Denis and Mazoyer, 1996). A meta analysis of the literature carried out by Thompson and Kosslyn (2000) suggests that activation of the primary visual areas occurs when high resolution images are required. Under these conditions activation of the primary visual cortex and inferior temporal lobe are observed. When only a general shape is required for achieving a task only the inferior temporal regions are activated and not the primary visual cortex. However, when spatial relations and no high resolution is required for achieving a task then the inferior parietal regions are activated and not the primary visual cortex.

For those areas of the visual cortex situated beyond the primary visual cortex there is less controversy.

One of the earliest neuro-imaging studies to look at areas of the brain activated during visual mental imagery used Single Photon Emission Computed Tomography (SPECT) (Roland and Friberg, 1985). In the study participants completed an imagery task that involved visualising themselves walking through a familiar neighbourhood, making alternate left and right-hand turns. The patterns of regional blood flow observed during the task revealed activation of the posterior regions of the brain, most importantly the parietal and temporal lobes of the visual cortex. However, there was no evidence of activation within the occipital lobe as would be the case if the participant were engaging in on-line vision. A later study, also using SPECT (Goldenberg, Podreka, Uhl, Steiner, Willmes, and Deecke, 1989), involved asking participants questions which either required mental imagery, e.g. “What is darker, green grass or a pine tree?” or questions that did not require imagery, e.g. “Is the categorical imperative an ancient grammatical form?” In all the scans produced during the study, visual imagery was found to be associated primarily with occipital and temporal activation.

These two studies are interesting as not only do they provide evidence for activation of the same brain areas during visual perception and visual mental imagery but they also provided evidence for task dependent activation of the ventral and dorsal pathways during visual mental imagery. By comparing the above two studies it has been observed that the scans in the Roland et al study showed greater parietal activity than the scans in the Goldenberg et al (1989a) study. These differences have been attributed to the different task demands involved in each study. In the Roland et al study participants imagined a mental walk through a known environment, a task that requires the representation of spatial aspects of the environment. By contrast the imagery task in the Goldenberg study required imagining objects for comparison purposes, a task emphasising object representation rather than spatial representation (Farah 2000).

Later studies using Event Related Potentials (ERP's) confirmed that the dorsal pathway was more highly activated during spatial imaging tasks. For example, Uhl, Goldenberg, Lang, Lindinger, Steiner and Deecke (1990) carried out a study in which participants were asked to image colours, faces and maps. Shifts in localised brain activity showed that maximum activity in the parietal regions was observed during map imagery, a task that requires spatial representations, whereas maximum activity over the occipital and temporal regions was observed during face and colour imagery.

Regardless of the many similarities that exist between visual perception and visual mental imagery, it is important to remember that the processes are not the same. The most obvious difference is that visual perception relies on 'on-line' sensory input from the environment, whereas imagery relies on sensory input stored in memory. This difference, in turn, has an affect on the amount of information readily available to the viewer/imager. As vision is 'on-line' the environment can act as an external store containing vast amounts of information, but mental imagery is limited both in terms of storage capacity and attentional capacity (Kosslyn, 1996).

Another major difference between the two processes is the pattern of individual differences that have been found to exist in the population. People's perceptual abilities are, by and large, uniform. Imagery abilities by contrast exhibit large individual differences. Those who score high on one type of imagery task will typically score high on another type of imagery task, but scores differ widely from one individual to another (Poltrock and Brown, 1984). Paradoxically this difference between the two systems has also provided the basis for further evidence to support the shared resources hypothesis. In two brain imaging studies carried out by Farah and Peronnet (1989), ERPs were employed to map out the scalp distribution of the ERP effects. As in previous studies a correlation was observed between patterns of activity produced in the visual cortex during a perceptual task and an imagery task (Farah, Peronnet, Weisberg and Monheit, 1989). However, in addition, both studies observed that participants who rated their imagery abilities as poor showed far less activity in their visual systems than those participants who reported vivid imagery.

Taken together, the evidence from several different research methodologies seems to suggest that some of the same cognitive and physiological structures are used in high level vision and visual mental imagery. In the next section of this chapter we will see how evidence of this kind has been used to construct a model of the imagery system.

2.3 The Visual Imagery System

Not surprisingly, the evidence for shared cognitive resources in visual perception and visual mental imagery has influenced cognitive models of the imagery system. The model of the imagery system to be presented in this section was developed by Kosslyn (1996). This model was developed from theories of high-level vision. Kosslyn's arguments for doing so are based on the evidence for common underlying cognitive systems in imagery and vision, and on the fact that more is known about the visual system than about the imagery system. In formulating his theory of imagery, Kosslyn notes that even within vision research the ability to formulate a theory of high level visual processing has been a challenge to researchers. However, he believes that it is only through trying to understand how high level visual processing works that we are able to understand the purpose of visual mental imagery. In accordance with this line of reasoning, Kosslyn sets out the details of what he calls a 'protomodel' of visual object identification to explain both high level visual perception and visual mental imagery. The model comprises seven components and is illustrated in Figure 4 (below).

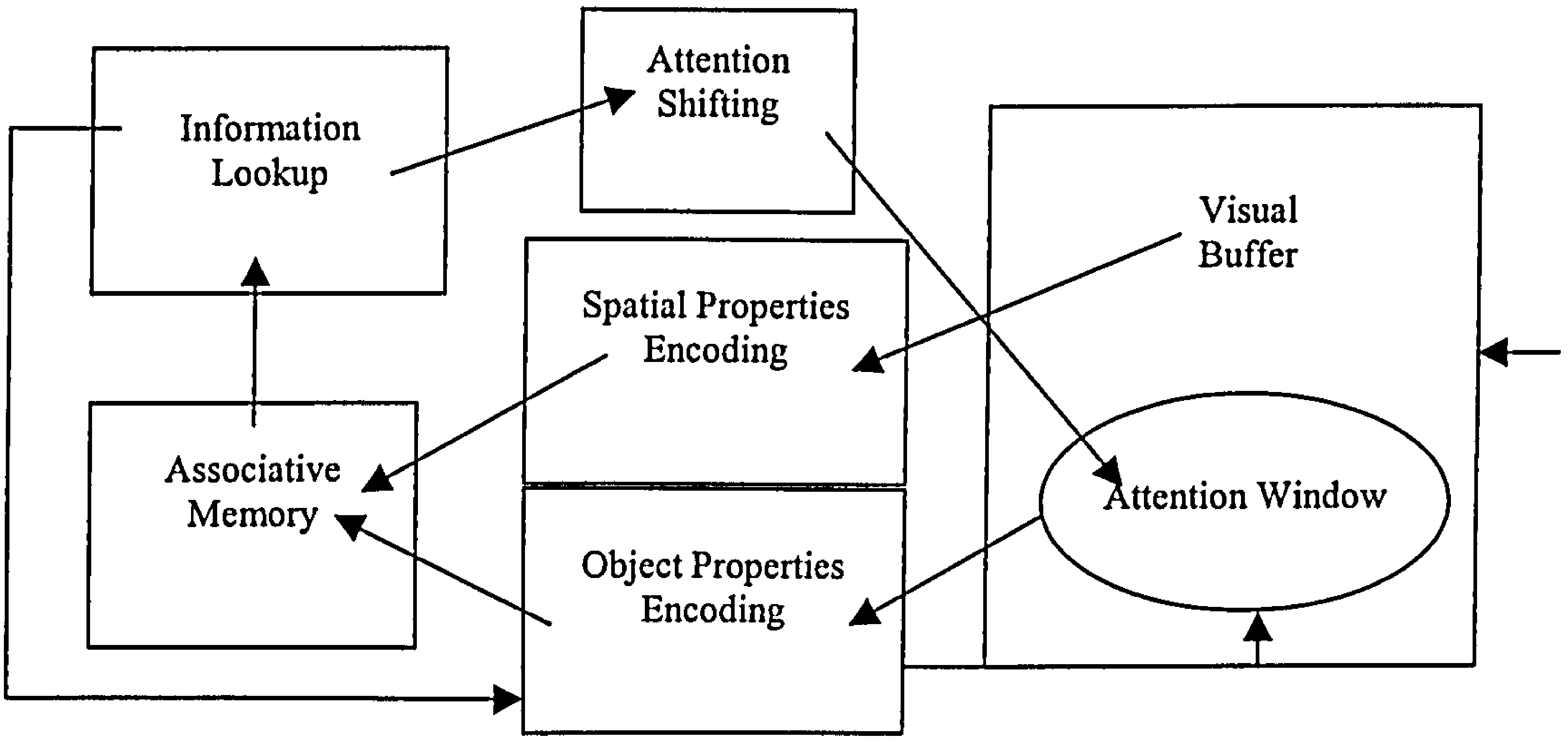

Figure 4
The Protomodel of the Imagery System (reproduced from Kosslyn, 1996, p.69)

The review of the 'protomodel' will concentrate attention on those areas of the model seen as having a direct bearing on the aims of this thesis. Therefore, only a brief review of each component will be given here. For an extended review refer to Kosslyn (1996).

The starting point in the model, and arguably the most important component in the model, is the Visual Buffer. During visual perception this structure is said to receive input from the eyes to produce a configuration of activity within the visual cortex that is used in low level visual processing, e.g. edge detection and figure/ground separation. However, in relation to visual mental imagery it is proposed that activation of the visual buffer can also be maintained after the cessation of direct on-line sensory input by using a rehearsal process and, more importantly, also as a result of stored sensory input. Kosslyn suggests that the claim that the imagery and perceptual system share the same visual buffer helps explain the fact that images fade quickly - on average after 250 milliseconds (msecs) without rehearsal (Kosslyn, 1994). He points out that in perception one does not want a representation to linger after shifting one's eyes, however this means that during the visual imagery process the representations fade without active rehearsal.

Another important feature of the visual buffer is that it is topographically organised. Support for this proposal comes from findings that show activation of topographically organised brain structures during both perceptual and visual image processing. However, it should be noted, as we saw in the last section, that debate continues as to the involvement of the primary visual cortex – one of the main topographically organised areas of the visual system. This topographical organisation within the visual buffer is considered important as it is used to account for the features of the second structure within the model, the 'attention window'.

The 'attention window' component of the protomodel relates to that part of the visual system that allows the viewer to covertly shift attention between different regions of the visual scene. The ability to shift attention between different regions of a visualised image is a well documented feature of the imagery system which is shared with the visual perceptual system. When looking at a row of shops in one's local high street, one is able to shift attention from one shop front to another. Similarly, when asked to form a visual mental image of the same street one is also able to scan the image and shift attention from one shop front to another. However, it can be noted that when viewing a row of shops one would normally move one's eyes – an overt attention shift. By comparison, when scanning an image one can use covert shifts of attention.

Given that there is always a vast amount of information available in a visual scene, the purpose of the attention window is to focus attention on those features that require further processing. Knowing just which features the system needs to concentrate on is another problem that requires explanation and is dealt with by the 'information lookup' system, which will be described shortly.

However, presuming that specific areas of sensory input have been identified for further processing, it is then necessary to understand just what that processing is. To answer this question Kosslyn refers the reader to Marr's (1982) theory of visual perception where a comprehensive description of the visual information thought necessary for visual perception can be found. However, based on the evidence for separate ventral and dorsal pathways within the visual system, Kosslyn's model differentiates between the processing of object properties and the processing of spatial relations. In a similar vein to early accounts of the function of the two visual pathways, Kosslyn proposes that object properties such as shape, colour and texture are processed in the ventral system and the relative locations of objects within a scene, by the dorsal system. It is interesting to note however, that the model does not propose any direct interaction between the two pathways, although, as we saw in the last chapter, the pathways are highly connected. Although Kosslyn does propose that

> "the dorsal (spatial-properties-encoding) system appears to encode information that is primarily used to guide actions, such as reaching and moving one's eyes" (Kosslyn, 1996, p.72)

the emphasis is on the output of representations containing spatial information for use by other cognitive systems such as the motor system. Importantly the flow of information is seen to be primarily in one direction – from vision to action - an assumption that we saw was also made by Marr. As was argued in the last chapter, evidence has accumulated to suggest that this assumption has underestimated the role of action in visual perception, and accordingly, may also underestimate the role of action in visual mental imagery.

In order to utilise the outputs from the ventral and dorsal systems, it is argued that the representations produced by these systems come together in the next structure to be described in the model, the associative memory. Having processed the sensory input, it is proposed that outputs from the ventral system, in the form of object properties, and outputs from the dorsal system in terms of spatial properties come together in the associative memory. Here they can be matched to stored information in order to aid the process of recognition. The processes of matching postulated in this theory revolve around the existence of non-accidental (Lowe, 1985, 1987) and signal properties (Kosslyn, 1996). Non-accidental properties are those aspects of an object's input image that remain relatively constant under changes of scale, rotation etc., whereas signal properties are seen as properties of surfaces such as texture gradients.

As well as matching perceptual representations, associative memory is thought to be responsible for access to names and categories etc., thereby allowing recognition and identification of stimuli to occur. However, Kosslyn notes that when we see an object in an unfamiliar position, or occluded, the outputs from the ventral and dorsal systems may not be sufficient for a match to occur with the representations stored in memory. To overcome this problem a further structure is postulated, one that uses the information available, say partially activated memories, to seek new additional information in order to implement a match. The structure responsible for this activity Kosslyn terms the 'information lookup' structure.

Having accessed additional information in the information lookup structure a final structure is then required to engage the mechanisms that will shift the whole system's focus of attention to the informative visual property identified in the information lookup system. The attention shifting mechanism therefore has a direct route to the attention window.

For several of the model's components, in particular the information lookup system and the associative memory, their role and function in visual perception is clear. However, during construction of a mental image the role of these components may seem less clear. Furthermore, Kosslyn suggests that the same components are required to explain how one inspects a visual mental image to glean information, say to answer a question. For instance, when asked to decide whether a certain building or tree is visible from an upper room in your home you may visualise the scene before inspecting it to make your decision.

In summary, the model of the visual imagery system put forward by Kosslyn is a system in which it is proposed that both high level visual processing and visual mental imagery occurs. Although the sensory input to the system is different for each process the processing stages and representations utilised in the system are hypothesised to be of a similar nature. However, like other computational models of vision, the model presupposes the production of purely visual representations for use by other cognitive systems including the motor system for the guidance of behaviour.

In the next section of this chapter literature seeking to explain the relationship between motor action and visual mental imagery is reviewed.

2.4 Visual Mental Imagery and Action

The majority of research looking at the association between action and mental imagery has concentrated its attention on motor imagery. Within this field several distinguishable types of association have been identified. Firstly, motor imagery can involve the voluntary manipulation of imaginary objects, or the imaginary manipulation of physically present objects. For example, when viewing a teapot one can imagine rotating it to see how it would look upside down, or one can conjure up the mental image of a teapot from memory and rotate that image. A slightly different sort of motor imagery involves imagining oneself performing the relevant motor actions. Again this can be broken down into several distinct action/imagery associations. For example, one is able to imagine oneself grasping a teapot and turning it upside down. In this instance one would be viewing the teapot as if one were carrying out the task in reality. In other words one would have a first person or "interior" view of the action. By contrast, one could also imagine viewing oneself performing the action, an "exterior" or third person view of the action (Jeannerod, 1995; Annett, 1995). These latter forms of motor imagery imply that one feels oneself executing an action and can therefore be differentiated from the former kind of imagery in which objects in the world or head are manipulated. Motor imagery involving a person's conscious awareness of their physical 'feelings' has been widely investigated in the field of sports psychology (Driskell, Copper, Moran, 1994; Feltz, Landers, 1983; Murphy, 1990). However, it is with the former type of motor imagery, that which involves the imaginary manipulation of either imaginary or physically present objects that the literature in this section will examine.

Annett (1995) suggests that all types of motor imagery are under voluntary control as they involve 'effortfulness' in the imagined transformations. It is claimed that this factor can distinguish motor imagery from perceived motion, as this does not require effort on the part of the viewer. Importantly, because of the voluntary element in imagery manipulation it has been postulated that internal manipulations probably partake of at least some of the properties of overt voluntary action, and therefore probably utilise some of the same brain mechanisms (Paivio, 1986; Kosslyn, 1996; Annett, 1995).

The proposal that mental manipulations draw on some of the brain's motor mechanisms can be used to help explain a well-documented imagery effect that has eluded satisfactory explanation for some time. In Shepherd and Metzler's (1971) now classic mental rotation experiment it was observed that the time taken to rotate an object is linearly correlated with the distance the object is rotated - the further an object is rotated the greater the time taken. Similar effects have also been reported in mental scanning experiments. These experiments have shown that the further apart two target stimuli are on a memorised map the longer it takes for the imager to mentally move between those stimuli (Kosslyn, Ball and Riser, 1973). When a physical object is rotated or the eyes scan a scene this relationship is not surprising as motor actions have a temporal component - the further one moves (all other factors being constant) the longer it takes. However, this relationship is rather surprising in mental imagery experiments given that the representations believed to underlie the mental images of objects are not constrained by the same physical properties as the objects themselves. If, as is proposed, the brain's motor mechanisms are required to carryout such tasks, then it may be that the brain is carrying out a simulation of the actual movements required to rotate or scan an object. If this is the case then one would also expect to observe a linear relationship between distance travelled and time taken, as the simulated motor actions would also have a temporal component.

Direct support for the proposal that mental manipulations utilise motor mechanisms, come from dual task studies that provide evidence of interference and facilitation effects between manual actions and mental manipulations.

Quinn and Ralston (1986) carried out an experiment in which they asked participants to listen to a list of digits being read out and to mentally place them in specific cells within an imaginary array. The participants in this study were assigned to four groups. In one group, participants were asked to carry out the imagery task with their hands held in front of them. In a second group participants were asked to carry out a concurrent tapping task. In groups three and four, the participants were asked to make hand movements which were either compatible or incompatible with the mental

movements that would be required to place the digits in the imaginary array.
For example in the compatible group participants would move their hands as if they were placing the imaginary digits in each of the imaginary cells, whereas in the incompatible group they would be asked to move their hands to positions which bore no relation to the position of the imaginary cells. Using memory recall as the independent variable, results showed that in conditions where hand movements were compatible with the imaginary movements recall was significantly better than in the conditions where participants performed incompatible hand movements, tapping or no movements at all.

Similar effects have also been identified in mental rotation experiments. In a study carried out by Wexler, Kosslyn and Berthoz (1998) participants were asked to carry out a standard 'Shepard and Metzler' type rotation task whilst manually rotating a lever. It was found that compatible mappings between the direction of rotation of the mental image and lever would result in faster and more accurate responses, than incompatible mappings. Wohlschläger and Wohlschläger (1998) reported almost identical findings. However in addition, this study also found that the facilitation effects were specific to the plane of rotation. Interference was observed only when mental and manual rotations occurred around the same axis.

According to Kosslyn (1996) there are two possible methods by which manipulation of mental images can occur. Firstly, a representation of the object can be formed by the imagery system then acted upon by the motor system. For example, one could form the image of a teacup in one's mind's eye and then proceed to rotate it. Kosslyn refers to these types of mental actions as 'motion-added' transformations. By contrast, he also argues that it is possible to encode an object that one has previously viewed in motion. For example, one may recall a particular goal being scored by a footballer. In this instance one would be encoding the object description together with the motion forming part of the representation. He refers to these type of actions as 'motion-encoded 'representations. It is suggested that when recalling a motion-encoded representation the motion element of the representation is activated at the same time as the object description, whereas for motion added transformations the object description is first constructed and then acted upon by the motor system to produce the required motion.

It can be noted that the concept of motion-encoded transformations described by Kosslyn suggests a coupling together of action and object representation, whereas motion-added transformations suggest the relative independence of object representation and action. Although in some ways motion encoded representations bear a resemblance to the ideas put forward in the last chapter, where it was argued that object representation was the coupling together of action encodings and object descriptions, motion-encoded representations and motion-added transformations differ in one important aspect to the action encodings discussed in the last chapter. Both motion-added and motion-encoded representations relate to the conscious awareness of the movement of objects in space, albeit imaginary space. However, in the last chapter the role of action in the visual perceptual process was discussed in relation to a theory of micro-affordances. According to this theory certain object attributes can potentiate relevant actions in the viewer because the object representations include encodings of the relevant actions that can be carried out on the objects. Unlike the motion-added transformations and motion-encoded transformations described by Kosslyn, micro-affordances do not involve the conscious awareness of the movement of an object through space. It seems important therefore to differentiate between two sorts of possible action in visual mental imagery. It is suggested that when motor action in visual mental imagery refers to action encodings which relate to the movement of object images in space – rotation, scanning etc – whether the movement arises from motion-encoded or motion-added representations, such actions can be referred to as "dynamic" action encodings.

By contrast, when motor action in visual mental imagery refers to action encodings that form part of the mental representation of an object even when there is no movement of the object through space, for example, as in the case of micro-affordances, these actions can be referred to as "non-dynamic" action encodings.

Although the experiments described in this section of the chapter have suggested a role for the brain's motor mechanisms in visual mental imagery, the relationship between action and visual mental imagery has been in relation to 'dynamic' actions. However, thus far no evidence has been presented for the latter role of action, 'non-dynamic' action encodings or micro-affordances. There are however a number of studies that suggest that 'non-dynamic' action encodings could form part of the representations underlying the visual mental images of objects.

In the last chapter it was noted that micro-affordance effects and the spatial Simon Effect both occur when some dimension of an object stimulus produces action potentiation effects even though the object dimension that produces the effects is irrelevant to the action task being carried out. In a study carried out by Tlauka and McKenna (1998), evidence is presented to suggest that the spatial Simon Effect also occurs during visual mental imagery. In the first experiment carried out for this study, participants were shown a copy of one of two maps, which they were asked to memorise. On each map two target stimuli were marked, "A" and "B". On one map the "A" was positioned on the left-hand side of the map and the "B" on the right-hand side, whereas on the other map the position of the letters were reversed. Having viewed and memorised one copy of the map, participants were shown a series of "A's" and "B's" (the target stimuli) at random, in the centre of a computer screen. Depending on the mapping rule given at the start of the experiment, participants were asked to press either a left or right positioned key in response to the stimuli whilst conjuring up a mental image of the previously viewed map. The results of the experiment revealed that when the stimuli being responded to were positioned in a congruent position on the imaged map to the hand of response, response times were significantly faster than when the stimuli were in an incongruent position. In a second experiment the results were replicated, but this time the effects were produced through a verbal description of the map rather than a vision-based stimulus.

Although the Tluaka and McKenna study presents evidence for compatibility effects arising from the spatial congruence between an action response and an object's position it does not necessarily provide evidence for micro-affordance effects, because as we saw in the last chapter these two effects appear to differ in at least two significant ways. It has been found that Simon Effects decrease with longer response latencies, whereas micro-affordance effects increase. In addition, it has been observed that cueing a participant response with colour will produce Simon Effects but not micro-affordance effects.

Other evidence to suggest that non-dynamic action encodings may be present in non-visual representations comes from a study involving the viewing and reading of action words (Martin, Haxby, Lalonde, Wiggs and Ungerleider, 1995). In this brain imaging experiment areas of regional blood flow in the premotor areas of the brain were examined when participants were asked to view action words and colour words. The results of the study revealed activation in the premotor areas usually associated with the perception of motion, when participants viewed action words but not when they viewed colour words. Although these findings do not show direct evidence for non-dynamic action encodings in visual mental imagery, they do suggest that it is not only the on-line visual processing of seen objects that produce action effects.

The only direct evidence for micro-affordance effects has arisen from a study looking at the relationship between short-term visual memory and action carried out by Richardson, Spivey and Cheung, (in preparation).

The study, based on the findings of Tucker and Ellis (1998) and Ellis and Tucker (2000), sought evidence of micro-affordances in 'off-line' visual processing. The study consisted of two experiments. In the first experiment participants were shown a series of eight object images in succession. The images contained a number of objects that had no obvious affordance for a left or right hand grasp and a number of objects that could be oriented to be grasped by both right and left hand grasps. Each object was presented for a period of 200 msecs. After presentation of the last image on a trial there was a one second pause before participants heard the name of an object. Participants then had to press one of two keys depending on whether the object named was present in the stimulus set (a 'yes' response) or not present (a 'no' response). Analysis of the results revealed that when participants responded 'yes' with a right key press to objects optimally oriented for grasping with a left-hand grasp, responses were significantly faster than right key presses to objects optimally oriented to be grasped with a right-hand, and vice versa. This 'incompatibility' effect contrasts sharply with the 'compatibility' effect reported by Tucker and Ellis (1998) which showed faster response times to objects which shared the same spatial dimension (left or right) with the hand of response (left or right).

To try and explain the difference in results between the two studies Richardson et al draw on a Theory of Event Coding, most recently developed by Stoet and Hommel (1999). According to this theory, perception and actions are coded in a shared medium. It is argued that following immediate presentation of an object image, features of that object can facilitate compatible or overlapping responses, e.g. a left-oriented objects and left-hand grasps. However, once these features have been activated for a certain period of time they become incorporated in what is termed an 'event file'. The event file consists of a temporal binding together of the feature codes and action codes that originally facilitated the compatible responses thereby making them no longer available for the planning and control of other actions. Once this binding occurs an incompatibility effect is observed in the data.

In support of their argument Richardson et al note that the response times in their 'visual memory' study were much longer than those recorded by Tucker and Ellis. The average response time recorded in the Richardson et al study was 1500 msecs, whereas in the Tucker and Ellis study it was approximately 700 msecs. This piece of evidence they suggest fits well with the Theory of Event Coding espoused by Stoet and Hommel (1999). In order to test the explanation further, Richardson et al carried out a second experiment.

In their second experiment participants were given a series of verbal descriptions, each one comprising a visual scene. Each description included one object which was oriented to be either maximally compatible with a left hand grasp or a right hand grasp. The scenes specified the orientation of the oriented object indirectly, with reference to other objects in the scene (see Figure 5). Having heard a description, participants were given a 'yes' or 'no' question regarding the oriented object in the scene, which they responded to with either a right or left-hand key press. The initial analysis revealed no significant interaction between object orientation and hand of response. However, when a second analysis was carried out to compare the slow trials (those below the medium response time of 1020 msecs) with the fast trials (those above the medium response time of 1020 msecs) a significant negative compatibility effect was observed for the slow responses. Although non-significant, the pattern of results for the fast trials showed an inverse relationship. Consistent with the findings of Tucker of Ellis (1998) right-hand responses to right-oriented objects were executed faster than right-hand responses to left-oriented objects and vice versa.

There is a breakfast table covered in a red and white tablecloth
On the left (right), there is a green egg cup with a flower painted on it.
To the right (left), there is a bowl of soggy cornflakes.
Between them, there is a blue milk jug.
Its spout points towards the bowl and its handle is next to the egg cup.
A newspaper lies folded on a chair.

- TONE –
-

Q. In the center of the tale, was there a milk jug?

Figure 5
Example of a Verbal Description Given to Participants in the Richardson, Spivey and Cheung Study (in preparation)

The findings of the Richardson et al study give direct support to the proposal that action encodings underlie the representations utilised in 'off-line' visual processing.

To return to the arguments put forward at the beginning of this chapter by Goodale and Humphrey (1998) and Ellis and Tucker (1998) in relation to the function of the ventral and dorsal systems in object representation, it can be seen that the evidence from the Richardson et al study is more consistent with the argument put forward by Ellis and Tucker (1998). According to these authors micro-affordances would be predicted in off-line vision as object representation is believed to be the coupling together of visual object descriptions and associated actions. However, such a prediction would not automatically arise from the argument put forward by Goodale and Humphrey (1998) for the relationship between the ventral and dorsal systems. According to these authors the Gibsonian approaches to vision, which include the notion of affordances, is under the remit of the dorsal system, and it believed that the dorsal system is primarily responsible for 'on-line' motor co-ordination.

Although the Richardson et al evidence helps support the notion that micro-affordances are present in off-line vision a number of questions still remain unanswered. Firstly, the 'orientation of an object for grasping' is only one example of the micro-affordance effects observed in on-line vision. As we saw in chapter one, micro-affordance effects have also been observed in relation to the compatibility of an object for grasping by either a power or precision grasp (Ellis and Tucker, 2000; Tucker and Ellis, 2001), and the direction of wrist rotation required to bring an object into its upright position (Tucker and Ellis, 1998). Questions therefore remain as to whether these additional object attributes also potentiate actions in off-line vision.

In addition, the Richardson et al study has only looked at two specific types of off-line visual processing. In Experiment One an experimental design was employed to investigate the presence of micro-affordances in short-term visual memory. Although as stated earlier, the processes underlying the different 'off-line' visual processes – short-term visual memory, long-term visual memory, visuo-spatial working memory and visual mental imagery - are likely to be highly connected, some researchers suggest there are differences in the cognitive resources utilised in visual mental imagery and visual memory experiments (Pearson, De Beni and Cornoldi, 2001; Pearson, Logie and Gilhooly, 1999). In the next section of this chapter some of these differences will be examined.

In the second experiment reported by Richardson et al, a visual imagery paradigm was used. Participants were asked to generate a visual mental image from a verbal description and then inspect the image to answer a question. Although, this second experiment was a visual mental imagery experiment it can be differentiated from other types of visual mental imagery. For example, participants could be asked to form the visual mental image of a recently viewed scene and then inspect that image to answer a question. An experimental design of this kind would differ from the short-term memory paradigm used in experiment one of the Richardson et al study, as participants would have to engage in 'effortful' retention, or reconstruction of the recently viewed scene to carry out the task. In addition, such a design would also differ from the experimental design employed in experiment two of the Richardson et al study. Although participants in that experiment engaged in visual mental imagery, the image was constructed from the long term memories of objects together and spatially arranged according to the information contained in the verbal description. It can be noted that the proposed alternative design also differs from the second, as it can be argued that the image to be retained or reconstructed would be accessed from short-term memory and not long-term memory.

In the remainder of this thesis eight experiments are reported which seek to provide further evidence for micro-affordance effects in off-line vision. The experiments will also examine the merits of experimental designs aimed at (1) examining the contents of short-term memory and (2) those investigating the construction and inspection of a visual mental image from a recently viewed scene.

2.5 Visual Memory and Visual Mental Imagery

As mentioned in the last section, researchers have suggested that there are differences in the cognitive resources utilised in visual mental imagery and visual memory experiments (Pearson, De Veni and Cornoldi, 2001; Pearson, Logie and Gilhooly, 1999). To understand these differences it is important to appreciate the differences in research focus that exists between the study of memory, and the study of visual mental imagery. These differences in research focus are clearly appreciated when the cognitive models developed in the different fields to explain off-line visual processes are compared.

For example, as we saw in section 2.3 above, the most prominent model to arise in the field of visual mental imagery is Kosslyn's (1996) 'protomodel' of the imagery system. According to this model, the topographically organised representations that give rise to the conscious awareness of visual mental imagery are held in sub-system called the 'visual buffer'. However, the model's primary focus is to explain the image processes themselves, particularly those involved in the high-level processing of visual representations, and during image generation and image transformation.

Kosslyn's model of the imagery system can be contrasted with Baddeley's (1986) working memory model. Baddeley's model is a memory model developed to explain the short-term retention and manipulation of both verbal and visual information. The model comprises three components: a central executive; a phonological loop, and a visio-spatial sketchpad. According to this model, visual information is accessed through activity in two components of the model – the central executive and the visuo-spatial sketchpad. The visuo-spatial sketchpad is described as a modular system designed for the short-term retention of visual material, whereas the central executive is described as a modular free system that supervises the processing within the visual-spatial sketchpad (and the phonological loop when verbal information is being processed).

More recent developments suggest that the visuo-spatial sketchpad can itself be divided into two separate sub-systems - a 'visual cache' supported by an active 'inner scribe' (Logie, 1995; Logie and Pearson, 1997). The visual cache is described as a passive storage system for the retention of visual information. Whereas the inner scribe is believed to be an active system involved in rehearsing the contents of the visual cache and in the planning and execution of movement. Information held in both these subsystems are believed to be extracted by the central executive component of the working memory model when required to complete various cognitive tasks.

Although both of the above models identify a main component for the retention of visual information - the visuo-spatial sketch in Baddeley's working memory model and the 'visual buffer' in Kosslyn's model of mental imagery, the two components cannot be considered analogous (Logie, 1995; Pearson , Logie and Gilholey ,1999). Whereas the visual buffer is thought to be a component of the imagery system where conscious mental images are represented, the contents of the visual cache and inner scribe are thought to be outside conscious awareness. It is argued that the visuo-spatial sketch stores visual information that is then extracted by the central executive and utilised during cognitive tasks such as visual mental imagery. By contrast, it is argued that the process of visual mental imagery draws on all components of the working memory system and is therefore reliant on visual memories but must be considered functionally separate to visual memory. One important feature that has been said to differentiate visual mental imagery from other off-line processing, is the effort required to generate the images (Annett, 1995; Kosslyn 1996). Moreover, it has been suggested that different imagery processes differentially involve components of the working memory system. For example, tasks that have been found to interfere with visuo-spatial working memory such as concurrent spatial tapping do not interfere with visual mental imagery. However tasks such as random generation, which are believed to rely on central executive function have been found to interfere with mental imagery (Logie, 1995; Bruyer and Scailquin, 1998).

Given the differences in research focus and subsequent findings that exist between the study of visual memory and visual mental imagery, it is not surprising that differences also exist in the empirical methodologies used to explore the nature of these two visual concepts. As we saw above, Richardson et al found evidence for micro-affordance effects arising from the orientation of an object using a standard short-term memory experimental paradigm in which participants had to respond to either the presence or absence of a target object in a previously viewed series of object images. In addition, orientation effects were also observed using an experimental design in which participants had to respond to either the presence or absence of a target object in a visual mental image of a scene constructed from long-term memory of objects by the use of verbal instruction. However, as we saw at the end of the last section, an alternative experimental design for investigating micro-affordances in visual mental imagery would be one in which participants were asked to retain or reconstruct the visual mental image of a recently viewed scene in order to make an action in response to some feature of the visual mental image.

2.6 Research Methodology and Hypotheses

In the following four chapters empirical evidence will be presented to further support and develop the proposal that the representations underlying the ‘off-line’ visual processing of objects contain action encodings. In addition the suitability of a number of different experimental paradigms designed to identify micro-affordance effects are investigated. In the course of the investigation it will be shown that unlike the spatial Simon Effects, the measurement of micro-affordance effects is sensitive to the particular experimental design employed to produce the effects.

In Chapter Three, two experiments are reported. The first experiment partially replicates the findings of Ellis and Tucker (2000) where it was observed that compatibility effects exist between the power and precision elements of a grasping action and the compatibility of a seen object for grasping by a power and precision grasp. Although, the design of the experiment is based on a similar SRC design employed in the earlier micro-affordance studies, it has been modified in order that it can be implemented in studies investigating the representations underlying imagined objects as well as those investigating seen objects. In addition, the modified design also provides evidence to suggest that a seen object can produce micro-affordance effects when placed in an array with other objects.

In the second experiment, reported in Chapter Three, the same experimental design and stimuli are used as in Experiment One. However, this time evidence is presented for compatibility effects between the power and precision element of a reach to grasp action and the compatibility of an ‘imagined’ object for grasping. The experimental design requires that participants either retain or reconstruct the visual mental image of an array of four recently viewed objects in order to carry out a S-R categorisation task.

In Chapter Four one experiment is reported. This experiment utilises the same experimental design and methodology used in Experiment Two. However, this time evidence is sought for compatibility effects arising from the orientation of an object for grasping by a particular hand. However, unlike experiment two, the results of this experiment find no evidence of micro-affordance effects.

In Chapter Five two experiments are reported. Once again the experiments use an experimental design in which participants are asked to construct a visual mental image from a recently viewed stimulus in order to carry out a response task. However, unlike the three previous experiments the experimental design used in these two experiments is adapted from the design employed in the Tlauka and McKenna (1998) study. This study, as we saw above, found evidence for the spatial "Simon Effect" in visual mental imagery. In the first experiment reported in this chapter evidence was again sought micro-affordances arising from the orientation of an object for grasping. As in the previous experiment no micro-affordance effects were observed for this component of the reach-to-grasp action. However, consistent with the findings of the Tlauka and McKenna study, the experiment does provide evidence of the spatial "Simon Effect" in visual mental imagery. In the second experiment reported in this chapter further evidence was sought for micro-affordance effects arising from the power and precision component of the reach to grasp action. However, unlike the results of Experiment Two reported in Chapter Three, no micro-affordance effects were observed. Once again, however, the experiment does provide evidence for the spatial Simon Effect in visual mental imagery.

In Chapter Six three experiments are reported. The experiments this time employ an experimental design aimed at testing participants' short-term memory. Unlike the previous experiments, participants are not required to form a conscious visual mental image to complete the task. The experimental design employed in all three experiments is similar to that employed in the first experiment reported by Richardson et al study. However, the number of images presented to participants on each trial, and stimulus-processing times are varied. In addition, in all three experiments participants make their action response to a written rather than a spoken object name. All three experiments report evidence of either or both compatibility and incompatibility effects arising from the orientation of an object for grasping by a particular hand.

In the final chapter a summary of the major experimental findings is presented followed by an outline of the theoretical implications of the results. Finally a short discussion is carried out to discuss ideas for future research.

Chapter Three

3.1 Introduction

This chapter describes two experiments. Each experiment was undertaken to obtain evidence for micro-affordance effects arising from the "power" and "precision" component of the reach-to-grasp action. In the original study that reported these effects (described in Chapter One), power grasp responses to seen objects optimally compatible with a power grasp response were executed faster and more accurately than precision grasp responses to seen objects optimally compatible with a power grasp response, and vice versa (Ellis and Tucker, 2001).

In Experiment One a modified version of the SRC categorisation task employed in the original micro-affordance experiments was used to try and replicate earlier findings for seen objects. Consistent with the earlier study, participants were presented with a series of trials in which they had to categorise an object as either "naturally formed" or "manufactured" using either a "power" or "precision" grasp response. However, in contrast to the experimental design used in the earlier study, where participants were presented with a single object on each trial, participants in this experiment were presented with an array of four objects on each trial. Each array comprised a combination of objects that were compatible with either a power or precision grasp and which could be categorised as either naturally formed or manufactured. In order to identify the object toward which participants were to respond (the "target" object), a small arrow appeared in the middle of the screen directing attention toward one of the four objects in the array.

This same design was then used in Experiment Two. However, this time the aim of the experiment was to identify micro-affordance effects arising from the visual mental image of an object. Although Experiment Two employed the same experimental design as that used in Experiment One, identification of the target object occurred 700 milliseconds after the array of objects had been removed from the screen. The arrow this time pointed to the position on the screen that had been occupied by one of the objects in the image array just viewed. In order to carryout the task, it was assumed that participants would form a visual mental image of the object array just viewed.

The reasons for employing the modified experimental design in these two experiments were two-fold. Firstly, the new design could be used when investigating both seen and imagined objects. Secondly, and more importantly, the design was intended to increase the likelihood of participants forming a visual mental image of an object when used in Experiment Two.

The design employed in the studies first reporting micro-affordance effects could have been used to induce visual mental imagery in participants. Participants could be shown each object image, asked to delay their responses until after each image was removed from view, while at the same time being asked to form a visual mental image of the object just seen. However, this strategy would rely solely on participants' motivation to adhere to the instructions. The easiest solution for participants in these circumstances would be to categorise the object as it was presented, and remember the category label in order to make the desired response after the object was removed from view, so removing the need to form a visual mental image. Although some evidence exists to suggest that participants do form visual mental images in tasks which rely entirely on the experimenter's instructions to do so (Tlauka and Mckenna, 1998), it was decided to create an experimental design in which visual mental imagery could be employed to aid participants in carrying out the categorisation task and so increasing the likelihood of participants employing visual mental imagery when instructed to do so. To this end, the decision to use four objects on each trial instead of one single object was made. The reasoning behind this decision was that visual imagery has been found to enhance people's ability to remember multiple item arrays when there is an increased cognitive load on working memory (Hatano and Osawa, 1983). In addition, it was hoped that by informing participants of this fact, it would further encourage them to adhere to the instructions to form a visual mental image to complete the task.

However, in spite of modifications to the experimental design it was still possible that participants would use the 'category coding' strategy described above to carryout the task in Experiment Two. For example, instead of creating a visual mental image of the four objects after they had disappeared from view as instructed, participants could complete the task by categorising all four objects in a picture before they had disappeared, and then remembering the spatial configuration of the 'category codes' – "manufactured" and "naturally formed".

To help minimise the likelihood of a 'category code' response strategy, an additional memory task, which it was believed would further increase the likelihood of participants using visual imagery, was included at random intervals during Experiment Two – the details of the task are described in Section 3.2.2 below.

3.2 Experiment One

3.2.1 Introduction

In this experiment participants were asked to categorise one object presented in an array of seen objects as either naturally formed or manufactured. The objects presented in the experiment were either maximally compatible with a "power" grasp, e.g. a hammer or banana, or maximally compatible with a "precision" grasp, e.g. a key or a peanut. Depending on the mapping rule given, participants were asked to press either a "power" grasp switch if the object was manufactured and a "precision" grasp switch if the object was naturally formed, or vice versa. It was hypothesised that power grasp responses to objects optimally compatible with a power grasp action would be executed faster and more accurately than power grasp responses to objects optimally compatible with a precision grasp action, and precision grasp responses to objects optimally compatible with a precision grasp action would be executed faster and more accurately than precision grasp responses to objects optimally compatible with a power grasp action.

3.2.2 Method

Participants

Forty participants from the University of Plymouth took part in the experiment. All participants had normal motor function in their right hand and normal or corrected to normal vision. Each was paid £3.00 for participating in the experiment.

Apparatus and Materials

The stimulus set comprised 84 colour photographs each picturing four objects. Each picture in the stimulus set depicted a combination of two objects that were optimally compatible with a precision grasp (between thumb and index finger) and two objects that were optimally compatible with a power grasp (whole hand). In addition, the objects were a combination of naturally formed objects, e.g. fruit and vegetables, and manufactured objects, e.g. tools and household implements. Each picture contained either: two naturally formed objects and two manufactured objects; 1 naturally formed object and 3 manufactured objects; or 3 naturally formed objects and 1 manufactured object. The objects chosen for inclusion in each photograph were taken at random, according to the above criteria, from a list of 40 objects (Appendix A).

The objects were photographed to appear in roughly the same position in each photograph, to the top, bottom left and right of the computer screen.

The pictures were viewed on a 19" monitor at a distance of approximately 50 cms. Each object subtended an angle of between 1.72 and 15.38 degrees (Appendix B).

Participant responses to the reaction time task were recorded on a specially designed hand held device, which they held in their right hand. The device had two switches, one held between the index finger and thumb and one held along the palm of the hand[2] (see Figure 6).

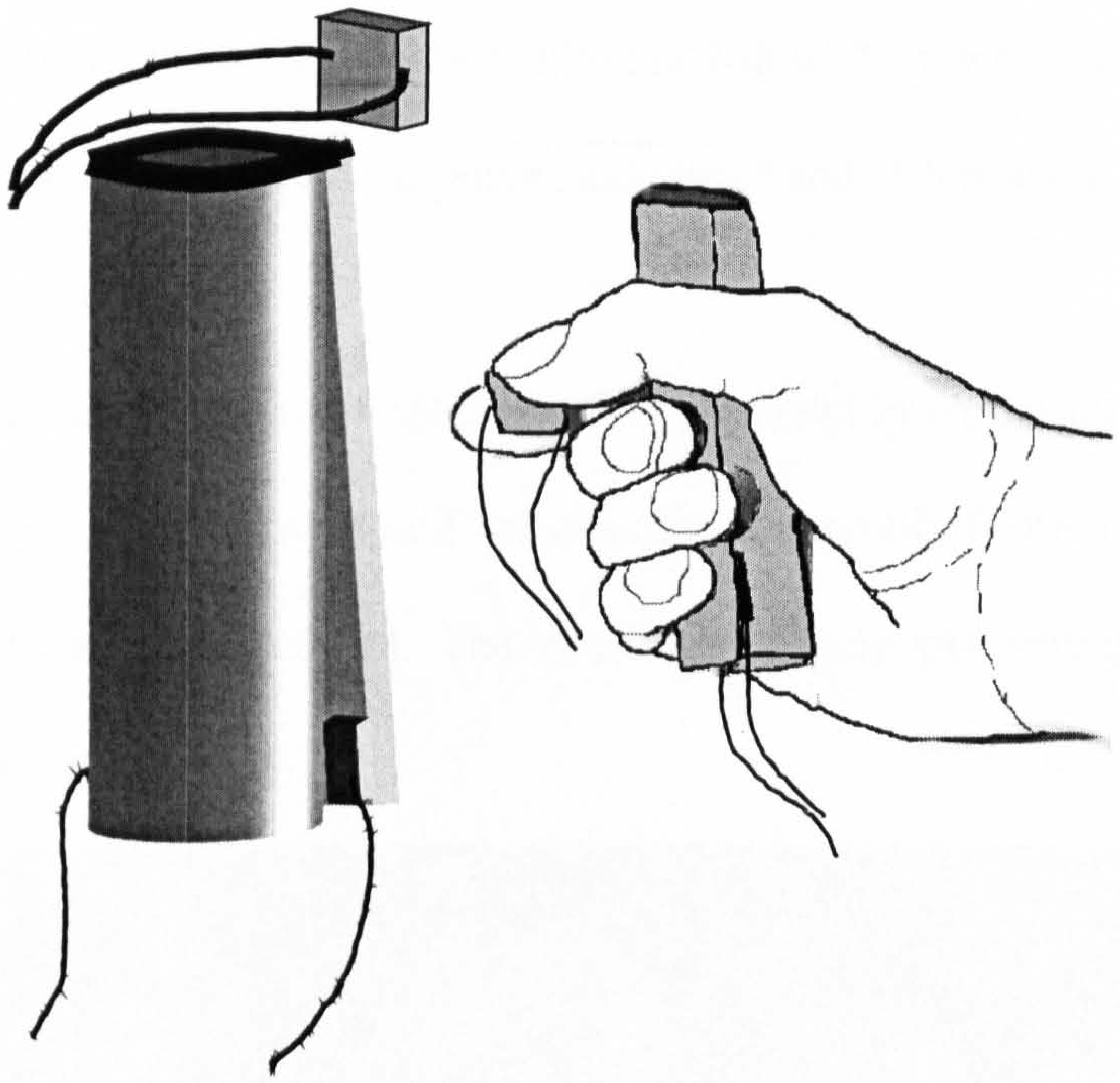

Figure 6
Response Device

Design

Each of the 84 photographs was presented to the participants on four occasions resulting in 336 trials. In order to ensure a balanced design, the combination of two power grasp and two precision grasp objects appeared in each of the six possible grasp position combinations[3]. In addition, for each of these grasp type combinations, the combinations of manufactured and natural objects appeared in each of the four positions in the photograph (top, bottom, left and right), resulting in 84 separate photographs (see Appendix C for a complete listing of object combinations). No object appeared twice in the same picture.

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[2] When used uni-manually the response device did not allow for a complete power grasp as the index finger on the response hand was positioned to make a precision grasp (see Figure 6).

[3] Positioning of two power grasp and two precision grasp compatible objects in the four computer screen positions: (1) Top-Power, Right-Power, Bottom-Precision, Left-Precision; (2) Top-Precision, Right-Power: Bottom-Power, Left-Precision; (3) Top-Precision, Right-Precision, Bottom-Power, Left-Power; (4) Top-Power, Right-Precision, Bottom-Precision, Left-Power; (5) Top-Precision, Right-Power, Bottom-Precision, Left-Power; (6) Top-Power, Right-Precision, Bottom-Power, Left-Precision.

An example of the stimuli is illustrated in Figure 7. Order of trial presentation was randomised independently for each participant. The combination of manufactured/natural and precision/power grasp objects resulted in 168 trials in which there was a compatible mapping between participant response and object and 168 trials in which there was an incompatible mapping.

Half the participants were assigned to a mapping condition in which they were asked to press the power switch if the object was naturally formed and the precision switch if the object was manufactured. The remaining participants were given the reverse mapping instructions.

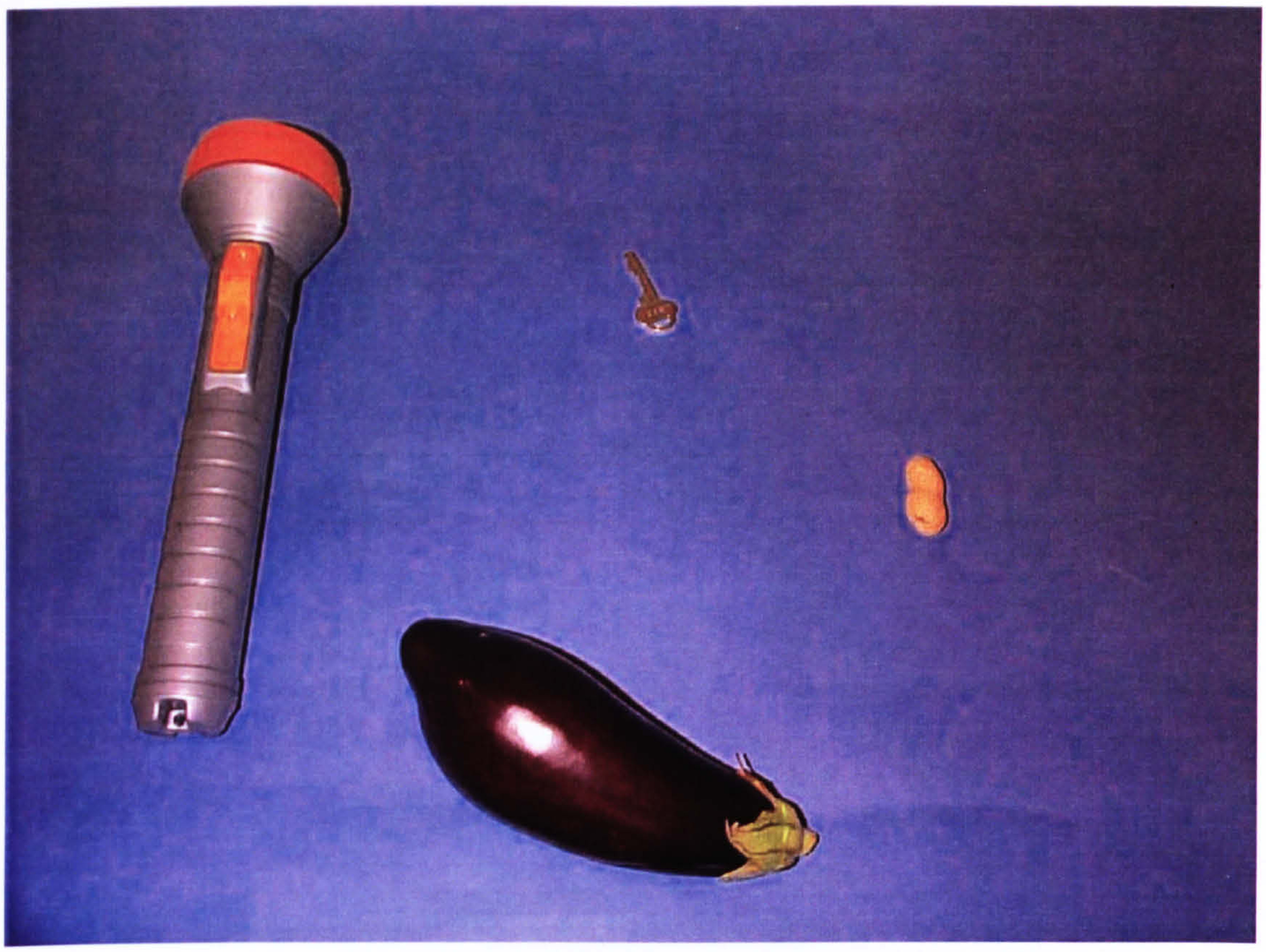

Figure 7
Example of the Object Array Used in Experiments One and Two

Procedure

At the start of each trial participants were presented with a written message informing them to "Get Ready" for presentation of the stimulus image. After 900 milliseconds (msecs) the message disappeared and a picture appeared on the screen. After a further 1100 msecs a small arrow appeared in the middle of the screen for a period of 600 msecs, directing attention toward one of the four objects in the picture. Participants were instructed to decide whether or not the object being pointed at was 'naturally formed' (e.g. a fruit or vegetable) or 'manufactured', (e.g. a key or saucepan). Having made the decision participants made their response by pressing the appropriate switch on the hand device. Participants were instructed to respond as fast as possible whilst maintaining accuracy. Incorrect responses resulted in a bleep from the computer. Having made a response the stimulus was removed from view and participants were instructed to prepare for the next trial. All participants were presented with written instructions (Appendix D) and completed 20 practice trials before commencement of the main experiment.

3.2.3 Results

Response Time Data

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment[4]. The mean error rate was calculated at 15.4[5] (St Dev 10.01). Based on this criterion the data from one participant was excluded from the analysis. In addition, errors and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Errors accounted for 4.5% of response trials, while reaction times greater than two standard deviations accounted for 8.1% of response trials. The remaining data are summarised in Table 1 (Appendix E) and were subjected to a three-way mixed ANOVA (Appendix F) with the within participants factors of Object Compatibility (power and precision) and Response Grasp (power and precision), and the between participants factor of Mapping Condition (precision-naturally formed: power-manufactured / precision – manufactured: power-naturally formed).

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[4] By excluding data sets with high error rates, participants who either responded randomly or appeared to make little or no effort to respond accurately were excluded from the analysis.

[5] Number of errors in 336 trials.

The analysis revealed a significant main effect of Object Compatibility [F(1,37) = 74.55, p<.0001], and Mapping Condition [F(1,37) = 7.16, p = .011], but no main effect of Response Grasp [F(1,37) = .658, p =.422]. The main effect of Object Compatibility revealed that responses to objects compatible with a power grasp response were executed significantly faster (m = 729.03 msecs) than responses to objects compatible with a precision grasp response (m = 754.13 msecs). This effect can be seen to arise from the fact that power compatible objects are larger than precision compatible objects and therefore more visually salient within the visual field. The presence of the effects replicates similar effects reported in earlier studies (Tucker and Ellis, 2001).

In respect of the main effect of mapping condition the results revealed that the assignment of a precision grasp response to naturally formed objects and a power grasp response to manufactured objects resulted in faster response times (m = 699.57 msecs) than the reverse mapping (m = 783.59 msecs). Mapping effects of this kind are reported elsewhere in the literature (Ellis and Tucker 2000). There are at least two possible explanations for this mapping effect. Firstly, unlike manufactured objects, naturally formed objects whether large or small are more likely to be interacted with using a precision grasp. The reasoning behind this is that the naturally formed objects (fruit and vegetables) are regularly dissected in order to be eaten, and to do this one requires precision grasp actions. Secondly, the naturally formed, precision compatible objects may represent better exemplars of their category than the manufactured, precision compatible objects, or the manufactured, power compatible objects may represent better exemplars of their category than the naturally formed, power compatible objects..

The most important result, however, was the significant interaction between Object Compatibility and Response Grasp. This interaction is illustrated in Figure 8. The interaction shows that responses to power grasp compatible objects were executed faster with a power response (m = 711.19 msecs) than with a precision response (M = 746.87

msecs), and responses to precision grasp compatible objects were executed faster with a precision response (m = 742.60 msecs) than with a power response (m = 765.66 msecs), [F(1,37) = 8.20, p = .007].

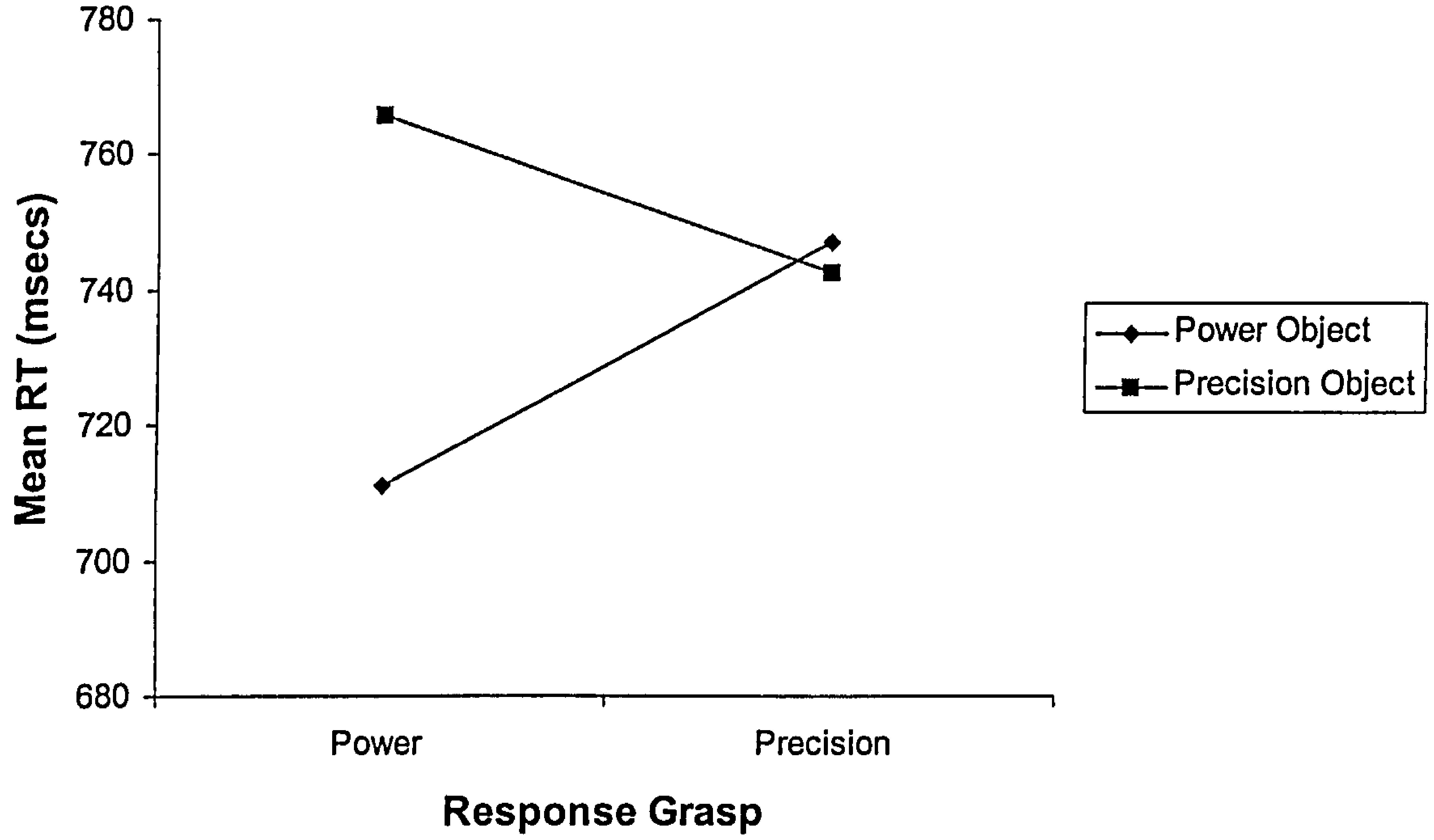

Figure 8
Mean Response Times for Power and Precision Responses to Power and Precision Compatible Objects

Significant interactions were also observed between Object Compatibility and Mapping Condition [F(1,37) = 6.03, p = .019], and Response Grasp and Mapping Condition [F(1,37) = 19.39, p<.0001]. In respect of the interaction between Object Compatibility and Mapping Condition, the analysis revealed that in both mapping conditions, responses to power grasp compatible objects were executed faster (m = 683.45 msecs and m = 774.60 msecs, respectively) than responses to precision compatible objects (m = 715.69 msecs and m = 792.57 msecs, respectively). However, the difference between the mean response time to power compatible objects and that for precision compatible objects was greater in Mapping Condition One (precision response - naturally formed/power response - manufactured) – a difference of 32.24 msecs - compared to a difference of only 17.96 msecs in Mapping Condition Two. No obvious explanation can be offered for the interaction.

In respect of the interaction between Response Grasp and Mapping Condition, the results revealed that in Mapping Condition one precision grasp responses were executed faster (m = 685.61 msecs) than power grasp responses (m = 713.53 msecs). In Mapping Condition Two the reverse pattern could be observed. Power grasp responses were executed faster (m = 763.32 msecs) than precision grasp responses (m = 803.86 msecs). This interaction can be interpreted in terms of faster response times to naturally formed objects. In Mapping Condition One, participants were asked to respond to naturally formed objects with a precision grasp, whereas in Mapping Condition Two participants were asked to respond to naturally formed objects with a power grasp.

No other interactions were found to be significant.

Error Data

The pattern of errors in Experiment One was similar to that observed in the response data. The error data is summarised in Table 2 (Appendix G) and were subjected to a three-way mixed ANOVA (Appendix H) with the within participants factors of Object Compatibility (power and precision) and Response Grasp (power and precision), and the between subjects factor of Mapping Condition (precision-naturally formed: power-manufactured / precision – manufactured: power-naturally formed).

The analysis revealed a significant main effect of Response Grasp [F(1,37) = 19.35, p<.0001], but no main effects of either Mapping Condition [F(1,37) = .009, p = .923] or Object Compatibility [F(1,37) = .632, p = .432].

The main effect of Response Grasp revealed that more errors were made in the precision grasp response condition (m = 4.33) than in the power grasp response condition (m = 3.04).

Again the most important result was an interaction between Response Grasp and Object Compatibility [F(1,37) = 53.27, p<.0001]. This interaction is illustrated in Figure 9. In the power grasp response condition more errors were made to precision grasp compatible objects (m = 4.01) than to power grip compatible objects (m = 2.07). However, in the precision grasp response condition more errors were made to power grasp compatible objects (m = 5.55) than to precision grasp compatible objects (m = 3.11).

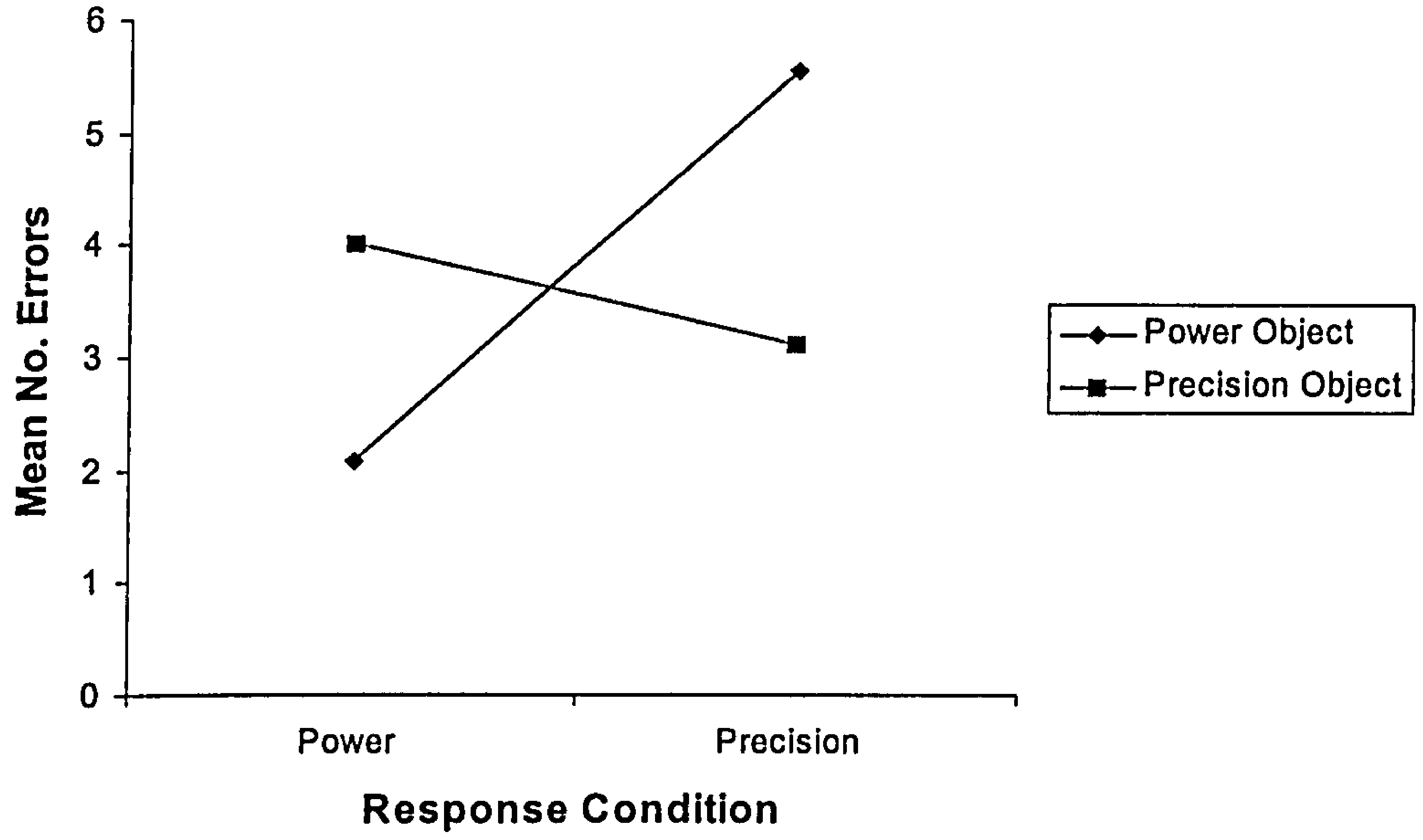

Figure 9
Mean Number of Errors for Power and Precision Responses to Power and Precision Compatible Objects

A significant interaction was also observed between Mapping Condition and Response Grasp [F(1,37) = 6.35, p = .016]. In Mapping Condition Two there was little difference between the number of errors in the power response condition (m = 3.37) and the precision response condition (m = 3.92). However, in Mapping Condition One more errors were made in the power response condition (m = 4.74) than in the precision response condition (m = 2.71). As with the interaction between Mapping Condition and Response Grasp observed in the response time data, this interaction can be interpreted in terms of the assignment of precision responses to naturally formed objects and power responses to manufactured objects in Mapping Condition One, and the reverse assignment in Mapping Condition Two.

No other interactions were found to be significant.[6]

3.2.4 Discussion

The results of Experiment One are consistent with the results of the earlier experiments which report micro-affordance effects for seen objects compatible with a power and precision response (Tucker and Ellis, 2001). Importantly, the results of this experiment demonstrate that micro-affordance effects arising from the power and precision component of the reach-to-grasp action can be obtained both when viewing an object presented on its own or, when attending to a single object presented in an array of objects.

As with the earlier experiments, interactions were observed between Object Compatibility and Response Grasp in both the response time data and the error data. Interestingly, the effect size in Experiment One appears to be greater than that observed in the earlier experiments. The average effect size for trials in Experiment One was 39.07 msecs, whereas in the earlier study the average effect size was 11.5 msecs (Tucker and Ellis, 2001).

It can also be noted that the interaction between Response Grasp and Mapping Condition is consistent with the earlier study, where it was found that responses to naturally formed objects are executed faster than responses to manufactured objects.

3.3 Experiment Two

3.3.1 Introduction

Having confirmed the efficacy of the modified experimental design in identifying micro-affordance effects with 'seen' objects, the design was employed in Experiment Two in an effort to identify "power" and "precision" micro-affordance effects arising from the visual mental images of objects. In the second experiment participants were presented with the same series of stimuli used in Experiment One, but this time object identification was assumed to rely on participants forming a visual mental image of the target object 700 msecs after it had been removed from view. It should be remembered at this point that in one of the earlier micro-affordance studies (described in Chapter One), participants were asked to respond to a 'seen' object 300 msecs after it had been removed from view. However, in this earlier study no significant compatibility effects were observed (Tucker and Ellis, 2001). In contrast to Experiment Two, presented here, it can be noted that in the earlier study no emphasis was put on participants forming a visual mental image. Moreover, it can be assumed that there was no motivation to do so – the categorisation task being easily carried out while the objects were in view.

As described at length in the introduction to this chapter, the experimental design employed in Experiment Two was designed to reduce the likelihood of a 'category coding' strategy occurring in this study. However, to reduce the likelihood further, a separate memory task was also included in the experiment at random intervals, the successful completion of which would further encourage participants to utilise a visual imagery strategy.

The memory task required that participants confirm the names of each of the four objects viewed in the previous trial together with their correct position on the computer screen. To carry out this task successfully, it can be argued that participants are more likely to use a mental imagery strategy, as successful completion of the task requires participants to store more information than would be needed to complete the 'category coding' strategy. The need to store more information in memory would therefore enhance the motivation to use visual imagery.

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[6] It is this author's view that a materials analysis (Clark, 1973) would not be useful as the objects chosen for inclusion in all experiments have been chosen to be optimally compatible with the response grasp investigated.

As in Experiment One, it was hypothesised that a compatibility effect would be observed between Response Grasp (power/precision) and Object Compatibility (power/precision) both in the response time data and the error data.

3.3.2 Method

Participants

Thirty participants from the University of Plymouth took part in the experiment. All participants had normal motor function in their right hand and normal or corrected to normal vision. Each was given credit as part of their course requirements and the sum of £3.00 for participating in the experiment.

Apparatus and Materials

The stimulus set and apparatus were the same as those used in Experiment One.

Design

The experiment comprised two tasks. The experimental design for task one was the same as that used in Experiment One.

The memory task involved the presentation of five trials in which participants were presented with the names of four objects. As with the objects in the main task, the object names were positioned to the top bottom, left and right of the screen. Participants then had to confirm whether or not the named objects and the spatial configuration of those objects were the same as in the stimulus photograph just viewed. Both the order of presentation, and the number of correct and incorrect object configurations were calculated at random for each participant.

Procedure

Main Task: The procedure for the main task was similar to that used in Experiment One. On each trial participants were presented with a written message informing them to "Get Ready" for presentation of the stimulus. After 900 msecs the message disappeared and a picture, taken from the stimulus set at random, appeared on the screen. The picture remained on the screen for 1.5 seconds before being replaced by a blank screen. After a further 700 msecs an arrow appeared in the middle of the screen, for a period of 600 msecs, directing attention toward the position occupied by one of the four objects shown in the previous picture. Participants were instructed to decide whether or not the object at that position had been 'naturally formed' (e.g. a fruit or vegetable) or 'manufactured', (e.g. a key or saucepan). Having made the decision participants made their response by pressing the appropriate switch on the specially designed hand device.

Having made a response the picture disappeared and participants were prepared for the next trial.

Memory task: At random intervals during the main task participants were asked to carry out a memory task. The task involved presenting participants with the names of four objects. Participants were asked to confirm whether or not the objects named, and the position of those objects, were the same as the objects shown in the previous picture. If they decided they were the same, participants were asked to press the precision switch, but if they decided they were different, they were asked to press the power switch. Each Participant carried out five memory tasks in total. The number of correct and incorrect object configurations presented to the participants during the memory task were calculated at random for each participant.

All participants were presented with written instructions (Appendix I) and completed 20 practice trials and 5 memory tasks before commencement of the main experiment.

3.3.3 Results

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment. The mean error rate was calculated at 18.3[7] (St Dev 14.10). Based on this criterion the data from three participants was excluded from the analysis. In addition, errors and reaction times more than two

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[7] Number of errors in 336 trials

standard deviations from the participants' means were excluded from the analysis. Errors accounted for 4.30% of response trials, while reaction times greater than two standard deviations accounted for 4.20% of response trials.

Response Time Data

The data are summarised in Table 3 (Appendix J) and were subjected to a three-way mixed ANOVA (Appendix K) with the within participants factors of Object Compatibility (power and precision) and Response Grasp (power and precision) and the between participants factor of Mapping Condition (precision-naturally formed: power-manufactured / precision-manufactured: power- naturally formed).

The analysis revealed no significant main effects of either Object Compatibility, [F(1,25) = .410, p = .528], or Response Grasp [F(1,25) = 1.15, p = .293]. Although the main effect of Mapping Condition was also non-significant at alpha = .05, the analysis suggests it was nearing significance [F(1,25) = 4.21, p = .051]. Consistent with the results of Experiment One, the data suggests that responses in Mapping Condition One (precision-naturally formed: power-manufactured) were executed faster (m = 676.18 msecs) than responses in Mapping Condition Two (precision-manufactured: power- naturally formed), (m = 781.68 msecs). As with Experiment One two possible explanations for this effect are: (1) that precision responses are more likely to be made toward naturally formed objects, whether large or small, as they can be dissected before being eaten using a precision type grasping action, and (2) the naturally formed precision compatible objects may be better exemplars of their category than the manufactured precision compatible objects or the manufactured power compatible objects may be better exemplars of their category than the naturally formed power compatible objects..

However, more importantly, the analysis revealed a significant interaction between Object Compatibility and Response Grasp [F(1,25) = 19.99, p<.0001]. This interaction is illustrated in Figure 10. The interaction shows that responses to power grasp compatible objects were executed faster with a power response (m = 709.80 msecs) than with a precision response (m = 745.34 msecs), and responses to precision grasp compatible objects were executed faster with a precision response (m = 722.69 msecs) than with a power response (m = 738.91 msecs).

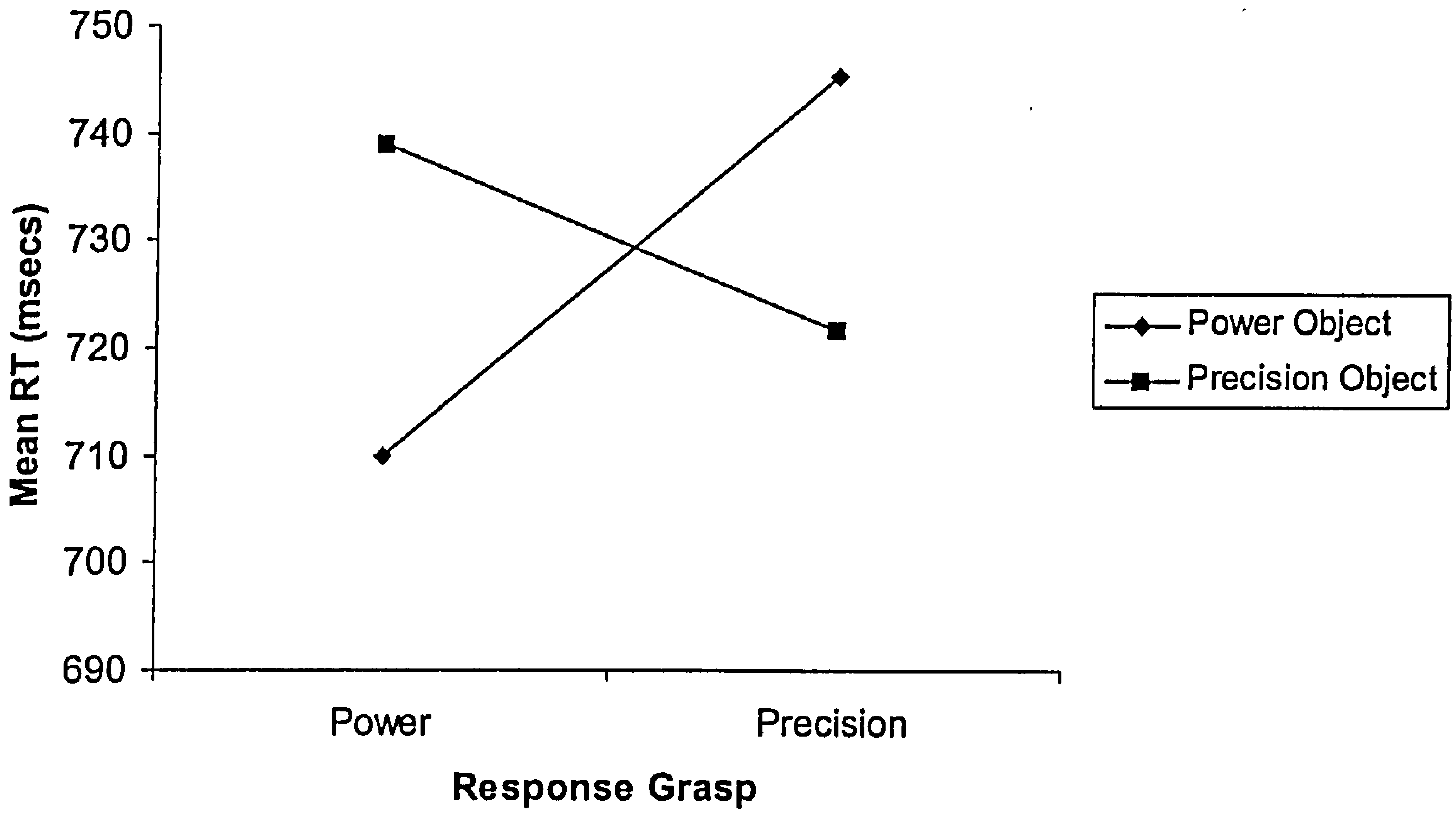

Figure 10
Mean Response Times for Power and Precision Responses to Power and Precision Compatible Objects

Interactions were also observed between Object Compatibility and Mapping Condition [F(1,25) = 4.27, p = .049], and Hand of Response and Mapping Condition [F(1,25) = 11.55, p =.002]. The interaction between Object Compatibility and Mapping Condition suggests that in Mapping Condition One responses to precision compatible objects were executed slightly faster (m = 673.14) than responses to power compatible objects (m = 679.22). Whereas in Mapping Condition Two, responses to power compatible objects were executed faster (m = 775.92) than responses to precision compatible objects (m = 787.46).

In respect of the interaction between Response Grasp and Mapping Condition, it can be observed that in Mapping Condition One precision grasp responses were executed faster (m = 666.29 msecs) than power grasp responses (m = 686.08 msecs). In Mapping Condition Two the reverse pattern could be observed. Power grasp responses were executed faster (m = 762.64 msecs) than precision grasp responses (m = 800.74 msecs). As with Experiment One, this interaction can be interpreted in terms of faster response times to naturally formed objects. In Mapping Condition One, participants were asked to respond to naturally formed objects with a precision grasp, whereas in Mapping Condition Two participants were asked to respond to naturally formed objects with a power grasp. Once again no three way interaction was observed between Mapping Condition, Response Grasp and Object Compatibility [F(1,25) =.0001, p = .983].

Error Data

The Error data is summarised in Table 4 (Appendix L) and were subjected to a three-way mixed ANOVA (Appendix M) with the within participants factors of Object Compatibility (power and precision) and Response Grasp (power and precision), and the between participants factor of Mapping Condition (precision-naturally formed: power-manufactured / precision-manufactured: power- naturally formed).

The analysis revealed a significant main effect of Response Grasp [F(1,25) = 5.18, p =.032], but no main effects of either Object Compatibility [F(1,25) = 2.06, p = .164] or Mapping Condition [F(1,25) = 2.59, p = .120]. The main effect of response grasp revealed that more errors were made in the precision grasp response condition (m = 4.00) than in the power grasp response condition (m = 3.22). This finding reflects the similar result observed in Experiment One where more errors were also observed in the precision grasp response condition.

Again the most important result was a significant two-way interaction between Response Grasp and Object Compatibility [F(1,25) = 12.21, p =.002]. This interaction is illustrated in Figure 11. In the power grasp response condition more errors were made to precision grasp compatible objects (m = 4.13) than to power grasp compatible objects (m =

2.32). Whereas in the precision grasp response condition more errors were made to power grasp compatible objects (m = 4.42) than to precision grasp compatible objects (m = 3.58).

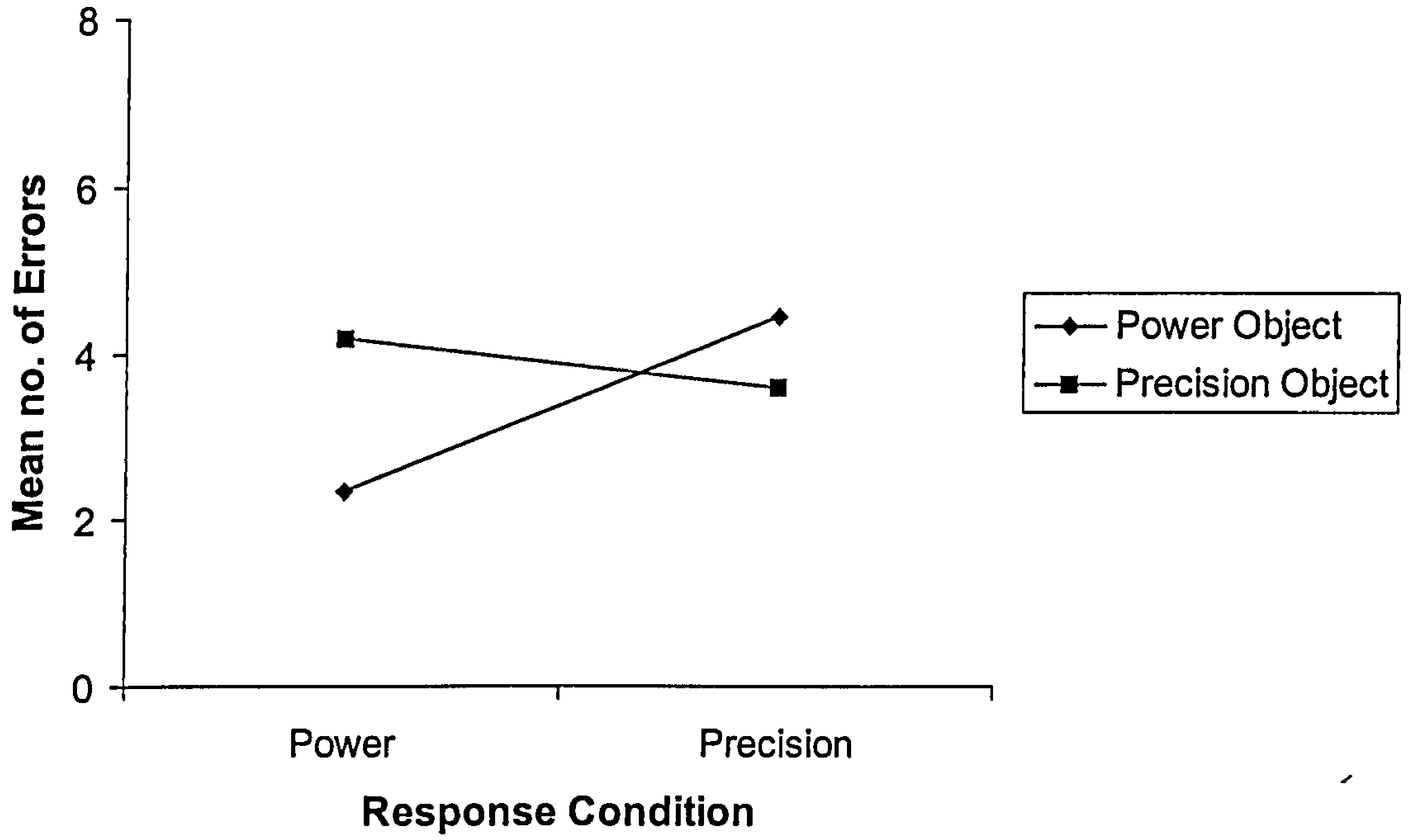

Figure 11
Mean Number of Errors for Power and Precision Compatible Responses to Power and Precision Compatible Objects

No other interactions were observed to be significant, however, the three-way interaction between Response Grasp, Object Compatibility and Mapping Condition was nearing significance [F(1,25) = 3.142, p = .088][8].

3.3.4 Discussion

In respect of the main hypothesis, the results of Experiment Two are consistent with those of Experiment One. The results show that whether or not an object is being

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[8] The data suggest that more errors were made in response to power compatible objects than to precision compatible objects in the precision response condition, and more errors were made in response to precision compatible objects than to power compatible objects in the power response condition. However, it can also be seen that the patterns of interaction between these two factors differ in the two mapping conditions. In Mapping Condition One (precision response = naturally formed and power response = manufactured) there was a larger difference in the number of errors in the power response condition than in the precision response condition. However, in Mapping Condition Two (precision response = manufactured and power response = naturally formed) the difference in the number of errors was similar.

"seen" or "imagined", power responses to power grasp compatible objects are executed faster and more accurately than power responses to precision grasp compatible objects, and vice versa. However, as the stimuli in Experiment Two were the same as in Experiment One, it was interesting to note that, although the interaction between Response Grasp and Object Compatibility was present in both experiments, there was no evidence in Experiment Two of the significant main effect of Object Compatibility observed in Experiment One. This result is of interest, as it would seem to suggest that object representations utilised in the visual condition (Experiment One) were not the same as those being used in the "off-line" imagery condition (Experiment Two). We return to this issue again in the General Discussion at the end of this chapter.

Before moving on to the General Discussion, section four of this chapter describes the results of a post hoc analysis carried out on the response time data from experiments one and two. The aim of the analysis was to compare the time-course of the effects observed in each experiment, both with each other, and with the earlier work on micro-affordances. As we saw in Chapter One, micro-affordance effects can be distinguished from the classic, standard, Simon Effect (Simon 1969) by observing the time course of the effects. Recent evidence suggests a steady increase in micro-affordance effects over a period of 1200 msecs from stimulus onset (Philips and Ward, 2002). Similarly, results of distribution analyses carried out on the response latency data of a study carried out by Tucker and Ellis (2001), suggests that effect size increases as response latency increases. These findings can be contrasted with studies examining the time course of the Simon Effect which generally show a decrease in effect size as response latency increases (De Jong, Liang and Lauber, 1994).

Although there has been some debate as to the interpretation given to the findings derived from distributional analysis (Zhang and Kornblum 1997), the results do demonstrate that the data from the two types of effects (Micro-affordance and Simon Effects) behave in a different manner to one another.

3.4 Time-Course Analysis on Experiments One and Two

A post hoc analysis was carried out to compare the time course of the micro-affordance effects in experiments one and two with those of the earlier studies. The procedure for the analysis involves dividing participants' response times into 'grasp compatible', and 'grasp incompatible' trials, and then rank ordering them. The RTs are then divided into six 'bins' and averaged. The difference between 'compatible' and 'incompatible' bin averages is taken as a reflection of the effect size at the different response latencies. The results of this analysis are displayed in Figure 12.

From the graph the pattern of data suggest an increase in effect size as response latency increases for both experiments. The observed difference in effect size between the two experiments at bin 6 is thought to reflect the unreliability of the measure at that point in the data distribution. Due to the procedure of ranking RTs, bin 6 includes fewer response trials than the other five bins and therefore reflects a less accurate measure of average response times for the longest response latencies.

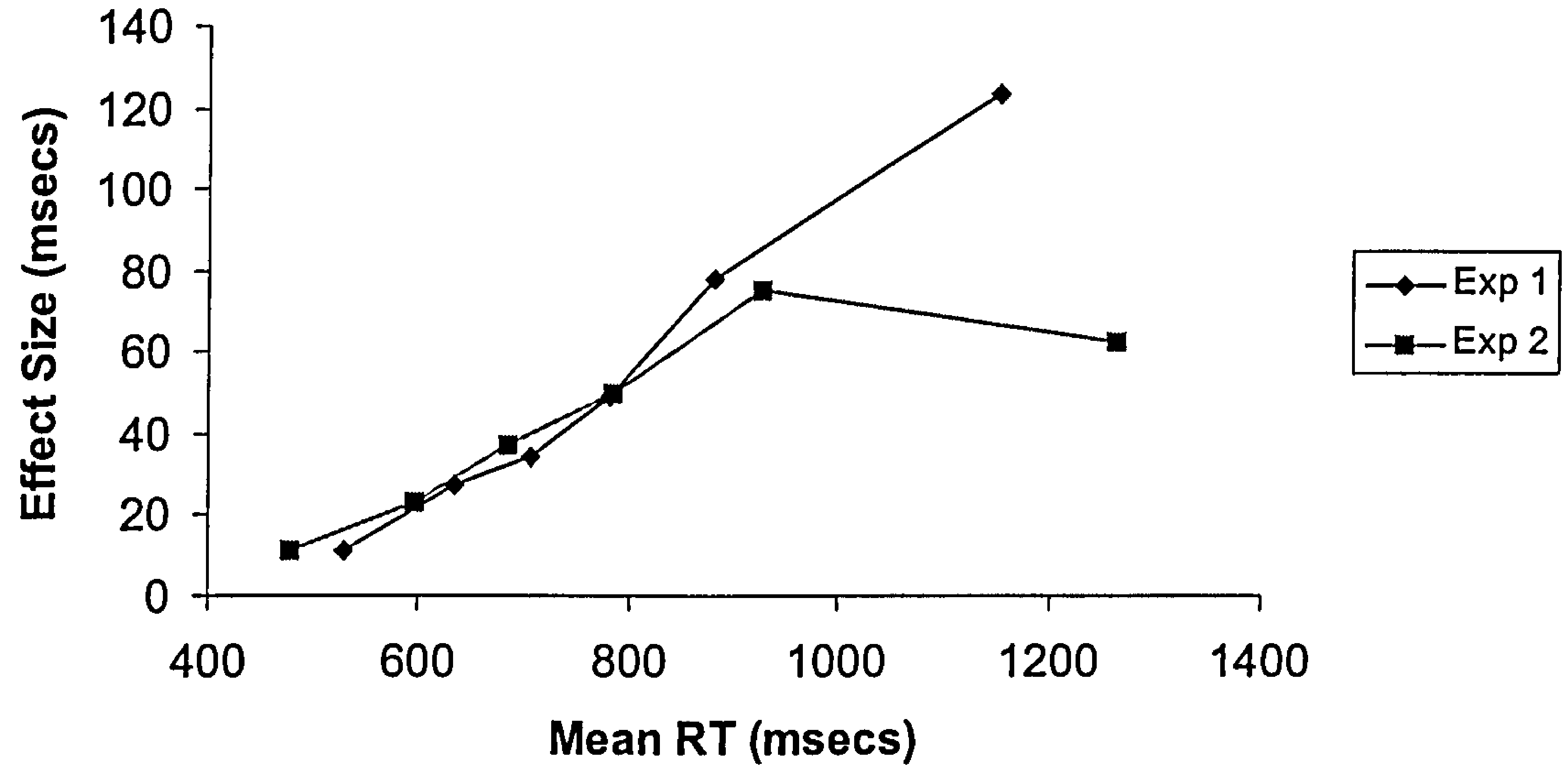

Figure 12
Time Course Analysis to compare the Effect Size in Experiments One and Two

To confirm the suggestion that effect size increases as response latency increases, regression functions were fitted to the distributional data for both experiments (Appendix N). As can be observed from the summary of the analyses in Table 5, both analyses revealed significant linear regressions with positive slopes. Moreover the results are consistent with the findings reported by Tucker and Ellis (2001).

Table 5
Coefficients of the Fitted Regression Functions of Effect Size by Reaction Time for Experiments One and Two

Experiment	Intercept (msecs)	Slope (*)	Sig.
1	-113.85	.22	P<.0001
2	-37.51	.11	P<.0001

* effect size per msec RT

3.5 General Discussion

In this chapter evidence has been presented to suggest that whether or not an object is "seen" or "imagined", power grasp responses to power grasp compatible objects are faster and more accurate than power grasp responses to precision grasp compatible objects, and vice versa.

In Experiment One, micro-affordance effects were observed in an on-line visual processing task in which participants had to direct their attention and make an action response based on one object placed in array of four objects. Consistent with the findings of earlier studies in which participants were presented with images of single objects (Tucker and Ellis, 2001), compatibility effects were observed both in the response time data and the error data.

Importantly, having provided further evidence for micro-affordance effects in on-line visual processing, Experiment Two presented new evidence for micro affordance effects in off-line vision. Again in this experiment participants had to direct their attention and make an action response to one object placed in an array of four objects, but this time the participants' attention and responses to the image could only be made 700 msecs after the object array was removed from view. Due to the fact that participants could only identify the target object after it had been removed from view, it was assumed that participants would employ some sort of off-line visual process to complete the task.

The results of Experiment Two, also provide support for the Richardson et al study, described earlier. In that study evidence was also presented for micro-affordance effects in off-line vision. However, the effects were observed in relation to the orientation of an object for grasping by a particular hand and were obtained using an experimental paradigm aimed at tapping short-term visual memory rather than one in which participants had to form a conscious visual mental image of a recently viewed object. Taken together, the results of the Richardson et al study and the results of Experiment Two, would seem to suggest that the representations utilised during both visual memory and visual imagery tasks can produce micro-affordance effects comparable to those observed in tasks where participants respond to visually present objects.

As was argued in Chapter One, the finding that off-line visual representations can potentiate actions in the imager could help establish the degree to which object representation is dependent on both the ventral and dorsal visual streams. As discussed in Chapter One, at least two alternative arguments have put forward to explain the role of the dorsal and ventral systems in visual object representation.

Firstly, Goodale and Humphrey (1998) have argued that the two visual streams are relatively independent of each other. According to this view object representation is the primary concern of the ventral system, whereas on-line visio-motor co-ordination (which encompasses the concept of affordances) is the primary concern of the dorsal system. Given that this view emphasises the 'on-line' nature of the dorsal system then the micro-affordances effects observed in the 'off-line' visual task reported in this chapter, would perhaps be unexpected.

However, an alternative argument, which predicted the presence of micro-affordances in off-line vision was put forward by Ellis and Tucker (1998). According to this argument the two visual pathways are mutually dependent and object representation is dependent on both the visual properties of an object and on the actions associated with the object.

In spite of the assumption that Experiment Two provides evidence for micro-affordances in off-line vision, a closer examination of the object attributes that give rise to these effects is required before accepting that the effects did in fact arise from off-line visual processing. In order to establish this fact it is necessary to appreciate how the object properties that give rise to the micro-affordance effects could be represented and processed.

If we examine each visual object property in turn, e.g. size, shape, weight, etc, it is possible to categorise these properties as either 'extrinsic' or 'intrinsic' object properties, and in some cases both. The term 'intrinsic' is being used here to refer to object properties that usually co-occur with the presentation of a seen object, for example, the 'object size' property, whereas, the term 'extrinsic' is being used to refer to object properties that do not always occur with the presentation of a seen object, for example, object orientation. To illustrate, when viewing a peanut, the image formed on the retina together with the distance of the object from the viewer tells us how small it is. In this example 'object size' would represent an extrinsic visual property, as it is dependent on the relationship between the object and the viewer. However, we also know peanuts are small without recourse to visual input. 'Smallness' is therefore also an 'intrinsic' object property. However, if we consider an object's orientation we can see that this attribute is solely an extrinsic visual property. When we view a saucepan, it can be positioned in many different orientations, however, knowledge of this attribute only comes about when the object is viewed and the viewer's position with respect to the object is taken into account.

It can be seen that the distinction between intrinsic and extrinsic object properties described here is related to the distinction Marr (1982) makes between object centred representations and viewer centred representations. For example, object orientation, an extrinsic object property, is a property of a viewer centred representation and not an object centred representation.

The concept of intrinsic and extrinsic object properties also closely mirrors Jeannerod's (1994) distinction between visual object properties that are processed for object identity purposes and visual object properties that are processed for the purposes of visio-motor co-ordination. Jeannerod differentiates between these two categories of visual object properties with reference to two modes of processing, the semantic mode and the pragmatic mode. According to this account object properties necessary for object identity are processed by the semantic mode and object properties necessary for visio-motor co-ordination are processed by the pragmatic mode. Consistent with the idea put forward above, that an object property, e.g. object size, can be both an 'intrinsic' and 'extrinsic' property, Jeannerod suggests that one object attribute can be processed by both the semantic system and the pragmatic systems, but to do so it must be represented in two different ways. Accordingly, Jeannerod also suggests that object size can be represented in two different forms, however, which representation will be processed at a given time will depend on the purposes for which it is being processed – object identity or visuo-motor co-ordination.

For the two experiments reported in this chapter it can be observed that the 'power' and 'precision' grasp distinction which gave rise to the micro-affordance effects can be seen to reflect at least two object attributes 'object size' and 'object weight'. Power graspable objects tend to be both larger and heavier than precision graspable objects. It can be noted therefore that in each of the above experiments participants had the opportunity to process object size as either, or both, an intrinsic and extrinsic object property and object weight as an intrinsic object property. Although the images depicted in the stimuli were in fact slightly smaller than the objects' actual size, the two categories of grasp compatible object images (power and precision) retained the relative size differential on the computer screen – power objects were larger than precision objects. However, as well as the object images varying in actual size, it can be assumed that the participants had knowledge of the objects' intrinsic size and weight. For example, a pencil is slim and light and can therefore be picked-up with a precision grasp, whereas a torch is larger and heavier and therefore requires a power grasp.

Inherent in the idea that object properties can be 'intrinsic' is the suggestion that such properties could be accessed without recourse to visual input. If this is the case, then it is possible that the effects observed in Experiment Two could have occurred without recourse to visual mental imagery. According to the information processing model put forward by Riddoch and Humphreys (1987) there is a direct link between the visual system and the semantic system. Moreover, it is suggested that the semantic system contains knowledge of the structure of objects, their function etc. Importantly, this knowledge can also be accessed through other modalities, auditory, tactile and verbal semantics. So, in principle, the observed effects could have arisen as a result of compatibility effects between semantic knowledge about the structure of objects and the actions that can be carried out on them. Moreover, to access this knowledge participants need not form visual mental images, but instead recall the verbal name labels associated with the objects just viewed.

The idea that object size can be represented as a semantic property is supported by Kosslyn (1994), who suggests that object size is encoded in associative memory together with many different properties of an object, including an object's visual pattern. In support of this assertion, Kosslyn cites a study carried out by Milliken and Jolicoeur (1992) that showed that the retinal size of an object could be dissociated from perceived actual size. Earlier studies had shown that recognition memory for shapes depends on differences between the size of shapes at the time of encoding and at the time of the memory test (Jolicoeur, 1987). Using this finding a series of experiments were undertaken in which participants were asked to study a series of novel shapes and then perform a recognition memory test in which the distance from the participants to the viewing screen at the time of testing was different from that at the time of encoding. The viewing distance and the size of the shapes were manipulated so that perceived and retinal sizes were dissociated. The results of the study showed that it was perceived size that accounted for the effect observed in the earlier study and not retinal size. It was therefore concluded that perceived size was encoded with the object representation.

Given the suggestion that object size can be represented and processed in two ways, it seems unclear as to whether the micro-affordance effects observed in the two experiments described in this chapter arose as a result of intrinsic or extrinsic object properties. One piece of evidence to suggest that different forms of representation may have been accessed in the two experiments was the presence of a main effect of Object Compatibility in Experiment One and the absence of this effect in Experiment Two. In

Experiment One it was observed that Power Grasp compatible objects were responded to faster than Precision Grasp compatible objects. However, in Experiment Two no difference in reaction times was observed between responses to power and precision compatible objects. Although the difference could also have come about by differences in the processing carried out by the imagery and visual system on an object representation, such an effect may also be expected if participants were accessing stored semantic knowledge in Experiment Two as opposed to 'viewing' a visual mental image.

In order to explore the relationship between micro-affordance effects and intrinsic and extrinsic object properties further, in the next chapter evidence will be sought for micro-affordance effects arising from a solely extrinsic object property, object orientation, when participants are instructed to form a conscious visual mental image of a recently viewed object.

Finally, one further point of interest to arise from the experiments reported in this chapter was the results of the distribution analysis carried out on the response time data. The analysis revealed a remarkably similar pattern of effects in the two experiments. In each experiment effect size was observed to increase as response latency increased. Moreover, this pattern of results reflects the pattern of results observed in the original micro-affordance studies and differentiates the effects from the patterns of results obtained by carrying out a distribution analysis on Simon Effect data, where effect size appears to decrease as response latency increases (Ellis and Tucker, 2001).

Chapter Four

4.1 Introduction

In this chapter the results of one experiment are examined. The experiment was undertaken to obtain evidence for micro-affordance effects arising from the relationship between the "orientation of an object for grasping" and the "hand of response" used to make a manual action in response to the visual mental image of a recently viewed object. As reported in Chapter One, results of studies with seen objects, have shown that when an object is positioned at an optimal orientation for grasping by a particular hand (left or right orientation), and participants make a response to that object with a compatible hand (left or right), action potentiation effects are observed (Tucker and Ellis, 1998). Similarly, as reported in Chapter Two, results of an experiment examining short-term visual memory for objects and an experiment involving the construction of a visual image from verbal information (Richardson et al [in preparation]) have also observed action potentiation effects arising from the compatibility between the orientation of an object for grasping and the hand of response. However, as also discussed in Chapter Two, short-term visual memory and visual mental imagery are not synonymous, and as yet no evidence exists for these effects in studies where participants are asked to create a visual mental image from a recently viewed object.

Experiment Three uses the same experimental design as that used in Experiment Two. This time, however, participants are presented with a series of trials in which they have to categorise one object, presented in an array of objects as either a "kitchen utensil" or a "garage tool" using either a "left-hand" response grasp or a "right-hand" response grasp. Each array comprises a combination of objects that are oriented to be optimally compatible with either a left-hand or right-hand power grasp and which can be categorised as either kitchen utensils or garage tools. Unlike the micro-affordance effects reported in Chapter Two, which theoretically could have arisen both from intrinsic and extrinsic object properties, the experiment reported in this chapter seeks evidence for micro-affordance effects arising from a solely extrinsic object property, that of object orientation.

4.2 Experiment Three

4.2.1 Introduction

Using the same experimental design employed in experiments One and Two, participants were asked to categorise one object presented in an array of four power 'graspable' objects as either as "kitchen utensils" and "garden tools", 700 msecs after the images were removed from view. The objects presented in the experiment were either maximally oriented to be compatible with a right-hand grasp or a left-hand grasp. Depending on the mapping rule given, participants were asked to press either a switch held in their left hand if the object was a "kitchen utensil" and a switch held in their right-hand if the object was a "garage tool", or vice versa. It was hypothesised that right-hand responses to objects optimally positioned for a right-hand grasp would be executed faster and more accurately than right-hand responses to objects optimally positioned for a left-hand grasp, and that left-hand responses to objects optimally positioned for a left-hand grasp would be executed faster and more accurately than left-hand responses to objects optimally positioned for a right-hand grasp.

Although the results of Experiment Two suggest that participants were using imagery to complete the task, it was decided to increase the number of memory trials in Experiment Three from five to ten. This was considered necessary as the categorisation task in this experiment (the garage/kitchen distinction) was judged during a short pilot study to be more difficult than the categorisation task in Experiment Two (the naturally formed/manufactured distinction). Due to the difficulty in completing the task it was thought that participants might be more likely to revert to the 'category code' strategy discussed in Chapter Three.

4.2.2 Method

Participants

Thirty-two participants from the University of Plymouth took part in the experiment. All participants had normal motor function in both hands and normal or corrected to normal vision. Each was given credit as part of their course requirements and the sum of £3.00 for participating in the experiment.

Apparatus and Materials

The stimulus set comprised 84 colour photographs each picturing four 'graspable' objects.

The pictures comprised a combination of two objects that were positioned to be optimally compatible with a right-hand 'power' grasp and two objects that were positioned to be optimally compatible with a left-hand 'power' grasp. The objects viewed in the pictures were a combination of garage tools, and kitchen utensils. The pictures contained either: two garage tools and two kitchen utensils; one garage tool and 3 kitchen utensils; or 3 garage tools and one kitchen utensil. In order to ensure a balanced design each object in each combination of garage tools and kitchen utensils, appeared in each of the four positions in the photograph (top left, top right, bottom left and bottom right)[12]. The objects chosen for inclusion in the photographs were picked at random (according to the above design) from a list of 20 garage tools and 20 kitchen utensils (Appendix O). No object appeared twice in the same picture.

The objects were photographed to appear in roughly the same position in each photograph - to the top left, top right, bottom left and bottom right of the screen.

The pictures were viewed on a 19" monitor at a distance of approximately 50 cms. Each object subtended a visual angle of between 6.87 and 14.81 degrees (appendix B).

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[12] This resulted in six orientation positions: top left and bottom left, objects left-orientated/top right and bottom right, objects right-oriented; top left and bottom left, objects right-oriented/top right and bottom right, objects left-oriented; top left and top right, objects left-oriented/bottom left and bottom right, objects right-oriented; top left and top right, objects right-oriented/bottom left and bottom right, objects left-oriented; top

Participant responses to the reaction time task were recorded on two specially hand held switches. Each switch comprised the 'power' switch section of the hand device used in Experiments One and Two and illustrated in Figure 4.

Design

The experiment comprised two tasks. Task One consisted of one block of 336 trials in which each of the 84 photographs in the stimulus set appeared four times. On each of the four occasions that a particular picture occurred, an arrow radiating from the centre of the photograph directed attention to a different position on the computer screen previously occupied by one of the four objects in the stimulus array. An example of the stimuli is illustrated in Figure 13. The combination of garage/kitchen and left/right oriented objects resulted in 168 trials in which there was a compatible mapping between the participant's hand of response and the orientation of the object, and 168 trials in which there was an incompatible mapping (see Appendix P for a complete listing of object combinations).

Half the participants were assigned to a mapping condition in which they were asked to press the power switch held in their left hand if the object was a kitchen utensil and power switch held in their right hand if the object was a garage tool. The remaining participants were given the reverse mapping instructions.

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left and bottom right, objects left-oriented/top right and bottom left, objects right-oriented; top left and bottom right, objects right-oriented/top right and bottom left, objects left-oriented.

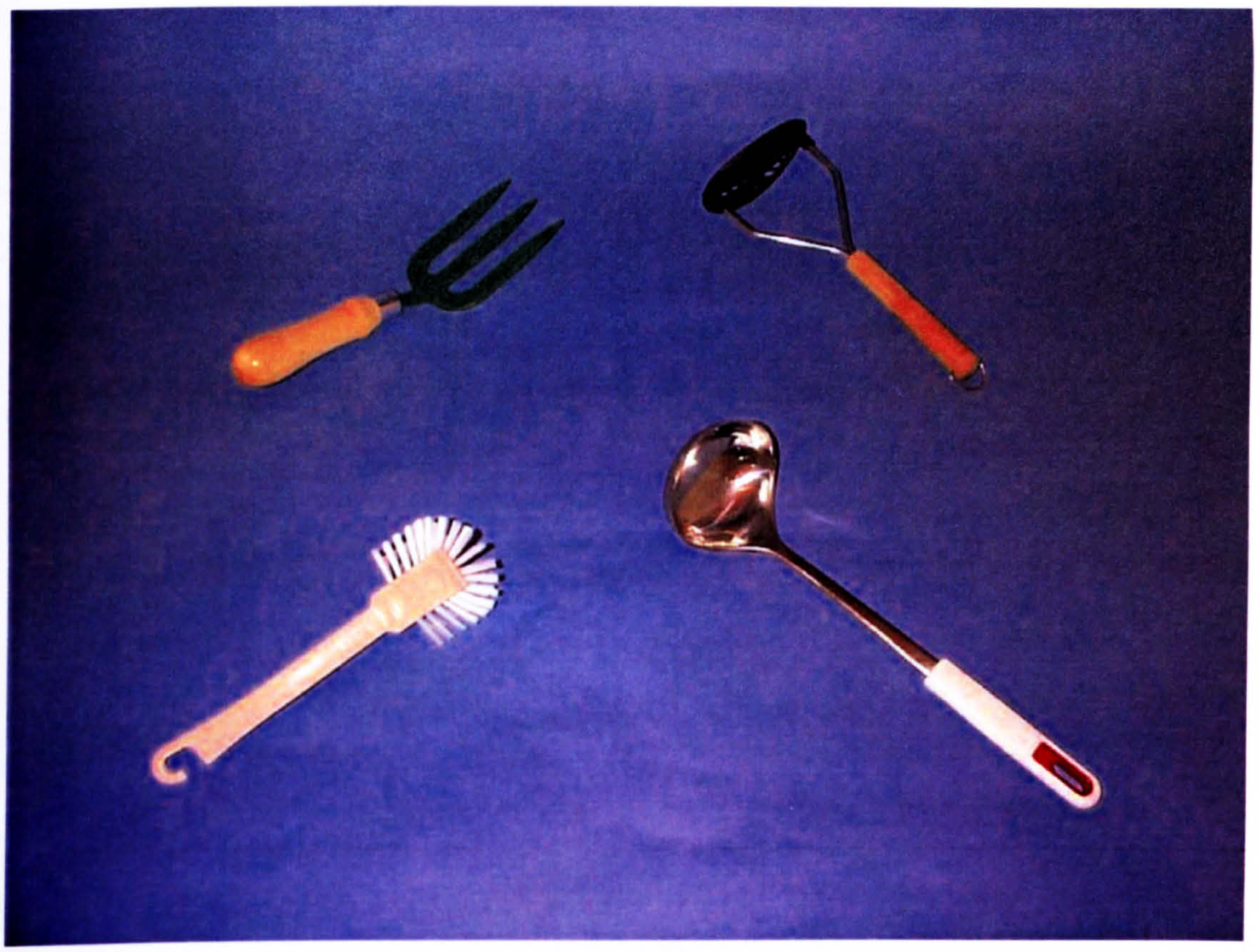

Figure 13
Example of Object Array used in Experiment Three

Procedure

Main Task: The procedure for the main task was the same as that used in Experiment Two. Again, participants made their responses to the stimuli after the images were removed from view. On each trial a written message informed participants to "Get Ready" for presentation of the stimulus. After 900 msecs the warning message disappeared and a picture, chosen from the stimulus set at random, appeared on the screen. The picture remained on the screen for 1.5 seconds before being replaced by a blank screen. After a further 700 msecs an arrow appeared in the middle of the screen, for a period of 600 msecs, directing attention toward the position of one the four objects shown in the previous picture. Participants were instructed to decide whether or not the object at that position was a "garage tool" or a "kitchen utensil". Having made the decision participants made their response by pressing the switch held in the appropriate hand. Participants were instructed to respond as fast a possible whilst maintaining accuracy. Incorrect responses resulted in a bleep from the computer.

Having made a response participants were prepared for the next trial.

Memory Task: At random intervals during the main task participants were asked to carry out a memory task. The task involved presenting participants with the names of four objects. As with the stimulus objects used in the main task, the names were positioned to the top left, top right, bottom left and bottom right of the screen. Participants were asked to decide whether or not the objects named, and the positions of those objects were the same as the objects shown in the previous picture. If they decided they were the same, they were asked to press the switch held in their left hand, but if they decided they were different they were asked to press the switch held in their right hand. The number of correct and incorrect object configurations presented to the participants in the memory task were calculated at random for each participant.

All participants were presented with written instructions (Appendix Q) and completed 20 'main task' trials and 5 'memory task' trials before commencement of the main experiment.

4.2.3 Results

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment. The mean error rate was calculated at 42.32[13] (St Dev 30.12). Based on this criterion the data from three participants was excluded from the analysis. The data from a further participant was also excluded from the analysis as they failed to complete the task. In addition, errors and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Errors accounted for 10.46% of response trials, while reaction times greater than two standard deviations accounted for 4.06% of response trials.

Two separate analyses were carried out on the Response Time data and the Error data. In the first analysis a three-way ANOVA examining the within participants factors of

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[13] Number of errors in 336 trials

object orientation, hand of response and the between participants factor mapping condition was carried out on the data. This analysis mirrors the analysis carried out on the data for experiments One and Two in which it was used to determine the presence of micro-affordance effects.

In the second analysis to be carried out on the data, the data was again subjected to a three-way ANOVA but this time with the within participants factors of object orientation, hand of response and object position on the computer screen. The aim of the analysis this time, was to establish whether or not the compatibility effects (as defined by an interaction between hand of response and object orientation) interacted with object position on the computer screen.

4.2.3.1 Analysis One

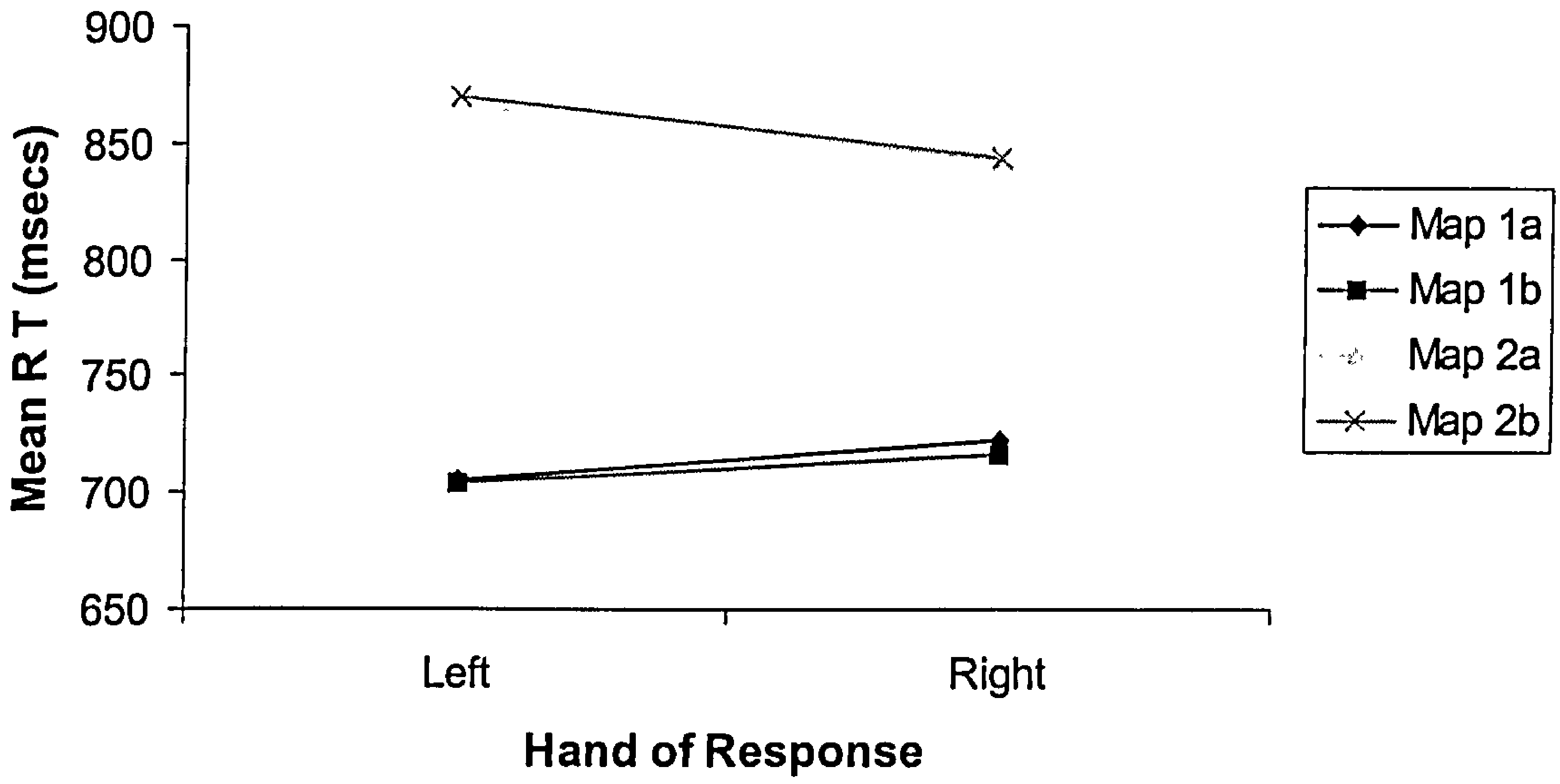
Response Time Data

The data are summarised in Table 6 (Appendix R) and were subjected to a three-way mixed ANOVA (Appendix S) with the within participants factors of Object Orientation (left and right), Hand of Response (left and right) and a between participants factor of Mapping Condition'(right-hand responses – garage tools: left-hand responses – kitchen utensils / right-hand responses – kitchen utensils: left-hand responses – garage tools).

The analysis revealed no significant main effects of either Object Orientation [F(1,26) = .009, p = .926] or Hand of Response [F(1,26) = .201, p = .657]. However, the analysis did reveal a significant main effect of Mapping Condition [F(1,26) = 4.29, p = .048]. The main effect of Mapping Condition suggests that the assignment of right-hand responses to garage tools and left-hand responses to kitchen utensils resulted in faster reaction times (m = 711.67 msecs) than the reverse mapping (m = 855.60 msecs). This pattern of results can be observed in Figure 14. Although no obvious explanation can be given to explain this effect, similar mapping effects have been reported elsewhere in the literature (Ellis and Tucker, 2000; Tucker and Ellis 1998; 2001). The presence of this strong mapping effect does suggest an effect of neural lateralisation. Evidence already exists to suggest that there are neural correlates of category-specific knowledge. For example, the naming of tools has been shown to selectively activate a left premotor area (Decety, Perani, Jeannerod, Bettinardi, Tadary, Woods, Mazziotta and Fazio, 1994) and the left middle temporal gyrus (Martin, Haxby, Lalonde, Wiggs and Ungerleider, 1995), whereas the naming of animals selectively activates the left medial occipital lobe (Martin, Wiggs, Ungerleider and Haxby, 1996).

Importantly, the analysis revealed no two-way interaction between Hand of Response Grasp and Object Orientation [F(1,26) = .091, p = .766]. The mean response times revealed that left-hand responses to left-oriented objects were only fractionally faster (m = 785.45 msecs) than left-hand responses to right-oriented objects (m = 786.82 msecs), and right-hand responses to right-oriented objects were only fractionally faster (m = 779.96 msecs) than right-hand responses to left-oriented objects (m = 782.31 msecs).

All other interactions were found to be non-significant at alpha = .05, although the interaction between Hand of Response and Mapping Condition was shown to be nearing significance [F(1,26) = 2.95, p = .098]. The data suggests that in Mapping Condition One left-hand responses were executed faster (m = 704.61 msecs) than right-hand responses (m = 718.74 msecs) but in Mapping Condition Two right hand responses were executed faster (m = 843.54 msecs) than left-hand responses (m = 867.66 msecs). This result can be explained by an effect of object category, whereby responses to the kitchen stimuli are executed faster than responses to the garage stimuli. In Mapping Condition One left-hand responses were made to kitchen utensils and right-hand responses to garage tools. However, in Mapping Condition Two the reverse mapping was the case. This interaction is similar to the interactions observed in experiments One and Two where it was found that "naturally formed" objects were responded to faster than "manufactured" objects.



Legend Key: Map 1a = Mapping Condition One - Left Oriented Objects
Map 1b = Mapping Condition One - Right Oriented Objects
Map 2a = Mapping Condition Two – Left Oriented Objects
Map 2b = Mapping Condition Two – Right Oriented Objects

Figure 14
Mean Response Times for Left and Right Hand Responses to Left and Right-orientated Objects in both Mapping Conditions

Error Data

The error data is summarised in Table 7 (Appendix T) and were subjected to a three-way mixed ANOVA (Appendix U) with the within participants factors of Object Orientation (left and right) and Hand of Response (left and right), and the between participants factor of Mapping Condition (right-hand responses – garage tools: left-hand responses – kitchen utensils / right-hand responses – kitchen utensils: left-hand responses – garage tools).

The analysis revealed no significant effects in any of the data. However, the mean number of errors recorded in Mapping Condition One (left-hand = kitchen utensils and right-hand = garage tools) did seem to suggest the presence of a compatibility effect although the three-way interaction between Mapping Condition, Hand of Response and Object Orientation failed to reach significance at alpha = .05 [F(1,26) = 1.81, p = .190]. In the right-hand response condition more errors were made in response to right-oriented objects (m = 9.36) than left-oriented objects (m = 6.93), whereas in the left-hand response condition slightly more errors were made in response to left-oriented objects (m = 9.07) than to right-oriented objects (m = 8.36). This interaction is illustrated in Figure 15.

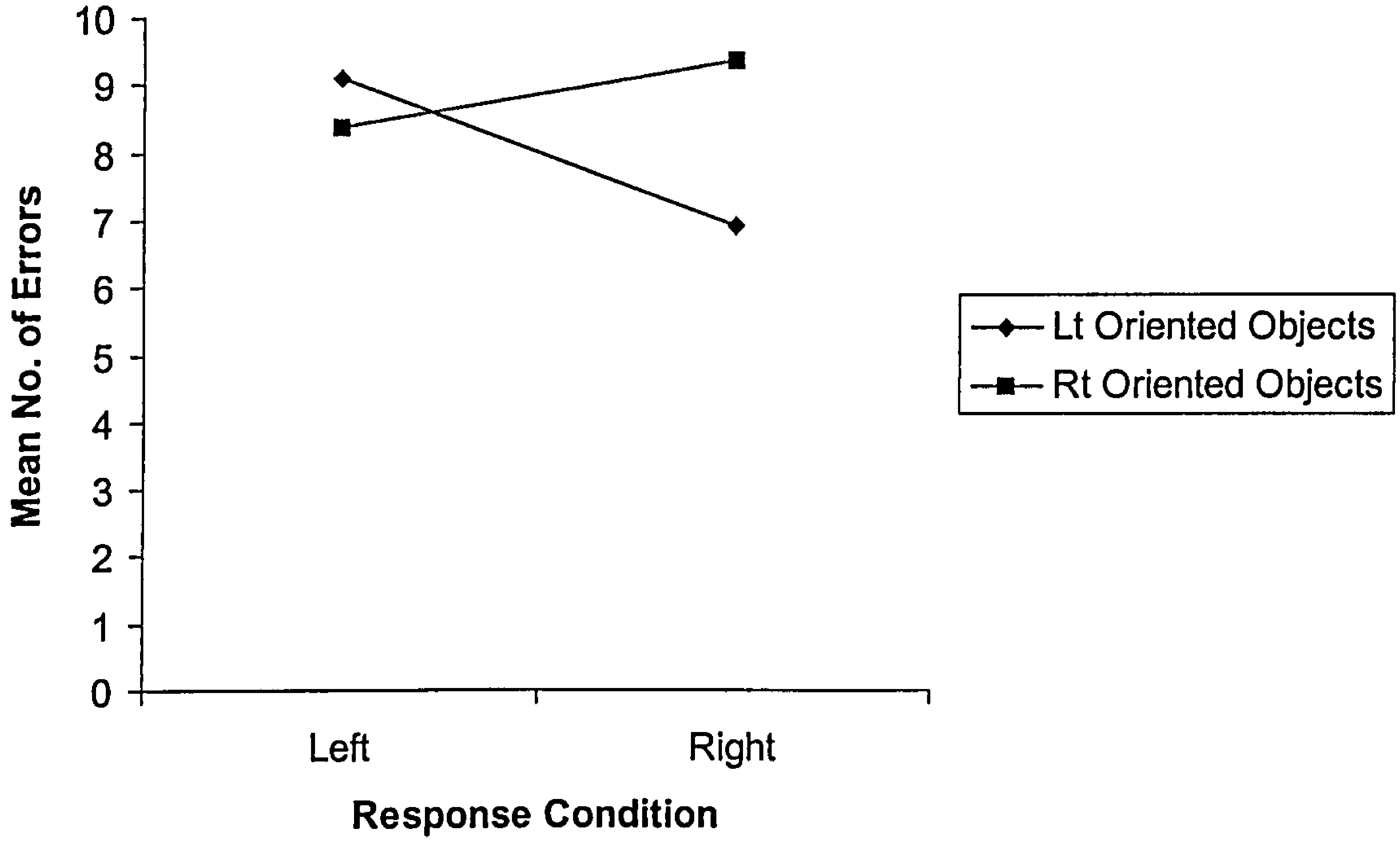


Figure 15
Mapping Condition One (Right Hand = Garage Tools, and Left Hand = Kitchen Utensils). Mean Number of Errors for Left and Right Hand Response Conditions to Left and Right-oriented Objects

4.2.3.2 Analysis Two

Response Time Data

Having failed to observe a significant interaction between Hand of Response and Object Orientation in either of the two mapping conditions, the data was subjected to a second three-way ANOVA (Appendix V). The analysis again included the within participants factors of Hand of Response (left and right) and Object Orientation (left and right), but also a third within participants factor of Object Position *on the computer screen* (top left, top right, bottom left and bottom right). A summary of the data is shown in Table 8 (Appendix W).

As with the ANOVA in Section 4.2.3.1, the analysis revealed no main effects of either Hand of Response [F(1,27) = .173, p = .680] or Object Orientation [F(1,27) =.006, p = .941]. In addition, there was no main effect of Object Position [F(2.1,56.8) =.308, p

=.747][14]. Once again, the analysis again revealed no two-way interaction between Hand of Response and Object Orientation [F(1,27) = .110, p = .742]. The three-way interaction between Hand of Response, Object Orientation and Object Position was also found to be non-significant [F(2.6,70.9) = .1.183, p = .320][7].

However, the analysis did reveal a significant interaction between Object Position and Hand of Response [F(2.7,73.1) = 9.807, p < .0001][11]. The interaction shows that left-hand responses to objects positioned to the top left and bottom left of the screen were executed slightly faster (m = 783.64 and 760.99 msecs, respectively) than right-hand responses to objects positioned to the top left and bottom left of the screen (m = 786.50 and 800.13 msecs, respectively). By contrast, for the objects positioned to the top right and bottom right of the screen the pattern was reversed, right-hand responses were executed faster (m = 755.94 and 764.89 msecs, respectively) than left-hand responses (m = 799.89 and 802.12 msecs, respectively). The interaction is illustrated in Figure 16.

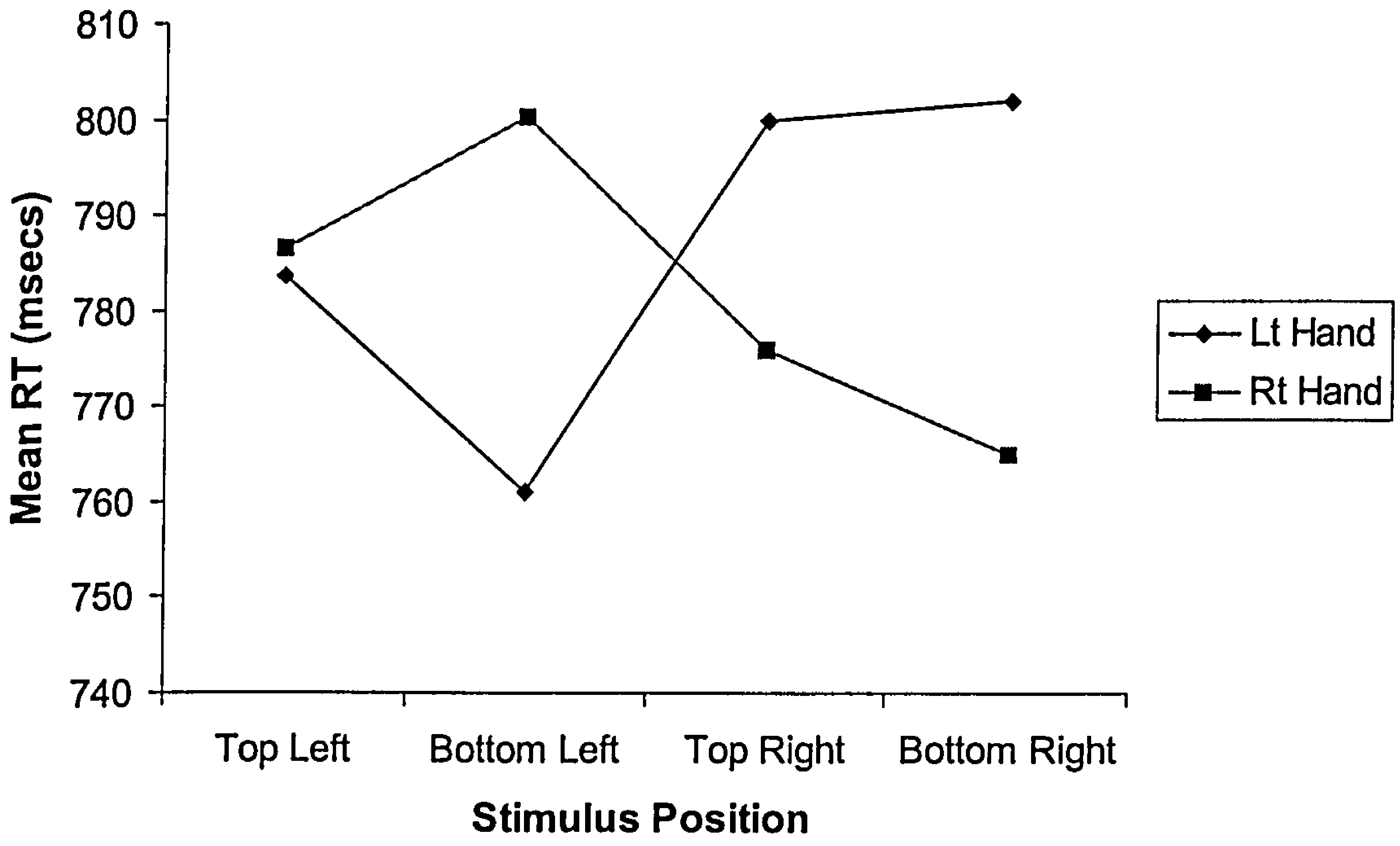


Figure 16
Mean Response Times for Left and Right Hand Responses to Objects Positioned to the Top Left, Bottom Left, Top Right and Bottom Right of the Computer Screen

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[14] Due to a violation of the sphrecity assumption, the significance values were adjusted using the Greenhouse-Geisser correction.

The interaction between Hand of Response and Object Position can be explained with reference to the spatial Simon Effect (1969). As reported in Chapter Two, the spatial Simon Effect occurs when there is a compatible association between a stimulus's position (left and right) and hand of response (left and right) even when the spatial positioning of the stimulus is irrelevant to the task. Additionally, it was also reported in Chapter Two that the Simon Effect has been observed in visual mental imagery experiments (Tlauka and McKenna, 1998). Although the results of Experiment Three clearly demonstrate the presence of the Simon Effect, it is not clear whether the effect arise from the positioning of the objects on the computer screen, or from spatial cues associated with the arrows used to direct attention to the position of those objects. The recording of motor cortex activation during the standard spatial compatibility task has allowed researchers to measure patterns of neural activation associated with left and right-hand responses (Coles, 1989; Coles, Gratton and Donchin, 1988). Importantly, the specific patterns of activation associated with left and right action responses have also been recorded prior to the onset of an action response if participants view arrows cueing the position of a soon to be revealed stimulus (Eimer, 1993; 1995).

The only other result of interest to arise from the analysis was an interaction between Object Position and Object Orientation [F(2.6,69.3) = 2.341, p = .090[15]]. Although non-significant at alpha = .05, the data suggest that for objects positioned to the top right and top left of the screen, left-oriented objects were responded to faster (m = 776.77 and 783.20 msecs, respectively) than right-oriented objects (m = 793.36 and 792.62 msecs, respectively). However for objects positioned to the bottom left and bottom right of the screen the reverse pattern was observed, right-oriented objects were responded to faster (m = 778.39 and m = 771.93 msecs, respectively) than left-oriented objects (m = 782.73 and 795.07 msecs, respectively). This interaction is illustrated in Figure 17.

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[15] Due to a violation of the sphrecity assumption, the significance values were adjusted using the Greenhouse-Geisser correction.

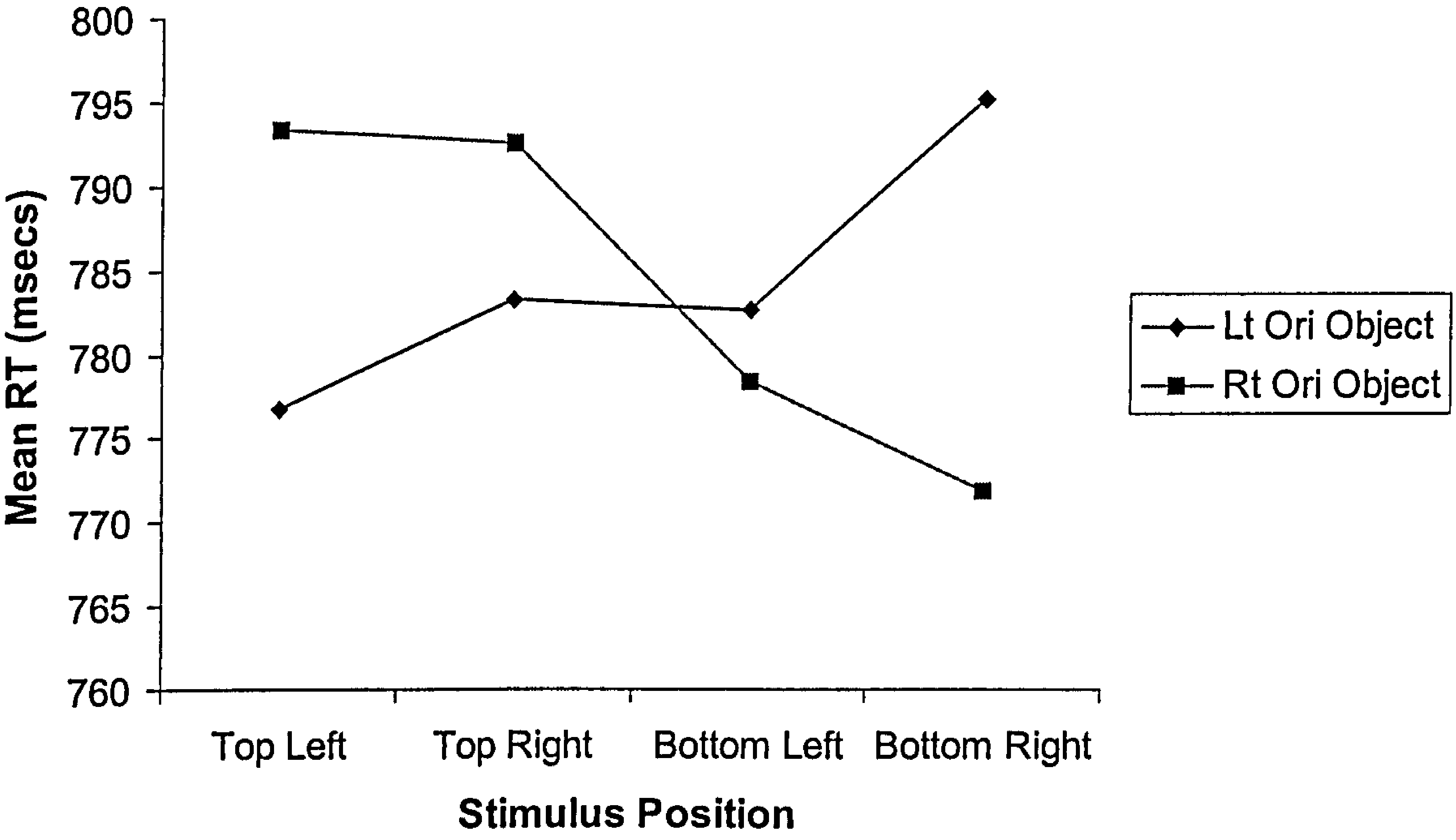

Figure 17
Mean Response Times for Left and Right-oriented Objects Positioned to the Top Left, Top Right, Bottom Left and Bottom Right of the Computer Screen

Although no obvious explanation can be put forward to explain this interaction, there is evidence that vertically positioned stimuli as well as laterally positioned stimuli can effect S-R compatibility pairings (Bauer and Miller, 1982; Michaels and Schilder, 1991).

In the Michaels and Schilder study evidence was presented for different compatibilities between actions made by left and right movements of the index finger on both the left and right hands in response to visual stimuli positioned either 3 cms above or 3 cms below a visual fixation point on a computer screen. The study revealed that if the index finger of the right hand is used to press a key 1 cm to the right of an initial starting position, faster reaction times are observed when the visual cue appears at the top of the screen than when it appears at the bottom of the screen. However, if the index finger of the left hand is used to press a key 1 cm to the right of its initial starting position, faster reaction times are observed when it is paired with stimuli presented at the bottom of the screen. Conversely, if a key press is made using an action which moves the right index finger 1 cm to the left, faster reaction times are observed when the stimulus is presented at the bottom of the screen, whereas if the key press is made using an action which moves the left index finger 1 cm to the left, faster reaction times are observed when the stimulus is presented at the top of the screen. Although the findings of this study cannot be mapped directly on to the results of Experiment Three, they do provide evidence for differential compatibilites between the left and right hands when an action (associated with "left" and "right" descriptors) is paired with stimuli placed in the top and bottom halves of the visual field. Furthermore, while caution needs to be used in drawing any conclusions from the interaction observed in Experiment Three (the interaction failing to reach statistical significant at alpha = .05), the presence of a statistically significant interaction would have indicated that the participants in the study were forming visual mental images and accessing the orientation information encoded in those images.

All other effects were shown to be non-significant.

Error Data

In accordance with the second analysis carried out on the response data, the error data was subjected to a second three-way ANOVA (Appendix X), with the within participants factors of Hand of Response (right and left); Object Orientation (right and left) and Object Position *on the computer screen* (top left, top right, bottom left and bottom right). A summary of the error data can be seen in Table 9 (Appendix Y).

Once again the analysis revealed no main effects of Hand of Response [F(1,27) = .001, p = .978], Object Orientation [F(1,27) = 1.238, p = .276] or Object Position [F(2.9,78.5) = 2.18, p = .099]. However, there was a significant interaction between Object Position and Response Condition [F(3,81) = 14.301, p = .0001]. The interaction is illustrated in Figure 18. The analysis revealed that for objects positioned to the top left and bottom left of the screen more errors were made in the right-hand response condition (m = 2.61 and m = 2.80 respectively) than in the left-hand response condition (m = 1.82

and m = 1.68 respectively). For objects positioned to the top right and bottom right of the screen the reverse pattern could be observed, more errors were made in the left-hand response condition (m = 2.05 and m = 3.05 respectively) than in the right-hand response condition (m = 1.71 and m = 1.46).

As with the response data, this interaction can be explained with reference to the Simon Effect (Simon 1969). The results revealed that participant responses were more accurate when there was a compatible mapping between object position (left and right) and hand of response (left and right).

No other effects were found to be significant.

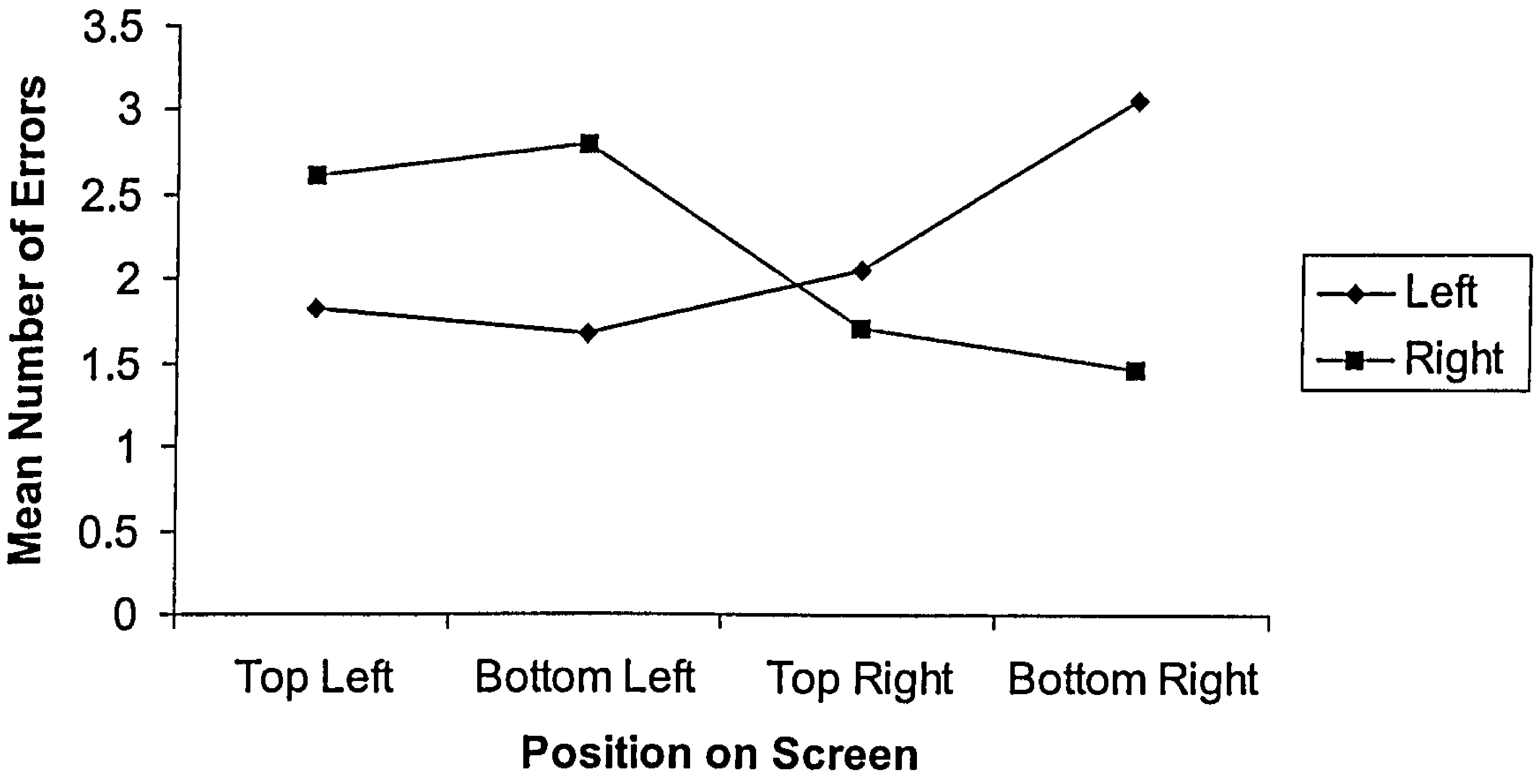

Figure 18
Mean Number of Errors for Left and Right Hand Responses to Left and Right-orientated Objects Positioned to the Top Left, Bottom Left, Top Right and Bottom Right of the Computer Screen

4.3 General Discussion

The results of Experiment Three provide no convincing evidence for compatibility effects between 'hand of response' and 'orientation of an object for grasping' when participants are asked to make an action response whilst forming a conscious visual mental image of a recently viewed object. The findings of Experiment Three can be contrasted with the findings of: (1) Tucker and Ellis (1998), where compatibility effects were observed between an oriented object and hand of response for seen objects, and (2) Richardson et al (in preparation) where similar compatibility effects were observed both in a short-term visual memory task and in a task which required participants to form the visual mental image of an oriented object from a verbal description.

Importantly, the results of Experiment Three can also be contrasted with those of Experiment Two. In Experiment Two, micro-affordance effects were observed when participants made either a power or precision response grasp to objects compatible with either a power or precision response grasp, when asked to form a visual mental image of the recently viewed object. However, as stated in the introduction to this chapter, the visual object properties thought to give rise to the micro-affordance effects observed in Experiment Two, 'object size' and 'object weight', are intrinsic object properties. By contrast the visual object property thought to give rise to micro-affordance effects arising from the compatibility between an object's orientation and hand of response, 'object orientation property', is an extrinsic object property.

The question raised then is why this effect was observed in both the Richardson et al (in preparation) experiments, but not in the experiment reported in this chapter? There appear to be at least three possible explanations for these findings.

Firstly, it may be the case that the visual mental image of a recently viewed object does not give rise to micro-affordance effects arising from the orientation of an object for grasping. Secondly, the visual mental image of a recently viewed oriented object does give rise to micro-affordance effects but the arrows indicating the position of the objects interfered with the expression of the compatibility effects. Thirdly, participants were not forming visual mental images to complete the task in Experiment Three, but instead relying on some form of labelling strategy such as the one discussed in the introduction to this chapter. These three possible explanations for the absence of compatibility effects will be reviewed in reverse order.

As discussed in Chapter Two, visual mental imagery and visual memory cannot be considered synonymous. However, researchers generally agree that the process of visual mental imagery will utilise the visual representations stored in memory as required (Logie, 1995; Kosslyn, 1996). If participants were trying to form visual mental images in Experiment Three by accessing the contents of short-term memory, then it seems surprising that compatibility effects were not observed in this experiment. Although it could be argued that the process of forming the visual mental image might interfere with the production of the micro-affordance effects, this seems unlikely. In the second experiment reported by Richardson et al, micro-affordances effects in relation to the orientation of an object for grasping were observed when participants formed a visual mental image of a scene from a verbal description.

However, if one is still to assume that participants were forming a visual mental image to complete the experimental task in Experiment Three, then there is perhaps an alternative explanation. Participants may have been forming visual mental images but the representations being accessed differed from those presumed to be utilised in the Richardson et al study.

As discussed in the last chapter, Marr's theory of visual perception proposes the existence of both viewer-centred and object-centred visual representations. According to this theory only viewer-centred object representations will encode object orientation. The need for object centred representations in object recognition is based on the fact that despite changes in the retinal image of an object caused by: distance of an object from the viewer; object position with respect to the viewer; occlusion by other objects; shadows, etc, object constancy is retained. It can be assumed therefore that in order for a visual object representation, whether on-line or off-line, to produce micro-affordance effects associated with orientation information, the representation must be processed as a viewer-centred representation. This can be contrasted with intrinsic object properties such as weight and size, which we argued in the last chapter, do not require viewer-centred representations or indeed, a visual representation at all.

Due to the fact that object recognition requires the use of object-centred representations, it has been argued that off-line visual processing will not contain orientation information as object recognition is based on these representations (Biederman, 1987; Marr 1984). Evidence that appears to support this argument can be found in a study carried out by Rubin and Kontis (1983). In this study it was found that participants failed to remember the direction in which Abraham Lincoln faces on a US penny, although they had recently viewed the coin. Similarly the results of Experiment Three would seem to support this argument. However, the results of the Richardson et al study clearly contradict this argument and provide evidence for the existence of viewer-centred representations in off-line vision.

Interestingly, not all researchers agree with the proposal that object-centred representations are required for the process of object recognition.

Edelman (1998) argues that the literature supporting the need for object centred representations often assume the creation of clearly defined representations. Drawing on research investigating problems associated with categorisation and prototype effects (Rosch et al, 1976), Edelman puts forward a theory in which, object constancy can be explained by reference to the similarities that exist between a limited number of "viewer-centred" object representations. Not only does this theory provide a mechanism for achieving object constancy, it also solves another problem for researchers in field of visual object recognition, that of our ability to generalise from one object example to another when identifying an object. Edelman proposes that instead of seeking absolute invariance in the representations necessary for object recognition, as would be the case with the construction of object centred representation, that a mere tolerance be sought between what the viewer sees and their internal mental representations. The theory therefore proposes that object recognition is based on the construction of "prototypical" object representations.

Given that the 'prototype' representations proposed by Edelman's theory are said to be constructed from specific viewer-centred encodings of an object image, viewer-centred orientation information must be encoded. Further, it also follows that any object prototype must reflect the attributes of the specific viewer-centred representations that were used to create it. This second point is important when it comes to considering an object's orientation. If the 'prototype' representation of an object is constructed from individual instances of a viewed object, and if those individual instances have been viewed more often in one orientation than another, then the prototype representation must contain orientation information. However, as to what that orientation would be for a particular object could be considered a matter of speculation. We will return to this question after viewing some of the empirical evidence for the existence of prototypical representations in visual imagery and visual memory.

In the Rubin and Kontis (1983) described above, it was shown that participants failed to recognise the direction a head faces on a recently viewed US penny. Although the results can be taken to suggest that participants were unable to encode orientation information, the results showed that three quarters of the participants failed the task believing the head faced to left. As all US coins with the exception of the penny have the head facing to the left the results of the study have also been taken to suggest that participants failed the task as they were recalling a prototypical example of a coin with the head facing right.

In a later study, further support was given to this assertion, however, this time evidence was also presented to show that participants could visualise the correct orientation under certain circumstances (Kosslyn and Rabin, 1999). In the study a series of experiments were again carried out using a US Penny depicting Abraham Lincoln's face. This time it was observed that participant's could remember the direction the head faced on the coins during an image inspection task but not during a recognition task. It should be noted however that even when the participants in this study were engaged in the image inspection task, the data from some participants suggested that the bias for the 'prototype' coin was difficult to overcome.

The findings of both the Rubin and Kontis study, and the Kosslyn and Rubin study are consistent with the theory put forward by Edelman for the construction of a prototypical object representation (for the head on a penny at least). Although the bias in the study towards the prototype appeared to be strong, it could be overcome. Whether or not it was, appeared to be dependent on the type of imagery task being used – image inspection versus image recognition. One reason given for the existence of a prototypically oriented head on coins is that heads on coins and also in portrait paintings (McManus and Humphrey, 1973) appear more often with the heads facing to the left and are therefore viewed more often in those directions.

If Edelman's theory is correct, then it may be the case that in Experiment Three participants were forming visual mental images of objects, but not using the viewer-centred object images stored in short-term memory, but instead relying on some form of prototypical object image. This argument is consistent with the findings of the Kosslyn and Rabin (1999) study reported above where it was observed that even when participants inspected the visual image of a recently viewed coin they found it difficult to overcome the 'prototype'.

However, unlike heads on coins or in portrait paintings, everyday objects are viewed in many different orientations and positions. Moreover, they are interacted with, picked up, walked around, used etc. It may seem therefore that most objects are viewed equally often in all orientations. However, we know that this is not the case. There is much literature in the field of vision and object recognition to dispute this initial assumption. The comparative difficulty in recognising objects from "unusual views" has been employed to help explain the process of object recognition itself (Palmer, Rosch and

Chase, 1981; Marr and Nishihara, 1978). The existence of unusual object views can be explained by reference to the fact that many objects have a function, and fulfilling this function means that an object is more often viewed in a particular orientation within the visual field. For example, "containing" objects must have a correct vertical orientation to fulfil their function due to the force of gravity - they are either the right-way up or upside down. But what of lateral orientation (left and right)? As we saw above there is some evidence to suggest that the heads on coins and portraits have a prototype orientation due to being viewed more often in one direction than another. Although objects may not be viewed in one particular orientation more than another, they are perhaps interacted with more when in one particular orientation. To interact with many graspable objects they need to be positioned at a particular orientation. If a prototype object representation containing orientation information does exist, it could be argued that this orientation would reflect the handedness of the individual carrying out the grasping. For example, for right-handed people the prototype orientation of a graspable object would be with the object's axis of elongation pointing towards the right-hand whereas for left-handed individuals it would be toward the left-hand. However, it is important to note at this juncture that handedness does not form an absolute dichotomy, some people are ambidextrous and others who consider themselves right or left handed do in fact carry out many tasks with their less dominant hand (Oldfield, 1971). Although no evidence exists to suggest that this is the case, if it were, one may expect to see a preference for right-oriented objects as reflected in faster response times for right-oriented objects, if participants in the above study were utilising prototypical object images in the task instead of visualising the viewer-centred object images just viewed. However, no such effect was observed in this experiment. In the next chapter the issue of prototypical object orientation will be revisited in the light of another experiment undertaken to find evidence for micro-affordance effects arising from the orientation of an object in visual mental imagery.

Before moving on to the second possible explanation as to why no micro-affordance effects were observed in Experiment Three, there were two findings from Experiment Three (which just failed to reach statistical significance) which cannot be ignored. Firstly, there was an indication in the response time data for an interaction between Object Position (on the screen) and Object Orientation. This interaction suggested that left-oriented objects positioned at the top of the screen (top left and top right) were responded to faster than right-oriented objects positioned at the top of the screen, and right-oriented objects positioned at the bottom of the screen (bottom left and bottom right) were responded to faster than left-oriented objects positioned at the bottom of the screen.

Secondly, the analysis carried out on the error data seemed to indicate that in Mapping Condition One (left-hand = kitchen/right-hand = garage) a compatibility effect between hand of response and object orientation was in fact present.

The above two findings are of considerable theoretical importance because to be statistically significant, participants would have had to visualise a viewer-centred representation of the stimuli presented in the task. Moreover, the presence of such effects would suggest that participants were forming visual mental images based on the contents of their short-term visual memory.

This brings us to the second possible explanation as to why no significant orientation effects were observed in Experiment Three, the effect of the arrows used to direct attention to the position of the objects to be imaged on each trial. It is possible that the spatial properties associated with the arrows interfered in some way with the information relating to the orientation of the object images. As discussed in the Results section above, one possible explanation for the Simon Effect observed in Experiment Three was the presence of arrows on each trial when participants' made their responses, as arrows have been shown to possess strong spatial cues (Eimer, 1995). In order to investigate this possibility an additional three-way ANOVA (Appendix Z) was carried out on the response time data, with the within participants factors of Arrow Direction (left and right), Object Orientation (left and right), and Hand of Response (left and right). The analysis revealed no significant interaction between the factors [F(1,27) = .904, p = .350], thereby suggesting that the spatial properties associated with the arrows were not a cause for the absence of a compatibility effect in this experiment.

The third possible explanation for the absence of a compatibility effect in Experiment Three is that participants may not have been using visual mental imagery at all but instead participants could have been using a 'category coding' strategy to complete the task. As discussed above, this strategy would not necessarily affect the observation of a compatibility effect in Experiment Two but it would in Experiment Three. In Chapter Three, the 'power' and 'precision' compatibility effects observed in Experiments One and Two could have arisen from an 'intrinsic' visual property of the objects potentiated by the objects' verbal name labels. However, in Experiment Three the 'orientation of an object for grasping' component of the image is an 'extrinsic' or viewer centred property of the object and therefore wholly dependent on the visual properties of that image. Specific verbal or semantic labels for orientation are therefore unlikely to be associated with a particular object.

Finally, a number of methodological issues need to be discussed which may have affected participants performance on the task in Experiment Three so contributing to the lack of compatibility effect observed in that experiment. These issues all relate to the difficulty experienced by participants in carrying-out the experiment. This difficulty was reflected in the maximum mean error rate of 43.23 errors (out of 336 trials) used for inclusion of participant data in the analysis of Experiment Three, and can be contrasted with maximum mean error rate of 18.30 errors (out of 336 trials) used for inclusion of participant data in Experiment Two. At least two possible causes may account for this difficulty.

Firstly, although the same basic experimental design was used in experiments Two and Three, there were a number of small differences. For example, the positioning of the objects in the stimuli used in Experiment Three was different to that used in Experiment Two. In Experiment Two the objects were positioned to the top, bottom, left and right of the screen, whereas in Experiment Three they were positioned to the top left, top right, bottom left and bottom right of the screen. Perhaps more importantly, the two experiments also differed in the categorising criteria used by participants to carryout the reaction time task. In Experiment Two participants categorised the objects as either 'naturally formed' or 'manufactured', whereas in Experiment Three participants categorised the objects as either 'garage tools' or 'kitchen utensils'. Of these two differences between the experiments, it is the difference in categorisation criteria that is a more likely contender for the cause of difficulty experienced by participants in Experiment Three. It can be noted that categories of 'kitchen utensils' and 'garage tools' both fall under the super-ordinate category label of tools, whereas the categories of 'naturally formed' and 'manufactured' are themselves super-ordinate category labels. Studies on semantic networks have shown that participants find it easier to make a category distinction when two objects are taken from distinct categories than when they come from the same category (Collins and Quillian, 1970).

The second possible cause for the difficulties experienced by participants in Experiment Three relates to the ease with which object orientation can be encoded. As discussed above, there is evidence to suggest that people may hold prototypical representations of objects in long term memory (portraits, faces etc). Although the existence of the prototype can be overcome in an image recognition task, evidence suggests a bias still remains. If one argues that everyday 'graspable' objects are also stored with no orientation information (object centred representation) or as a prototype, with orientation information, then participants may have competing representations to contend with when trying to construct a visual mental image from a recently viewed object. Whatever the explanation for the high error rate in Experiment Three, the data suggests participants were experiencing difficulty in forming visual mental images, and thereby reducing the likelihood of observing micro-affordance effects.

Taken together the methodological issues discussed above suggest task difficulty as a possible explanation for the absence of micro-affordance effects in Experiment Three. In the next chapter an alternative, simplified, experimental design is employed to again investigate the presence of micro-affordance effects arising from the relationship between the orientation of an object for grasping the hand of response used to make an action toward the visual mental image of a recently viewed object.

Chapter Five

5.1 Introduction

In this chapter the results of two experiments are examined. In the first experiment, evidence is again sought for micro-affordance effects arising from the relationship between the 'orientation for grasping' of a recently visualised object and 'hand of response'. In the second experiment, evidence is again sought for micro-affordances effects arising from the relationship between the 'power' and 'precision' component of the reach-to-grasp action and of a recently visualised object image that is compatible with a power or precision grasp.

As in previous experiments, both the experiments reported in this chapter utilise an SRC experimental design, however the design used in these two experiments differs from that employed in the first three experiments reported in this thesis. The design is adapted from an experiment carried out in the Tluaka and McKenna (1998) study described in Chapter Two.

To recap on the Tlauka and McKenna study, the aim was to identify spatial Simon Effects in visual mental imagery. In one of the experiments reported, participants were given a copy of a map to memorise. The map contained two crosses, one positioned on the left-hand side of the map and one on the right-hand side. On one version of the map the crosses were marked 'A' and 'B', respectively, and on the other version, 'B' and 'A'. Having memorised one copy of the map participants were given a series of trials in which they had to respond with left and right key presses to a series of randomly presented A's and B's positioned at the centre of a computer screen. Whilst responding, participants were asked to form a mental image of the map they had memorised at the start of the experiment. Consistent with the results of studies using seen stimuli, a compatibility effect was observed between position of the stimulus on the memorised map and hand of response. Right-hand responses to stimuli positioned on the right-hand side of the map were executed faster than right-hand responses to stimuli positioned on the left-hand side of the map, and vice versa.

In adapting the experimental design for this study, participants in each experiment are presented with four blocks of trials. At the start of each block of trials participants are shown a 'target' photograph and asked to memorise it. In Experiment Four the target photograph contains two objects oriented to be optimally compatible with a left and right-hand grasp and positioned, one on the left and one on the right side of the photograph. In Experiment Five the target photograph contains only one object that is either optimally compatible with a precision grasp or a power grasp, and positioned either on the left or right-hand side of the photograph. Having memorised the target photograph participants are then presented with a series of trials in which they are asked to make compatible or incompatible action responses (Exp.4: left and right hand grasps /Exp.5: power and precision grasps) to a series of cues whilst trying to form a visual mental image of the target picture memorised at the beginning of the block of trials.

Although as discussed at the beginning of Experiment One, it is desirable in an imagery experiment to implement an experimental design in which task completion is dependent on, or at least helped, by the use of imagery, the presence of the Simon effect in the Tlauka and McKenna study suggests that participants did try to form a visual mental image as requested. It is argued therefore that if the Simon Effects are replicated in the two experiments reported in this chapter, then participants are attempting to form visual mental images, or at least some form of spatial representation.

5.2 Experiment Four

5.2.1 Introduction

In this experiment participants are asked to complete four blocks of 50 trials. Before each block of trials participants view a 'target' picture containing two 'graspable' objects, each pictured at an orientation that is either maximally compatible with a left-hand grasp or a right-hand grasp. Having memorised the target picture, participants complete a series of trials in which they see one or other of the objects from the target picture presented in the middle of the screen at a relatively neutral orientation (with its axis of elongation positioned vertically on the computer screen). By positioning the 'response' object in this way it is argued that the object's position will not afford grasping by a particular hand. Depending on the 'response' object viewed, participants are instructed to respond to the image with either a left or right-hand switch press, whilst trying to visualise the object as it appeared in the original 'target' picture. As with the Tlauka and McKenna study, compliance to the visualisation instructions is dependent on participants' motivation.

It is hypothesised that: (1) right-hand responses to a visualised object optimally oriented for a right-hand grasp will result in faster and more accurate responses than right-hand responses to a visualised object optimally oriented for a left-hand grasp, and vice versa; (2) that right-hand responses to objects positioned on the right-hand side of the computer screen in the target picture will be faster and more accurate than right-hand responses to objects positioned on the left-hand side of the computer screen, and vice versa.

5.2.2 Method

Participants

Forty participants from the University of Plymouth took part in the experiment. All participants had normal motor function in both hands and normal or corrected to normal vision. Each was given the sum of £2.50 for participating in the experiment.

Apparatus and Materials

The stimulus set comprises 32 colour 'target' photographs and 8 colour 'response' photographs. Both sets of photographs picture objects that are optimally compatible with a 'power' (whole hand) grasp. The 'target' photographs each contain two objects, one positioned on the left-hand side of the photograph and one on the right-hand side. In addition, the two objects are oriented to be either maximally compatible with a left-hand grasp or a right-hand grasp. The object pairs shown in the photographs are listed in

(Appendix a). Each object pair is photographed to appear in both object positions (object one on the left and object two on the right, or vice versa) and in four possible object orientation combinations[12] (making a total of eight target photographs for each of the four object pairs). An example of a 'target' stimulus is shown in Figure 19. Each of the 8 'response' photographs picture one of the items listed in Appendix a. The objects in the 'response' photographs are positioned in the centre of the photograph at a neutral orientation (with their axis of elongation positioned vertically on the computer screen). An example of a 'response' photograph is shown in Figure 20.

The pictures are viewed on a 19" monitor at a distance of approximately 50 cms. The objects subtend an angle of between 2.29 and 10.85 degrees (Appendix B).

Participant responses to the reaction time task are recorded on two hand held switches. Each switch comprises the 'power' switch section of the hand device used in experiments One to Three above (Figure 4, Chapter 3).

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[12] both objects oriented to the left; both objects oriented to the right; left object oriented to the right and right object oriented to the left; right object oriented to the right and left object oriented to the left.

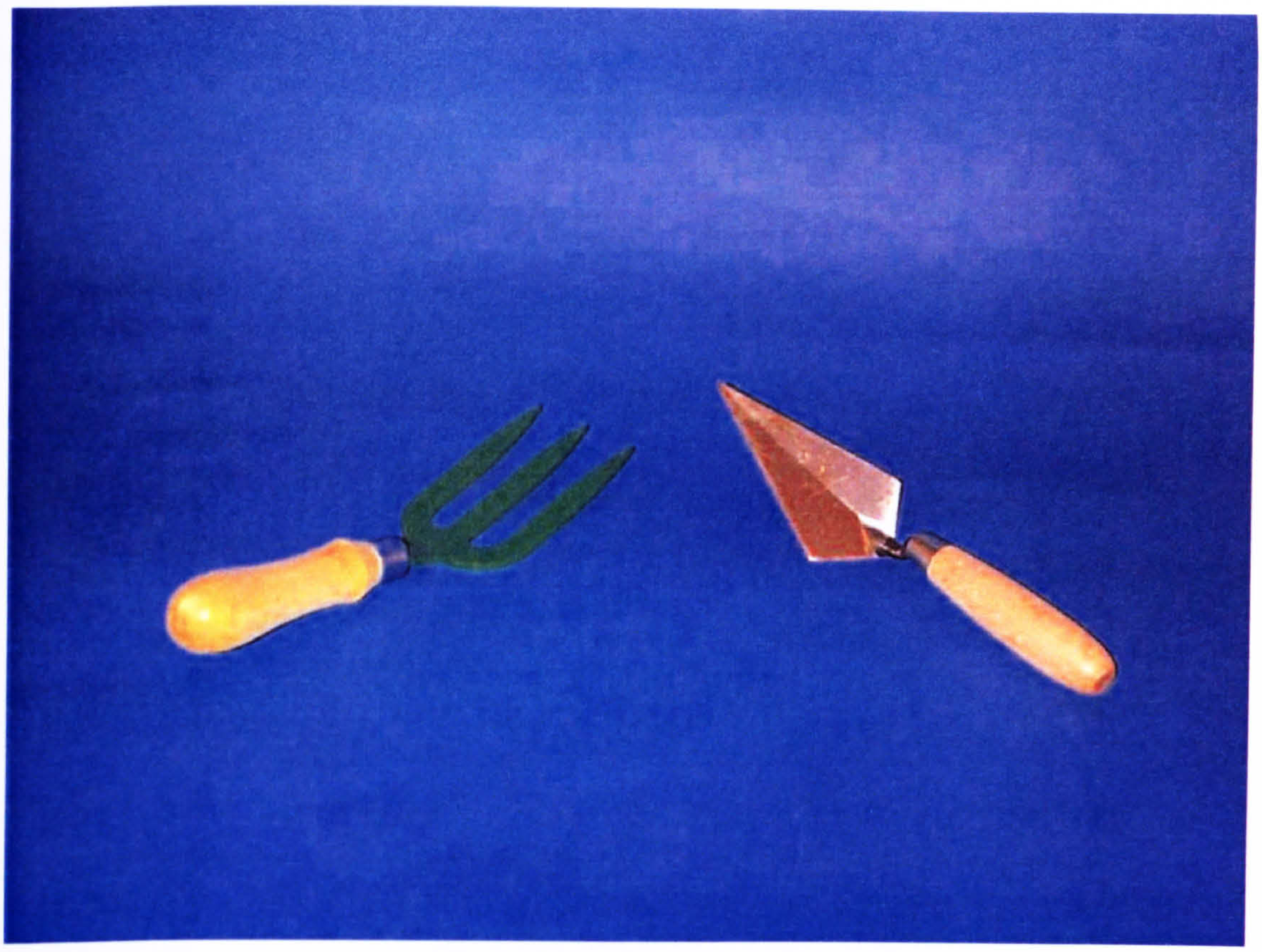

Figure 19
Example of Target Stimulus used in Experiment Four

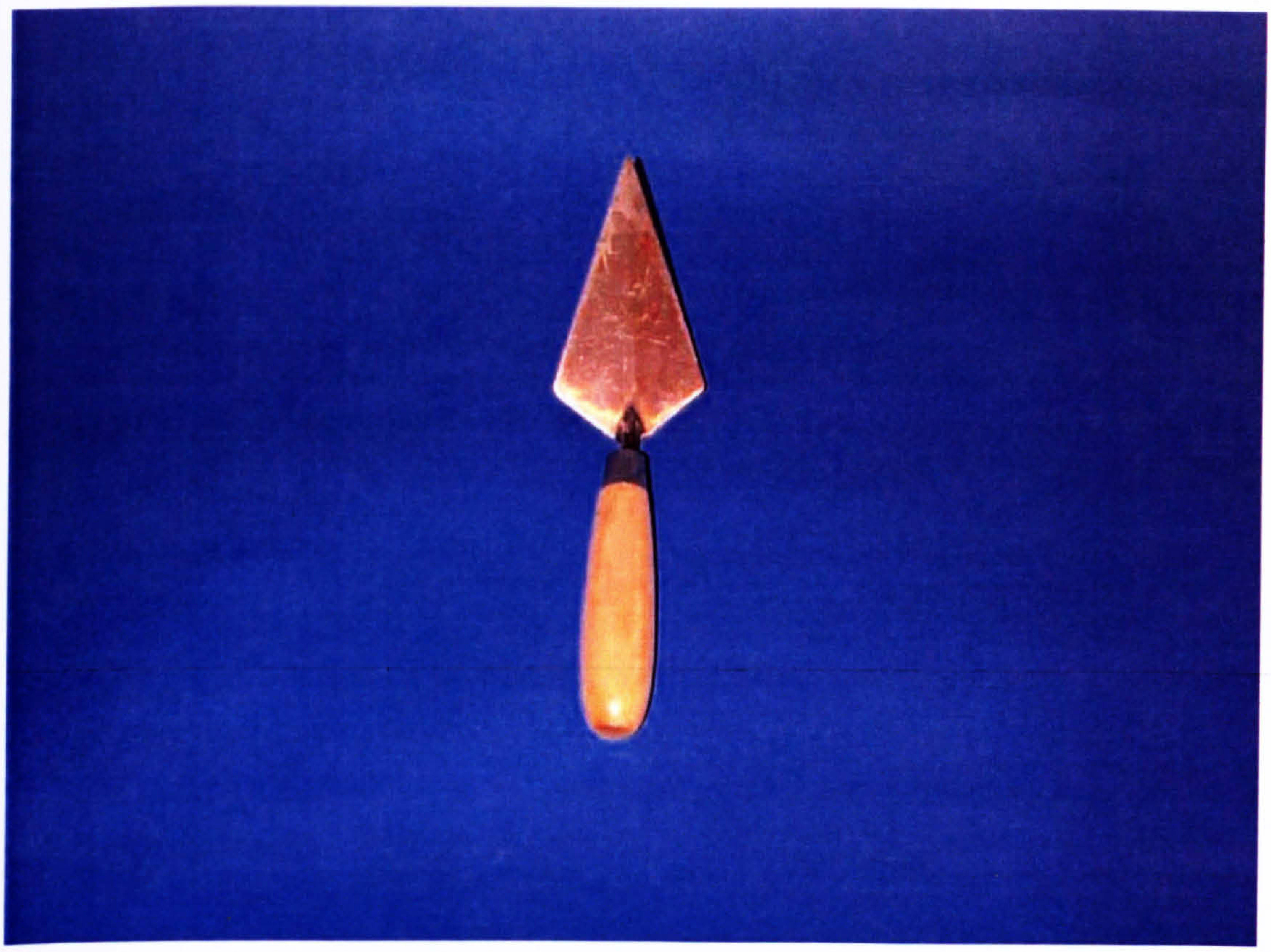

Figure 20
Example of Response Stimulus used in Experiment Four

Design

The experiment comprises four blocks of 50 trials. At the start of each block of trials participants are shown a photograph taken at random from the 32 'target' stimuli. In order to ensure a balanced design, all participants are presented with four object pairs, reflecting all four possible orientation combinations. The positioning of object pairs on the screen (object one on the left and object two on the right or vice versa) is randomised separately for each block of trials and for each participant.

Procedure

At the start of each block of trials participants are presented with a target picture. The picture is shown for a period of 15 seconds after which it is replaced with a screen containing written instructions to the participants to "try and form a visual mental image of the picture now". After 10 seconds the target picture is shown again for a period of 20 seconds. Once the target picture disappears from view for the second time, participants are presented with a response rule. This rule informs participants that in the following trials they are to respond with a particular hand (right or left) when they see one or other of the objects from the target picture. For example, if the target picture contains a hammer and mallet then the participants are to respond with their left-hand when they see the mallet and their right-hand when they see the hammer. Having been given the response rule participants are then presented with a series of 50 trials in which they see one or other of the objects from the target picture positioned in the centre of the screen (response photographs). As each object appears on the screen participants have been instructed to conjure up a visual mental image of the object as it appeared in the original target picture whilst making the required response. Participants are instructed to respond as fast as possible whilst maintaining accuracy. Incorrect responses result in a bleep from the computer.

All participants are presented with written instructions (Appendix b) and complete two blocks of 10 trials before commencement of the main experiment.

5.2.3 Results

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment. The mean error rate was calculated at 4.8[13] (St Dev 5.5). Based on this criterion the data from one participant was excluded from the analysis. In addition, errors and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Errors accounted for 2.12% of response trials, while reaction times greater than two standard deviations accounted for 4.00% of response trials.

Two sets of analyses were carried out on the data[14]. In the first analysis a three-way ANOVA with the within-participants factors of object orientation and hand of response and the between participants factor of mapping condition, was carried out on the data in an attempt to identify micro-affordance effects arising from the relationship between the orientation of an object for grasping and the hand used to make an action in response to the visual mental image of an object. In the second analysis a two-way ANOVA with the within-participants factors of position of stimulus on the computer screen and hand of response, was carried out, but this time with the aim of providing evidence for the spatial Simon Effect reported by Tlauka and McKenna (1998).

5.2.3.1 Analysis One

Response Time Data

The data are summarised in Table 10 (Appendix c) and were subjected to a three-way mixed ANOVA (Appendix d) with the within participants factors of Object Orientation (left and right) and Hand of Response (left and right), and the between participants effect of Mapping Condition[15].

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[13] Number of errors in 200 trials

[14] It should be noted that due to the random positioning of object pairs on the left and right-hand side of the computer screen, the factors of hand of response, object orientation and object position on the screen could not be combined in one three-way ANOVA.

[15] Mapping Condition One: left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer – right-hand response paired with; Trowel, Wooden Spoon, Screwdriver and Mallet.

The analysis revealed a significant main effect of Hand of Response [F(1,37) = 6.75, p = .013]. The data showed that right-hand responses were executed significantly faster (m = 486.44) than left-hand responses (m = 503.42). The advantage of right-hand responses over left-hand responses can be seen to reflect either, the right-hand dominance of the majority of the participants in the study, or a compatibility effect arising from viewing the response photographs. Although the objects in the response photographs were positioned to be relatively neutral with regard to left or right-hand grasps, it is possible that object's position could still potentiate actions in the viewer.

Although the main effects of Mapping Condition and Object Orientation were both non-significant at alpha = .05, ([F(1,37) = .049, p = .827] and [F(1,37) = 3.58, p = .066] respectively), the main effect of Object Orientation was nearing significance.

In respect of the main effect of Object Orientation, the data suggest that responses to objects oriented to the right were executed slightly faster (m = 486.36) than objects oriented to the left (m = 503.42). A possible explanation for the presence of a main effect of object orientation is discussed at the end of this experiment. The main effects of Hand of Response and Object Orientation are illustrated in Figure 21.

Importantly, the analysis revealed no significant interactions between Object Orientation and Hand of Response (F(1,37) = .083, p = .775) or between Object Orientation, Hand of Response and Mapping Condition [F(1,37) = 1.18, p = .284]. In addition, all other interactions were found to be non-significant.

Mapping Condition Two: left-hand response paired with; Trowel, Wooden Spoon, Screwdriver and Mallet – left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer.

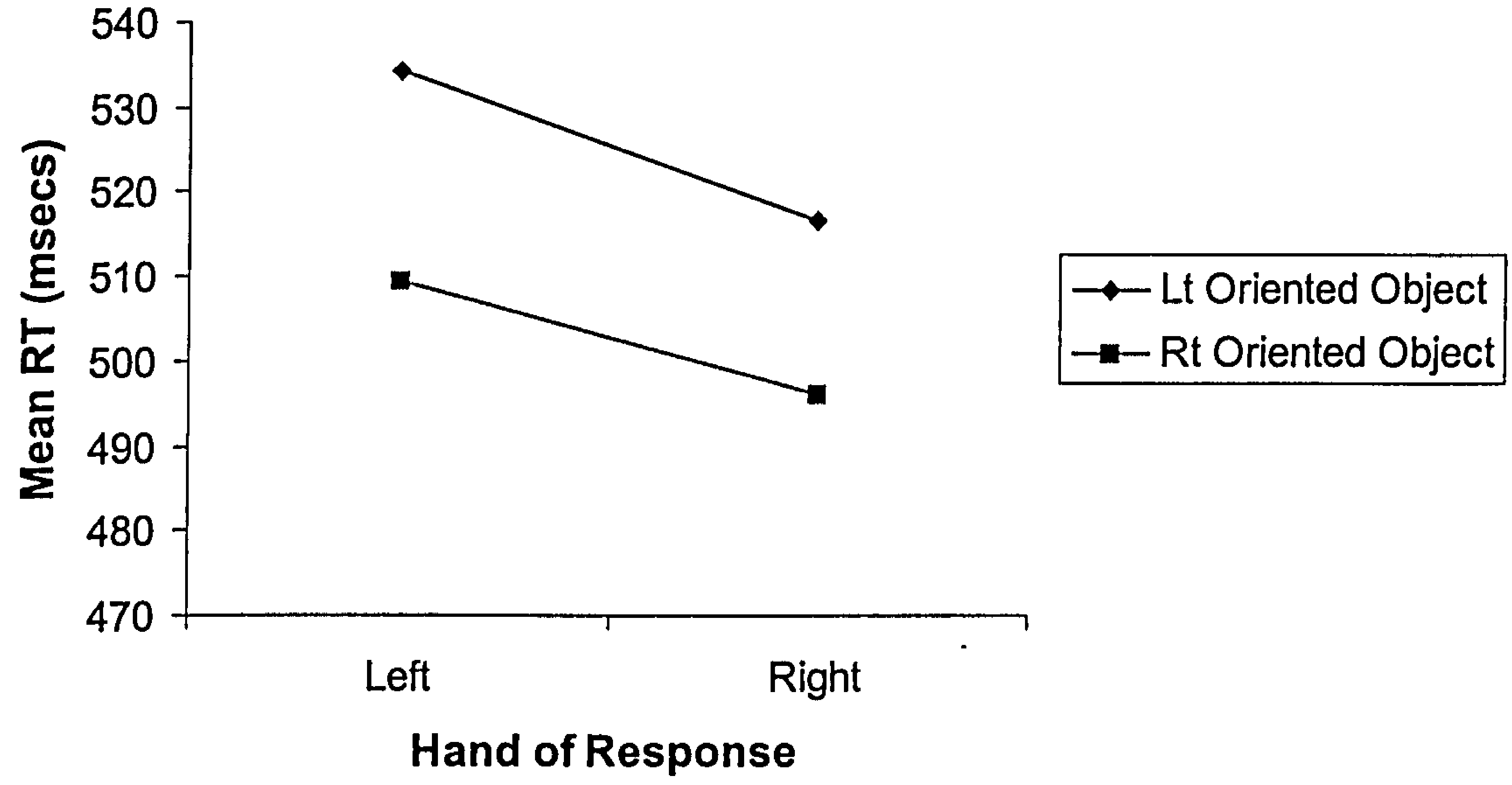

Figure 21
Mean Response Times for Left and Right Hand Responses to Left and Right-orientated Objects

Error Data

The error data is summarised in Table 11 (Appendix e), and were subjected to a three-way mixed ANOVA (Appendix f) with the within participants factors of Object Orientation (left and right) and Hand of Response (left and right) and the between participants factor of Mapping Condition[16].

The data appear to suggest the presence of a three-way interaction between Response Condition, Object Orientation and Hand of Response. In Mapping Condition One the mean scores suggest a positive compatibility effect between Object Orientation and Response Condition. The analysis revealed that in the right-hand response condition more errors were made to left-oriented objects (m = 1.76) than to right-oriented objects (m = 1.29), but in the left-hand response condition more errors were made toward right-oriented objects (m = 1.59) than to left-oriented objects (m = 0.88). In contrast, for Mapping Condition Two the analysis suggests a negative compatibility effect. The analysis

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[16] Mapping Condition One: left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer – right-hand response paired with: Trowel Wooden Spoon; Screwdriver and Mallet.
Mapping Condition Two: left-hand response paired with; Trowel, Wooden Spoon, Screwdriver and Mallet – left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer.

revealed that in the right-hand response condition more errors were made to right-oriented objects (m = 1.33) than to left-oriented objects (m = 1.00), but in the left-hand response condition more errors were made toward left-oriented objects (m = 1.33) than to right-oriented objects (m = 1.00). However, the three-way interaction failed to reach significance [F(1,30) = 2.00, p =.167]. All other effects were found to be non-significant.

5.2.3.2 Analysis Two

Having failed to identify an interaction between Hand and Response and Object Orientation, a second analysis was carried out on the data. The aim of this analysis to find evidence for the spatial Simon effect in visual mental imagery as reported by Tlauka and McKenna. It is argued that if participants were attempting to comply with the instructions to form a visual mental image, then evidence of the spatial Simon Effect should be apparent in the data.

The data were subjected to a two-way ANOVA (Appendix g) with the within participants factors of Object Position *on the Computer Screen* (left and right) and Hand of Response (left and right). A summary of the data can be seen in Table 12 (Appendix h).

The analysis revealed no main effect of Object Position [F(1,38) = .437, p =.513]. However, once again the analysis revealed a significant main effect of Hand of Response [F(1,38) = 17.19, p<.0001]. Consistent with the first analysis carried out on the data set, the results revealed that right-hand responses were executed faster (m = 486.06 msecs) than left-hand responses (m = 503.22 msecs).

The analysis also revealed a significant interaction between Object Position and Hand of Response [F(1,38) = 4.68, p = .037]. Left-hand responses to objects which had been positioned on the left-hand side of the screen were executed faster (m = 493.02 msecs) than left-hand responses to objects positioned on the right-hand side of the screen (m = 513.43 msecs). Conversely right-hand responses to objects on the right-hand side of the screen were executed faster (m = 478.46 msecs) than right-hand responses to objects which had been positioned on the left-hand side of the screen (m = 493.66 msecs).

The Interaction is illustrated in Figure 22.

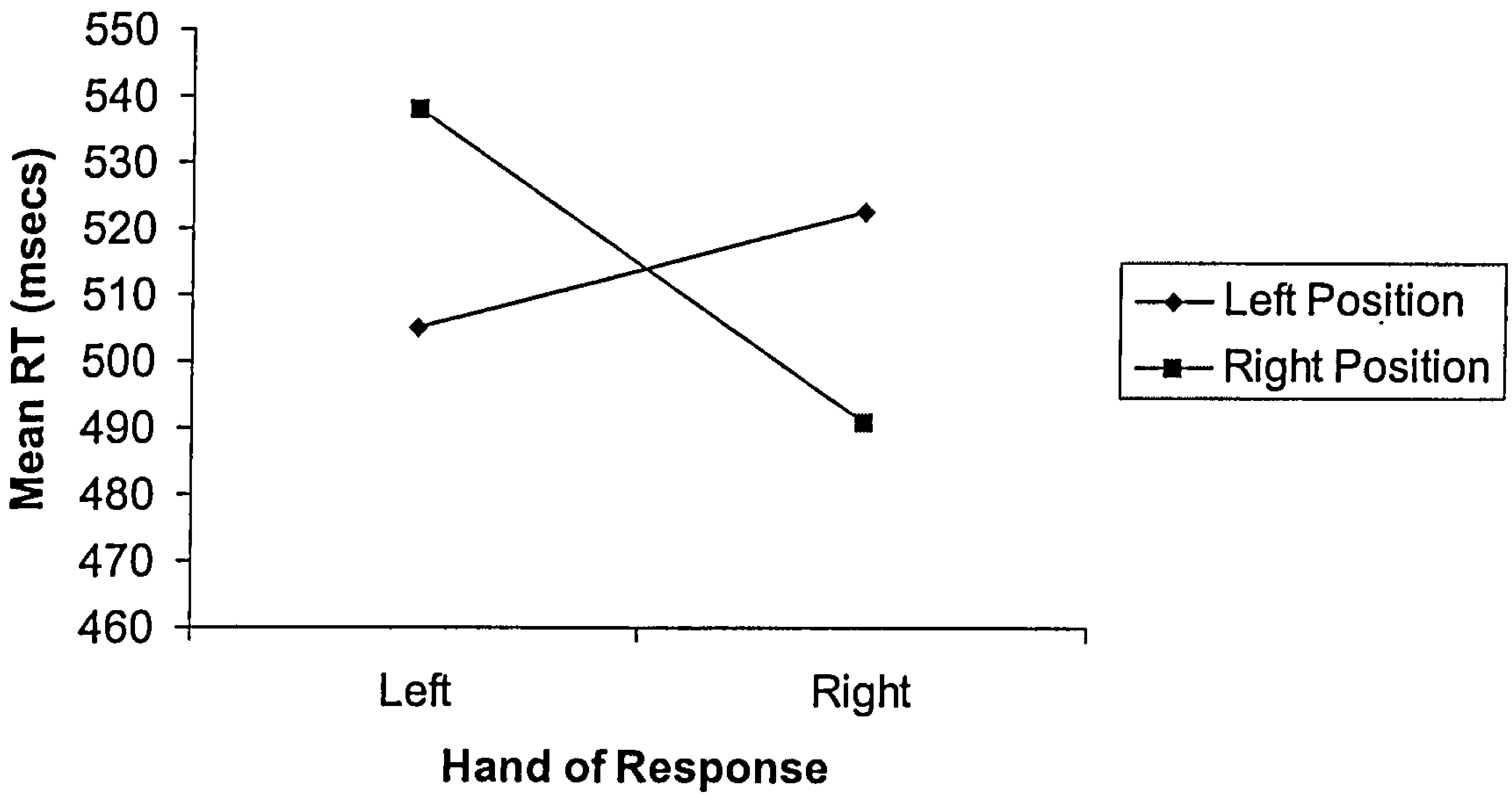

Figure 22
Mean Response Times for Left and Right Hand Responses to Objects Positioned on the Left and Right Sides of the Computer Screen

Error Data

A two-way ANOVA (Appendix i) was carried out on the error data with the within participants factors of Object Position *on the computer screen* (left and right*)* and Hand of Response (left and right). The data for this analysis is summarised in Table 13 (Appendix j).

Consistent with the analysis carried out on the response time data, the error data appear to suggest a compatibility effect between Object Position and Hand of Response. The analysis revealed that in the right-hand response condition more errors were made to left-oriented objects (m = 1.59) than to right-oriented objects (m = 1.16). In the left-hand response condition more errors were made to right-oriented objects (m = 1.31) than to left-oriented Objects (m = 1.09). However, the interaction failed to reach significance [F(1,31) = 1.36, p = .252]. In addition, all other effects were found to be non-significant.

5.2.4 Discussion

The results of experiment Four revealed two important findings. Firstly, consistent with the results of Experiment Three, the analysis revealed no convincing evidence for compatibility effects (micro-affordances) between 'hand of response' and 'orientation of an object for grasping' when participants were asked to form the visual mental image of a recently viewed object.

As with the results of Experiment Three it can be argued that the absence of micro-affordance effects in this study was due to the fact that the visual mental image of recently viewed objects does not give rise to micro-affordance effects arising from the orientation of an object for grasping. One suggestion discussed in the last chapter as to why this might be the case was that participants in the study were not forming visual mental images from information stored in short-term visual memory but instead forming visual mental images of prototypical objects held in long term memory. One effect from Experiment Four, that just failed to reach significance at alpha = .05., could prove to be theoretically significant in regard to this proposal. The data suggest a main effect of object orientation. It was observed that responses to right-oriented objects were executed faster than responses to left-oriented objects.

It was also suggested in the last chapter, that if people possess prototypical representations of everyday 'graspable' objects which contain orientation information, then participants may find it easier to conjure up the image of a recently seen object if the object conforms to a stored prototype. This effect could then be observed as a main effect of object orientation. The fact that responses to right-oriented objects were executed faster than responses to left-oriented objects in Experiment Four could be taken to suggest that the 'prototype' representations of the objects viewed in this experiment are stored with a right-oriented view. To support this proposal evidence was reviewed in the last chapter that suggests that people have prototypical representations for the profile of heads on coins (Rubin and Kontis, 1983; Kosslyn and Rabin, 1999) and in portraits (McManus and Humphrey, 1973). Importantly, additional evidence also exists to suggest that the memory for the direction in which a head faces on a coin is dependent on the handedness of the individual (Martins and Jones, 1999). The results of this study revealed that left-facing heads were more likely to be remembered correctly by right-handed participants whereas right-facing heads were more likely to be remembered correctly by left-handed participants. To explain these findings the authors proposed that motor memories for the drawing of heads is stored with the representations used in recognition, and that right-handed individuals are more likely to draw a head facing left and left-handed individuals with the head facing right.

Unlike heads on coins or in portraits, objects are interacted with, many of which can be picked up, manipulated etc. Consistent with the argument put forward by Martins and Jones - that right handed people draw heads more often facing one direction that another - it is possible to argue that right-handed people have a longer history of interacting with 'graspable' objects with their right-hands, and therefore possess some type of action schema for interacting with right-oriented objects. If this argument is correct then it can be further argued that right-handed people are more likely to possess a prototype representation more strongly weighted in favour of an object oriented for a right-hand grasp. Of the 40 participants taking part in Experiment Four, only four were left-handed (by self-report). Although the number of left-handed participants taking part in the study is too few for a satisfactory analysis, a preliminary look at the data for these participants reveals that three of the participants (75%) recorded faster response times to left-oriented objects than to right-oriented objects. This is surprising, because as we saw above, the analysis carried out on all the participant data suggested that right-oriented objects were responded to faster than left-oriented objects. Of the remaining 35 right-handed participants, 11 (32%) recorded faster response times to left-oriented objects than to right-oriented objects. A summary of the mean response scores for left-handed participants can be seen in Table 14 (Appendix k).

Notwithstanding the importance of the main effect of object orientation in supporting the notion of prototypically oriented objects, the presence of this effect, is also important as it suggests that participants were encoding a visual representation of the target stimuli viewed at the beginning of each block of trials.

The second important result to arise from Experiment Four was the presence of the Simon Effect. The analysis revealed that, right-hand responses were executed faster than left-hand responses to the 'response' stimuli when the portrayed objects were positioned on the right-hand side of the 'target' stimuli viewed at the start of each block of trials. Similarly, left-hand responses were executed faster than right-hand responses when the response stimuli portrayed objects positioned on the left-hand side of the 'target' stimuli viewed at the start of each block of trials. These results replicate those reported by Tluaka and McKenna (1998). In replicating the Simon Effect it seems reasonable to assume that participants were adhering to the instructions to try and form some type of visual or spatial representation.

The presence of the Simon effect is also important as it suggests that extrinsic object attributes, in this case the spatial positioning of an object within a scene, can be represented in visual mental imagery. However, although the spatial positioning of an object within a scene can be classed as an extrinsic object attribute, it can be differentiated from the extrinsic object attribute of object orientation. In Chapter One it was reported that Baylis and Driver (1993) have proposed a distinction between 'object' based and 'frame' based spatial relations. Frame based spatial relations refers to the position of objects or items within a visual scene. For example, the position of the objects as viewed by the participants in the target stimuli used in experiment four. Baylis and Driver argue that this type of frame based spatial relations differs from object based spatial relations which rely on the relative locations of the contours of an object. For example, an object's orientation depends on shape information which itself depends on the relative location of the contours of an object. Importantly, Baylis and Driver suggest that frame based spatial relations and object based spatial relations will be processed by different systems within the visual cortex. They suggest that object based spatial relations relates to 'what' information which as we saw in Chapter One is believed by many researchers to be under the remit of the ventral system and that frame based spatial information relates to 'where' information which is believed to be under the remit of the dorsal system.

As the Simon Effect can be presumed to arise from frame based spatial information which is processed by the dorsal system it can be argued that this information can be processed in the absence of object based or 'what' information. In arguing this point the assumption made earlier that participants were forming visual mental images of the target object images based on evidence of the Simon Effect is perhaps premature. Although spatial location is one attribute of the objects viewed in the photographs in this study, it is quite possible that the memory for the objects' spatial locations could be disassociated from the visual features of an object which are believed to be responsible for micro-affordance effects. For example, in Experiment Four it could be the case that participants were completing the task by verbalising the object names and pairing this verbal label with a spatial position. In these circumstances one would not expect to see micro-affordance effects arising from object orientation, as orientation is 'object' based property of an object, but one may expect to observe the Simon Effect.

Before moving on to Experiment Five, one other explanation for the absence of micro-affordance effects in Experiment Four needs to be examined, the effect of the visual cue used to elicit the response from the participants. As already suggested in the results section above, the main effect of Hand of Response observed in the data could have arisen in two ways. Firstly, the effect could be seen to reflect the right-hand dominance of the majority of the participants. However, the effect could also have arisen from compatibility effects elicited from the response photographs. Whether or not this second explanation was a contributory factor to the main effect of hand of response it is certainly possible that the response photographs interfered with the participants' ability to form visual mental images of the objects viewed in the target photographs. Indeed as we saw in Chapter Two, there is plenty of evidence to show that visual perception can interfere with visual mental imagery (Craver-Lemely and Reeves, 1987; Farah, 1985).

5.3 EXPERIMENT FIVE

5.3.1 Introduction

As discussed earlier in this thesis, the 'precision' and 'power' components of the reach-to-grasp action can be seen to reflect the 'small' and 'large' dimension labels of the 'object size' attribute. As object size can form both an 'intrinsic' and an 'extrinsic' property of an object (Jeannord, 1994) it can be noted that when investigating the power and precision components of the reach-to-grasp action in a micro-affordance study one cannot use a 'neutral' view of the target objects to cue participant responses. To overcome this confound it was decided that in Experiment Five participants' responses would be cued with high and low pitched tones instead of visual cues.

In the experiment participants are asked to complete four blocks of 50 trials. Before each block of trials participants view a target picture containing either one power grasp compatible object or one precision grasp compatible object. Having memorised the target picture, participants complete a series of trials in which they hear either a high pitch or low pitch tone. Depending on the tone heard, participants are asked to press either a power compatible switch held in their left-hand or a precision compatible switch held in their right-hand (or vice versa) whilst at the same time trying to visualise the object seen in the target picture.

It is hypothesised that: (1) power grasp responses to objects optimally compatible with a power grasp action, will be executed faster and more accurately than power grasp responses to objects optimally compatible with a precision grasp action, and precision grasp responses to objects optimally compatible with a precision grasp action, will be executed faster and more accurately than precision grasp responses to objects optimally compatible with a power grasp action; (2) that right-hand responses to objects positioned on the right-hand side of the computer screen will be faster and more accurate than right-hand responses to objects positioned on the left-hand side of the computer screen and vice versa.

5.3.2 Method

Participants

Sixty participants from the University of Plymouth took part in the experiment. All participants had normal motor function in both hands and normal or corrected to normal vision. Each was given either the sum of £3.00 or course credit for participating in the experiment.

Apparatus and Materials

The stimulus set comprised 8 colour target photographs and two auditory signals. The target photographs each contained one object that was positioned either on the left-hand side of the photograph or one the right-hand side of the photograph. The stimulus set comprised two objects that were maximally compatible with a precision grasp (between index finger and thumb) and two objects maximally compatible with a power grasp (whole hand). The objects are listed in Appendix I. In order to ensure a balanced design each object depicted in the 'photographs was photographed both on the right-hand side of the screen and the left-hand side of the screen (making a total of 8 target photographs). An example of the 'target' stimuli is shown in Figure 23.

The pictures were viewed on a 19" monitor at a distance of approximately 50 cms. The objects subtended an angle of between 2.29 and 10.85 degrees (Appendix B).

The auditory signals used in the experiment were a high and low pitched tone. The high tone comprised a 400 Mhz signal lasting for a duration of 400 msecs. The low tone comprised a 800 Mhz signal lasting for a duration of 400 msecs.

Participants' responses to the reaction time task were recorded on the specially designed hand device used in the previous experiments (Figure 4, Chapter 3).

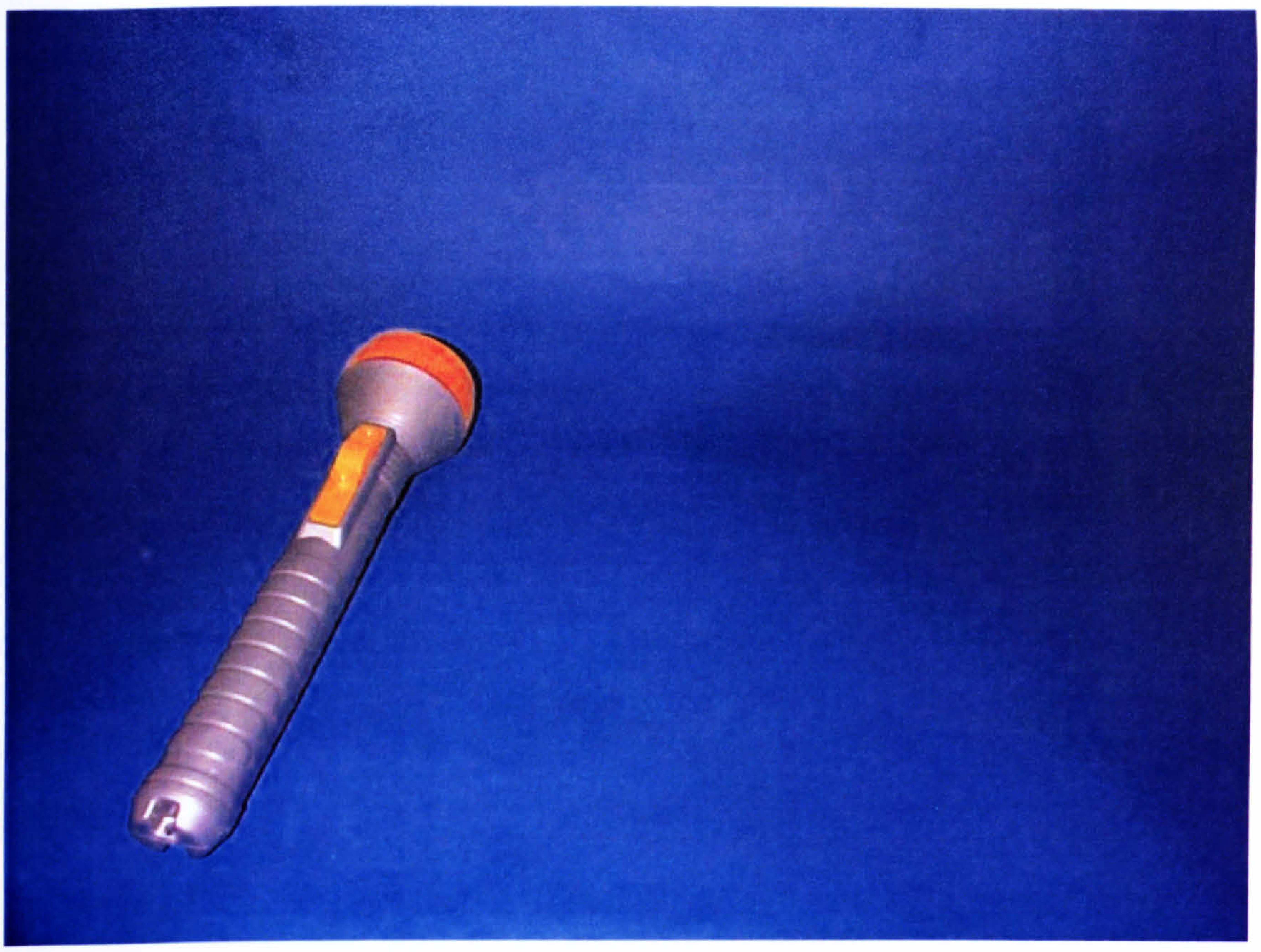

Figure 23
Example of the Target Stimuli used in Experiment Four

Design

The experiment comprised 4 blocks of 50 trials. At the start of each block of trials participants were presented with one target photograph taken from the set of eight target photographs. Participants saw all four objects. In order to ensure a balanced design each participant saw both one power and one precision object placed on the left-hand side of the screen and one power and one precision object placed on the right-hand side of the screen. At the start of the experiment participants were randomly assigned to one of two mapping conditions. In mapping condition one the participants viewed the four target pictures with the mallet on the left and the torch on the right, and the key on the left and the coin on the right. In Mapping condition Two the objects were viewed on the reverse side of the screen. Order of presentation for the target photographs was randomised independently for each participant.

Procedure

At the start of each block of trials participants were presented with a target picture. The picture was displayed for a period of 15 seconds, after which it was replaced with a screen containing written instructions to the participants to "form a visual mental image now". After 10 seconds the 'target' picture was displayed again for a period of 15 seconds. Once the target picture was removed from view for a second time, the response trials began.

At the start of each response trial participants were given a written message for a period of 300 milliseconds to remind them to "form image now". After a further 300 milliseconds a tone sounded. Depending on the mapping rule given at the start of the experiment participants either pressed the switch held in their left-hand when they heard the high tone and the switch held in their right-hand when they heard the low tone, or vice versa. In addition, for each of these two groups half the participants held the power switch in their right-hand and the precision switch in their left-hand, and the remaining participants held the switches in the opposite hands. Having made the appropriate response participants were prepared for the next trial.

Participants were asked to respond as quickly as possible whilst maintaining accuracy. Errors resulted in an error message being flashed on the screen.

All participants were presented with written instructions (Appendix m) and completed two blocks of 10 trials before commencement of the main experiment.

5.3.3 Results

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment. The mean error rate was calculated at 4.44[17] (St Dev 6.96). Based on this criterion the data from four participants was excluded from the analysis. Errors and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Error data accounted for 1.85% of response trials, while reaction times greater than two standard deviations accounted for 4.57% of response trials.

Two sets of analyses were carried out on the data[18]. In the first analysis a three-way ANOVA with the within-participants factors of object compatibility and response grasp, and the between participants factor of mapping condition, was carried out on the data in an attempt to identify micro-affordance effects arising from the power and precision element of the reach-to-grasp action. In the second analysis the aim was to identify Simon Effects arising from the position of the stimuli on the computer screen (left/right) and the hand of response (left/right).

5.3.3.1 Analysis One

Response Time Data

The data are summarised in Table 15 (Appendix n) and were subjected to a three-way ANOVA (Appendix o) with the within participants factors of Response Grasp (power and precision) and Object Compatibility (power and precision) and the between participants factor of Mapping Condition[19].

The analysis revealed a significant main effect of Response Grasp [F(1,52) = 10.05, p =.003], but no main effects of either Object Compatibility [F(1,52) = .004, p = .951] or Mapping Condition [F(3,52) = .186, p = .906]. In respect of the main effect of Response Grasp the analysis revealed that power responses were executed significantly faster (m = 594.07 msecs) than precision responses (m = 614.96 msecs). This effect replicates the same effect found in Experiments One and Two, and in the earlier studies looking at 'seen' objects (Ellis and Tucker, 2000).

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[17] Number of Errors in 200 trials

[18] Due to the design of the experiment Object Position (left and right) Response Position (left-hand and right-hand), Object Compatibility (power and precision) and Response Grasp (power and precision) could not be combined into one 4-way ANOVA.

[19] Mapping One: Power Switch in Left Hand-Precision Switch in Right Hand: High Tone Right Hand-Low Tone Left-hand. Mapping Two: Power Switch in Left Hand-Precision Switch in Right Hand/High Tone Left Hand-Low Tone Right Hand. Mapping Three Precision Switch in Left Hand-Power Switch in Right Hand/High Tone Left Hand-Low Tone Right Hand. Mapping Four: Precision Switch in Left Hand and Power Switch in Right Hand/High Tone Right Hand-Low Tone Left Hand.

Importantly, the analysis revealed no significant interactions between Response Grasp and Object Compatibility [F(1,52) = .169, p =.683] or between Response Grasp, Object Compatibility and Mapping Condition [F(3,52) =.566, p =.640]. In addition, all other effects were found to be non-significant.

Error Data

The error data are summarised in Table 16 (Appendix p), and were subjected to a three-way ANOVA (Appendix q) with the within participants factors of Object Compatibility (power and precision) and Response Grasp (power and precision) and the between participants factor of Mapping Condition[20].

Consistent with the results of the analysis carried out on the response time data, the interaction between Response Grasp and Object Compatibility and the interaction between Response Grasp Object Compatibility and Mapping Condition were found to be non-significant: [F(1,36) = .068, p = .796] and [F(3,36) =.329, p = .804] respectively. In addition, all other effects were found to be non-significant.

5.3.3.2 Analysis Two

Response Time Data

The data were subjected to a two-way ANOVA (Appendix r) with the within participant factors of Object Position *on the computer screen* (left and right) and Hand of Response (left and right). As in Experiment Four, the aim of this analysis was to establish whether or not the data contained evidence of the spatial Simon Effect identified in the Tlauka and McKenna study. The data are summarised in Table 17 (Appendix s).

The analysis revealed no significant main effects of either Object Position [F(1,55) = .401, p = .529] or Hand of Response [F(1,55) = .304, p = .583]. However, the analysis did reveal evidence of the spatial Simon Effect as reflected in the significant interaction between Object Position and Hand of Response [F(1,55) = 6.84, p = .011]. The results revealed that right-hand responses were executed faster (m = 602.51 msecs) for objects which had been positioned on the right-hand side of the screen than for objects which had been positioned on the left-hand side of the screen (m = 607.62 msecs) whereas, left-hand responses were executed faster (m = 601.55 msecs) for objects which had been positioned on the left-hand side of the screen than for those which had been positioned on the right-hand side of the screen (m = 614.80 msecs). The interaction is illustrated in Figure 24.

As the right positioned power graspable objects were always oriented toward an optimal right-hand grasp and the left positioned power graspable objects always oriented toward an optimal left-hand grasp, a second analysis was carried out on just the data for precision compatible objects. The data for the precision compatible objects were subjected to a two-way ANOVA (Appendix t) with the within participant factors of Object Position *on the computer screen* (left and right) and Hand of Response (left and right). A summary of the data can be seen in Table 18 (Appendix u).

The analysis again revealed no significant main effects of either Object Position or Hand of Response. In addition, the interaction between object position and hand of response was also found to be non-significant. However, the effect was nearing significance [F(1,55) = 2.96, p = .091]. The data suggest that for objects positioned on the left-hand side of the computer screen left-hand responses were executed slightly faster (m = 601.72) than right-hand responses (m = 602.87), and for objects positioned on the right-hand side of the screen, right-hand responses were executed faster (m = 606.23) than left-hand responses (m = 618.81)

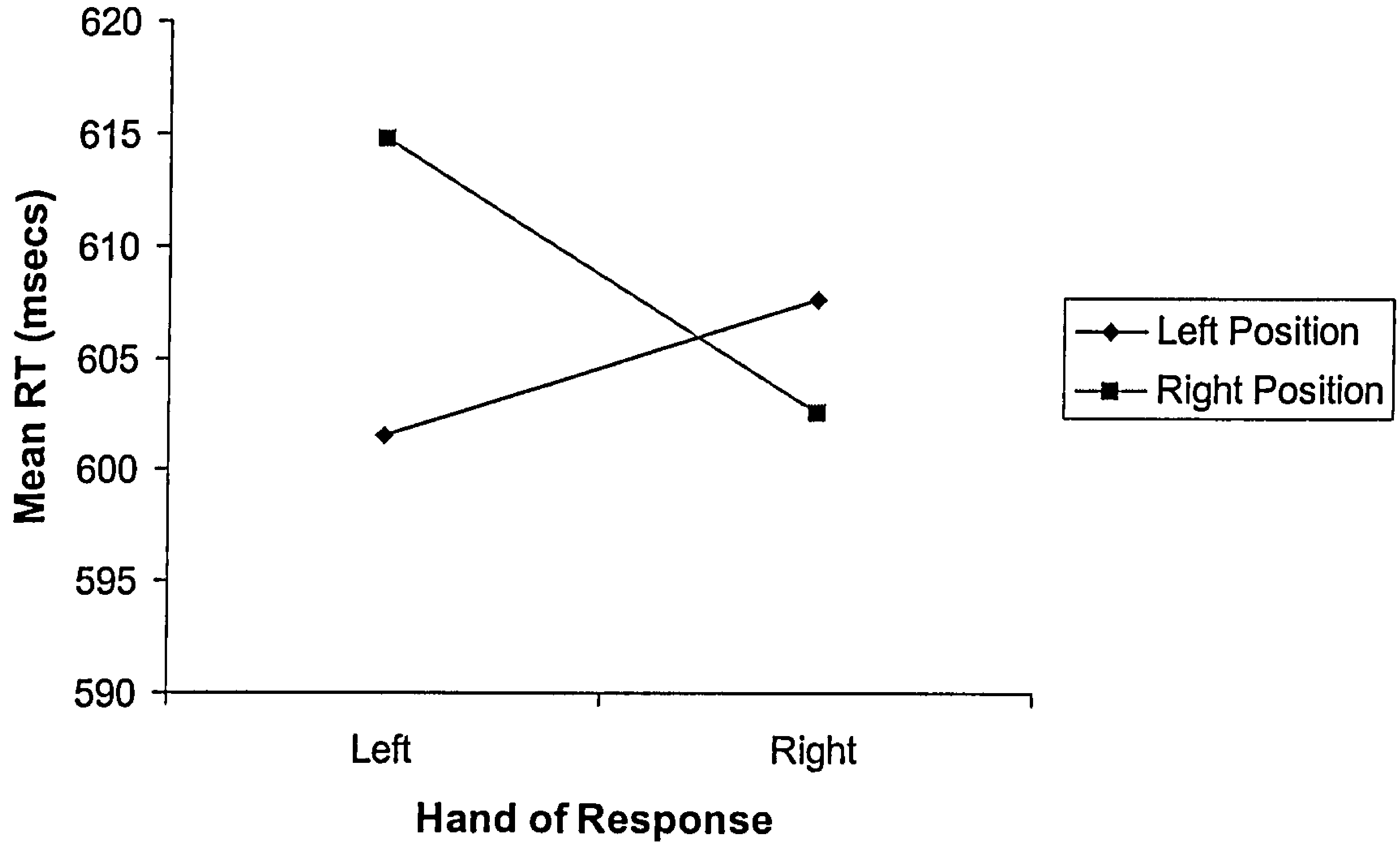

Figure 24
Mean Response Times for Left and Right Hand Responses to Objects Positioned on the Left and Right Sides of the Computer Screen

Error Data

The error data are summarised in 19 (Appendix v) and were subjected to a two-way ANOVA (Appendix w) with the within participants factors of Hand of Response (left and right) and Object Position (left and right).

Importantly, the analysis revealed no interaction between Object Position and Hand of Response [F(1,39) = .184, p = .670]. In addition, all other effects were found to be non-significant.

5.3.4 Discussion

The results of Experiment Five revealed two important findings. Firstly no evidence was found for a compatibility effect between the precision and power component of the reach-to-grasp action and the compatibility of the imaged objects for grasping with a power or precision grasp. This finding is surprising, given that in Experiment Two, reported in Chapter Three, the effect was observed in an experiment in which participants were also asked to make a response to the visual mental image of a recently viewed object.

It was argued in Chapter Three that the presence of micro-affordance effects from the power and precision component of the reach-to-grasp action observed in Experiment Two could have arisen from either intrinsic or extrinsic object properties. According to this argument, both a semantic route and a visual route to action could account for the effects depending on whether participants were forming visual mental images or using some form of verbal labelling strategy to complete the task in Experiment Two. The complete absence of the effect in this experiment therefore raises questions as to whether participants were forming any type of object representation, visual or semantic, while completing the task in the experiment.

The second important finding to arise from experiment Five was evidence of the spatial Simon Effect. Consistent with the findings of Experiment Four and those of the Tluaka and McKenna study (1998), the response data revealed evidence of the spatial Simon Effect. However, in contrast to the findings of those two experiments the spatial Simon Effect in this experiment arose in response to an auditory signal and not a visual cue whilst at the same time trying to form the visual mental image of a previously viewed object. The data revealed that right-hand responses made to an auditory tone resulted in faster response times if the stimulus participants were asked to image contained an object positioned on the right-hand side of the photograph than if the object was positioned on the left-hand side, and vice versa. In addition, the Simon Effects observed in Experiment Five were produced when participants were asked to conjure up the visual mental image of an object from a stimulus which contained only one target object. This can be contrasted with Experiment Four and the Tlauka and McKenna study, as in each of these experiments the imaged stimulus contained two objects/items.

5.4 General Discussion

The aim of the two experiments described in this chapter was to clarify the position in regard to the capacity of a visual mental image of a recently visualised object to potentiate compatible actions (micro-affordances) in the imager.

The results of Experiment Four were consistent with those of Experiment Three. In both these experiments no evidence was found for micro-affordance effects arising from the orientation for grasping of a recently viewed object and hand of response. However, the results of Experiment Five were not consistent with those of Experiment Two. In Experiment Two evidence was presented to suggest that the visual mental image of a recently viewed 'power grasp' or 'precision grasp' compatible object could potentiate compatible actions in the imager.

The absence of micro-affordance effects in experiment Four seems to confirm the non-significant findings reported for Experiment Three and suggest that the 'orientation of an object for grasping' does not evoke action compatibility effects when a visual mental image is formed for a recently viewed object. However, the results of Experiment Four did reveal an effect which just failed to reach significance at alpha = .05, which has potential theoretical significance. The analysis of the response time data in Experiment Four revealed a main effect of object orientation whereby right-oriented objects were responded to faster than left-oriented objects. This effect is theoretically important as firstly it suggests that participants were trying to form visual mental images of the target stimuli as requested or at least utilising some code that included orientation information.

Secondly, the effect is important as it suggests that right-oriented objects viewed in the target stimuli were more salient than left oriented objects. One explanation put forward as to why this might be the case was that when trying to form visual mental images of the target stimuli participants were not drawing on information held in short term visual memory but instead reconstructing the object images with information held in long term visual memory. Moreover, it was proposed that these images represented prototypical object images that contain orientation information. The finding that right-oriented objects resulted in faster response times was taken to suggest that any prototypical object image might be right-oriented.

Although not too much can be read into the main effect of object orientation in this experiment (as it failed to reach significance), the effect can be compared with an effect in Experiment Three that also just failed to reach statistically significance. In that experiment a three-way interaction was observed between object orientation, hand of response and position of the objects on the computer screen. It was observed that left-oriented objects positioned at the top of the computer screen were responded to faster than right-oriented objects, and right-oriented objects positioned at the bottom of the screen were responded to faster than left-oriented objects. As with Experiment Four the results of this experiment suggest that participants were trying to form visual mental images of the objects viewed in stimuli.

The failure of Experiment Five to replicate micro-affordance effects for the power and precision component of the reach-to-grasp action observed in Experiment Three was surprising. As it has been argued that micro-affordance effects arising from the power and precision component of the reach-to-grasp action could arise from either extrinsic or intrinsic object properties and therefore may arise from the construction of either a visual or semantic representation the results raise questions as to what type of representation, if any, participants were utilising when completing the task.

In spite of the absence of significant micro-affordance effects in both experiments, Experiments Four and Five did provide evidence of the spatial Simon Effect in visual mental imagery. The results of the analyses revealed that objects positioned on the right-hand side of the computer screen were responded to faster than those positioned on the left-hand side of the computer screen, and vice versa. Although the initial assumption was to suggest that the presence of this effect provided evidence that participants were forming visual mental images of objects, as already noted in the discussion section at the end of Experiment Four, an alternative explanation for the result is possible. It can be argued that in order to complete the experiment participants were forming a 'frame' based spatial representation but not an object based representation.

Chapter Six

6.1 Introduction

In Chapters Three to Five, four experiments were described which had the aim of identifying micro-affordance effects in visual mental imagery. In the first two experiments participants were required to make an action response whilst carrying out an object categorisation task based on a recently viewed array of four objects. Results from first of these two experiments suggested the presence of micro-affordance effects arising from the power and precision component of reach-to-grasp action in visual mental imagery. However, the second experiment found no evidence for micro-affordance effects arising from the orientation of an object for grasping and hand of response in visual mental imagery.

In the second two experiments a slightly different experimental design was employed. In the first of these experiments participants were required to make an action response to a seen object whilst conjuring up the image of that object as viewed in an earlier photograph. As in the first experiment looking at micro-affordance effects arising from the orientation of an object for grasping and hand of response, no evidence was found for these effects. In the second of these experiments participants were required to make an action response to an auditory tone whilst again conjuring up the image of a previously viewed photograph. However, unlike the second visual mental imagery experiment aimed at identifying micro-affordance effects rising from the power and precision component of the reach to grasp action, no evidence of these effects were observed.

The above four experiments were all designed to enable the observation of micro-affordance effects when participants were asked to form a 'conscious' visual mental image of a recently viewed object. However, as we saw in Chapter Two, visual mental imagery is only one phenomenon within the field of off-line vision. Although in the four experiments reported above participants were asked to form the visual mental image of a recently viewed object, a task which can be assumed to demand the resources of short-term visual memory, visual mental imagery and short-term memory cannot be considered analogous (Logie, 1995 and Pearson, Logie and Gilholey,1999). It is always possible that when trying to form visual mental images from recently viewed stimuli participants draw on other memory structures and processes, for example, semantic memory and long-term visual memory. One argument put forward in the last chapter as to the absence of orientation effects in these studies was that participants were indeed drawing on off-line visual representations and processes in addition to short-term visual memory. As orientation is an extrinsic, viewer centred property of an object it was argued that this would only be a property of short-term memory representations and not necessarily other off-line visual processes. It was further argued that if this were the case then it would not affect the observation of micro-affordances arising from the power and precision component of the reach to grasp action. As the object properties thought to be responsible for these effects, those of object weight and object size, are both intrinsic object properties they do not require input from short-term visual memory or indeed visual memory of any kind.

In this chapter the results of three experiments are examined. Once again the experiments aim to identify micro-affordance effects arising from off-line visual processes. However, unlike the previous four experiments, these three experiments aim to examine more closely the visual representations assumed to be held in short-term visual memory. In each of the three experiments participants are shown a series of object images one after another on a computer screen for varying durations, followed by the name of an object written in the middle of the computer screen. In each series of object images participants are presented with one object that is maximally compatible with either a left or right-hand power grasp and the remaining objects are optimally compatible with neither grasp. Participants are then asked to make a power grasp response with either their left or right hands to declare whether or not they remember seeing the named object in the series of object images just viewed. All three experiments seek evidence for micro-affordance effects arising from the relationship between the orientation of an object for grasping and hand of response.

Unlike the four experiments reported in previous chapters, participants in the experiments described in this chapter are asked only to decide whether or not they remember seeing a named object in the series of images just viewed. As no instructions are given to form a visual mental image of the object before responding, although, of course this does not rule out the possibility of participants doing so.

All three experiments reported in this chapter utilise a similar design and procedure to that employed in the first experiment reported in the Richardson et al (in preparation) study, described in Chapter Two. In that study evidence was presented to suggest that the visual memory of an object can potentiate both a 'compatibility' effect and an 'incompatibility' effect between the orientation of an object for grasping and hand of response when participants make an action response to the visual memory of an oriented object. The incompatibility effect manifested itself in the finding that right-hand responses to left-oriented objects were executed faster than right-hand responses to right-oriented objects, and vice versa. The 'incompatibility' effect was only observed for relatively slow response times (mean of approximately 1500 msecs). When participants made relatively fast responses (mean of approximately 700 msecs) a 'compatibility' effect was observed.

Given that speed of response has been reported to effect the expression of the micro-affordance effects, the three experiments reported in this chapter aim to both replicate those findings and identify other factors that may affect the expression of micro-affordance effects reported in the Richardson et al study.

In Experiment Six participants are presented with a series of four object images, each for a period of one second closely followed by the name of an object. Participants are then asked to declare whether or not the named object is present in the series of images just viewed using a power grasp response. By contrast, in Experiment Seven participants are presented with a series of four object images but this time each image is presented for a period of 200 milliseconds.

In carrying out experiments Six and Seven, factors relating to the number of images presented on each trial and the stimulus processing time are investigated. Experiment Six differs from the Richardson et al study in that the number of object images presented on each trial is reduced from eight object images to four. By reducing the number of images from eight to four it is anticipated that response times will also be reduced as participants will have fewer images to recall when making their decisions. However, stimulus processing time has also been increased from 200 milliseconds to one second. In order to tease apart the effects of these two factors and compare the results with the Richardson et al study, participants in Experiment Seven are again presented with four object images on each trial but this time for a period of 200 milliseconds each.

Finally, Experiment Eight aims to replicate the Richardson et al study by presenting participants with a series of eight object images on each trial for a period of 200 milliseconds each. All three experiments differ from the Richardson et al study in that the response cue (the object name) is presented visually rather than auditorally.

As well as examining the effects of changes in the number of object images presented on each trial and changes in stimulus processing time, the experiments aim to explore other factors. Firstly, additional analyses are undertaken to examine the presence of the micro-affordance effects over the time course of the experiment. It can be argued that as participants become increasingly familiar with the experiment procedure, practice effects will be observed – response latencies will reduce over the time course of the experiment. If this is the case then one may expect to observe changes in the expression of micro-affordance effects over the time course of the experiment given the findings of the Richardson et al (in preparation) study. To recall, in that study it was shown that relatively slow response times were associated with an incompatibility effect and relatively fast response times with a compatibility effect. In order to explore this possibility analyses are carried out on all three experiments to compare response data collected in the first and second halves of the experiments. In addition, experiments Seven and Eight are run consecutively (balancing for order effects) to allow analyses of the response data over a longer period of time. Experiments Seven and Eight each contain object images taken from the same stimulus set, and utilise the same experimental procedure.

Finally, Experiments Seven and Eight also aim to seek evidence for micro-affordance effects arising from presentation of an oriented object on each trial when responses are made to named non-oriented objects in the stimulus array, and to named objects that were not presented in the stimulus array ("No" responses). It can be argued that if participants are accessing visual memories of the objects viewed on each trial to complete the task, then it may be the case that all 'trial' objects have the potential to potentiate actions in the viewer.

6.2 Experiment Six

6.2.1 Introduction

In this experiment participants are asked to complete a series of trials in which they view four images of 'graspable' objects in succession for a period of one second each. On each trial one object image depicts an object that is optimally oriented to be grasped by either a left or right-hand grasp, and three images that depict objects which have no optimal orientation for grasping by either hand. Having viewed all four images, participants are presented with the name of an object on the computer screen and have to decide whether or not the named object is one of the four objects just viewed. Participants then make a series of "yes, object present" or "no, object not present" responses by pressing switches held in each hand.

The aim of this experiment is to investigate the presence of micro-affordance effects arising from the relationship between hand of response and orientation of the object viewed when participants are presented with a relatively small number of object images. It is hypothesised that in presenting a small number of object images that (1) response times will be relatively fast (see Richardson et al study); (2) a compatibility effect will be observed between hand of response and orientation of an object for grasping.

6.2.2 Method

Participants

Fifty participants from the University of Plymouth took part in the experiment. All participants had normal motor function in both hands and normal or corrected to normal vision. Each received course credit for participating in the experiment.

Apparatus and Materials

The stimulus set comprised 75 colour photographs, each containing one object positioned to the centre-front of the photograph. Twenty-five photographs contained objects which were optimally oriented to be grasped with a right-hand grasp and twenty-five photographs contained the same 25 objects optimally oriented to be grasped with a left-hand grasp, e.g. saucepans, mugs etc. An example of an optimally oriented object is illustrated in Figure 25. The remaining 25 photographs contained objects that had no apparent orientation for grasping by a particular hand, e.g. an apple and a vase (see Appendix x for a list of all objects). An example of an object with no optimal orientation for grasping is illustrated in Figure 26.

The pictures were viewed on a 19" monitor at a distance of approximately 50 cms. The objects subtended an angle of between 6.3 and 18.18 degrees (Appendix B).

Participants' responses to the reaction time tasks were recorded on the specially designed hand device used in the previous experiments.

Figure 25
Example of an Object Stimulus used in Experiments Six, Seven and Eight which is Optimally Oriented for Grasping with a Right Hand

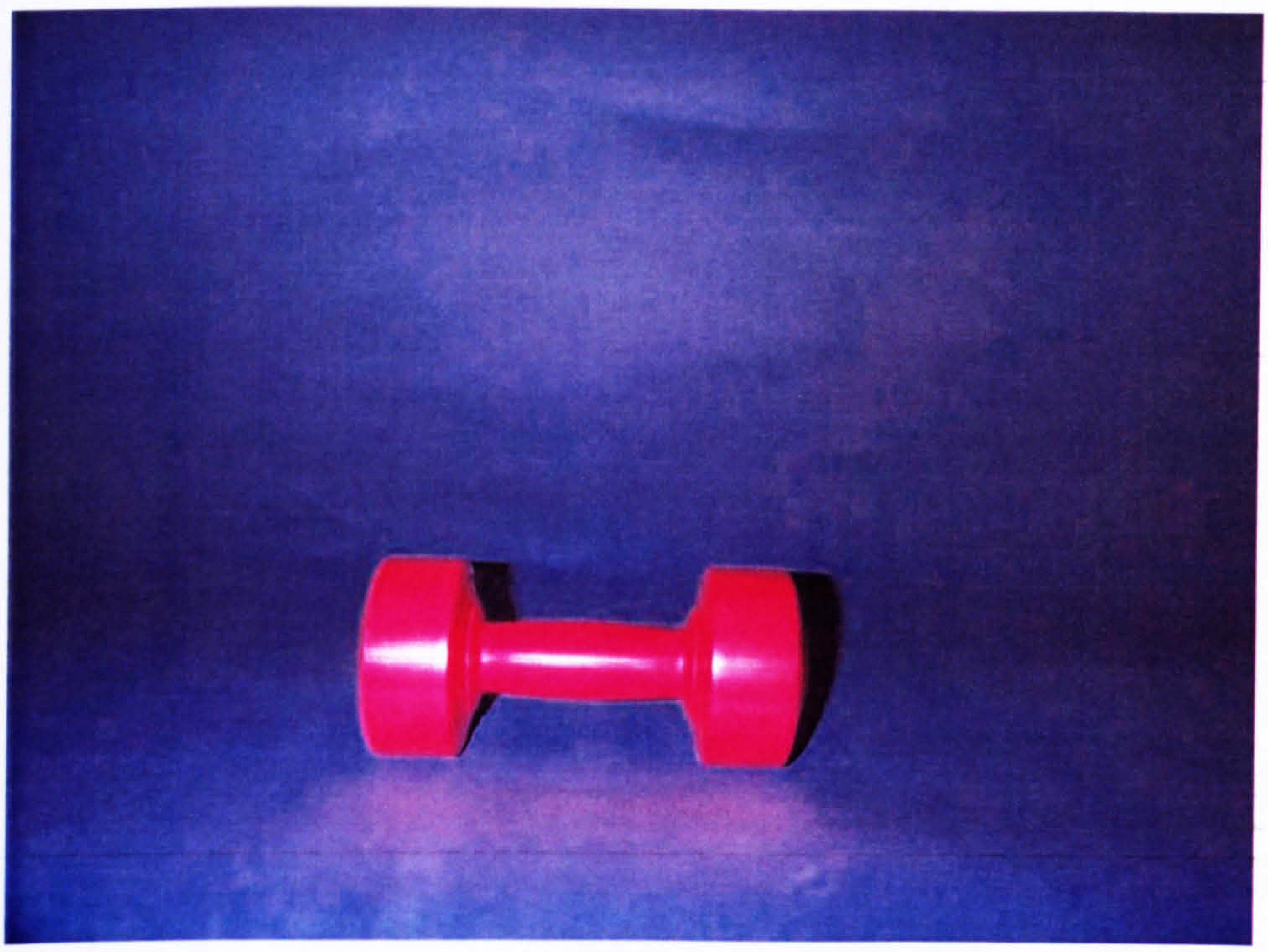

Figure 26
Example of an Object Stimulus used in Experiments Six, Seven and Eight which has No Optimal Orientation for Grasping by a Particular Hand

Design

The experiment comprised 240 trials. On each trial participants were presented with four photographs. Three of the photographs depicted objects from the list of objects with no optimal orientation for grasping by a particular hand and one photograph depicted an object from the list of 50 orientated objects. No object appeared twice on the same trial. The object images used for inclusion on each trial were taken at random from the object lists according to the above criteria.

Participants were shown the named 'target' object on half the trials. This resulted in 120 occasions on which the participants responded "Yes" (object present) to the task, and 120 trials on which the participants responded "No" (object not present). Of the 120 trials on which the named target object was presented, 60 trials identified an object with no optimal orientation for grasping, and 60 trials identified an object with an optimal orientation for grasping. Of the 60 trials where the object had an optimal orientation for grasping, 30 pictures contained objects oriented to be optimally compatible with a left-hand grasp and 30 pictures contained objects oriented to be optimally compatible with a right-hand grasp. This resulted in 30 trials where there was a compatibility relationship between orientation of the object and hand of response and 30 trials in which there was an incompatible relationship between orientation of the object and hand of response.

In order to ensure a balanced design the order of presentation of "trial type" (target object present/ target object not present/orientated object/non-orientated object) was randomised independently for each participant. In addition, half the participants were assigned to a mapping condition in which they responded with their left-hand for "Yes" responses (object present) and right hand for "No" responses (object not present) and the remaining participants to a mapping condition with the reverse instructions.

Procedure

On each trial participants were presented with a message to prepare for presentation of the object stimuli. After 200 milliseconds the message was removed from the screen and a series of four pictures were presented on the screen, each for a period of one second. After the fourth picture was removed from the screen a blank screen appeared. After a further 100 msecs the name of an object appeared in the middle of the screen. Participants then pressed either the switch held in their left-hand or in their right-hand depending on whether or not they remembered seeing the named object. Error trials resulted in a bleep from the computer

Having made a response participants were instructed to prepare for the next trial. All participants were presented with written instructions (Appendix y) and completed 10 practice trials before commencement of the main experiment.

6.2.3 Results

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment. The mean error rate was calculated at 34.79 (St Dev 22.79)[20]. Nine participants were excluded from the analysis on the basis of this criterion. The data from a further two participants was removed from the analysis as they failed to complete the experiment. Error trials and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Errors accounted for 10.21% of response trials, while reaction times greater than two standard deviations accounted for 4.44% of response trials[21].

Two sets of analyses were carried out on the data. The aims of the first analysis was to: (1) identify micro-affordance effects arising from the compatibility between the orientation of an object for grasping and hand of response, and (2) establish whether or not any micro-affordance interacted with object position in the trial series (first, second, third or last object viewed).

The aim of the second analysis was again to identify micro-affordances arising from the compatibility of an object for grasping and hand of response, but this time also to

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[20] Number of errors in 240 trials.

[21] Error rates were calculated on the whole data set before the data was separated for analysis of "Yes" trials.

explore the effect in relation to the time course of the experiment. This was achieved by comparing responses produced in the first and second halves of the experiment[22].

6.2.3.1 Analysis One

Response Time Data

The response data from the "Yes" trials on which participants were asked to respond to an oriented object were subjected to a three-way mixed ANOVA (Appendix z) with the within participants factors of Object Orientation (left and right) and Stimulus Position (one to four), and the between participants factor of Hand of Response (left and right)[23]. A summary of the data can be seen in Table 20 (Appendix AA).

The analysis revealed a significant main effect of Stimulus Position [F(3,111) = 17.34, p <.0001], but no significant main effects of either Object Orientation [F(1,37) = 1.90, p = .176] or Hand of Response [F(1,37) =. 889, p = .352].

Although non-significant (alpha = .05) it is interesting to note that in-line with the trends observed in experiments three and four, the main effect of object orientation did suggest that responses to right-oriented were executed faster (m = 751.94 msecs) than responses to left-oriented objects (m = 767.48 msecs).

In respect of the main effect of Stimulus Position, the data suggest the presence of both a primacy and recency effect. The mean response times to objects at each position in the trial series shows that responses to the last object in the series (position four) were executed faster (m = 697.10 msecs) than responses to the images at position three (m = 750.67 msecs). Similarly, responses to the first object in the trial series (position one) were executed faster (m = 789.91 msecs) than responses to the images at position two (m = 801.15 msecs). In a follow-up analysis (Appendix BB) the data revealed that only the recency effect was significant (T(37) = 45.98, p<.05). This finding is consistent with studies that suggest for written and verbal recall of lists both a primacy and recency effect

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[22] The decision to carry out two separate analyses on the data was taken as some participants had insufficient data points to complete each cell of a combined design.

is observed (Postman and Phillips, 1965; Glanzer and Cunitz, 1966) whereas for short-term visual memory only a one item recency effect is observed (Phillips and Christie, 1977).

Importantly, the analysis revealed a significant interaction between Object Orientation and Hand of Response [F(1,37) = 4.23, p = .047]. Right-hand responses to objects positioned to be optimally compatible with a right-hand grasp were executed faster (m = 767.28 msecs) than right-hand responses to objects optimally compatible with a left-hand grasp (m = 805.99 msecs). Similarly, left-hand responses to objects positioned to be optimally compatible with a left-hand grasp were executed faster (m = 728.97 msecs) than left-hand responses to objects optimally compatible with a right-hand grasp (m = 736.59 msecs). The interaction is illustrated in Figure 27.

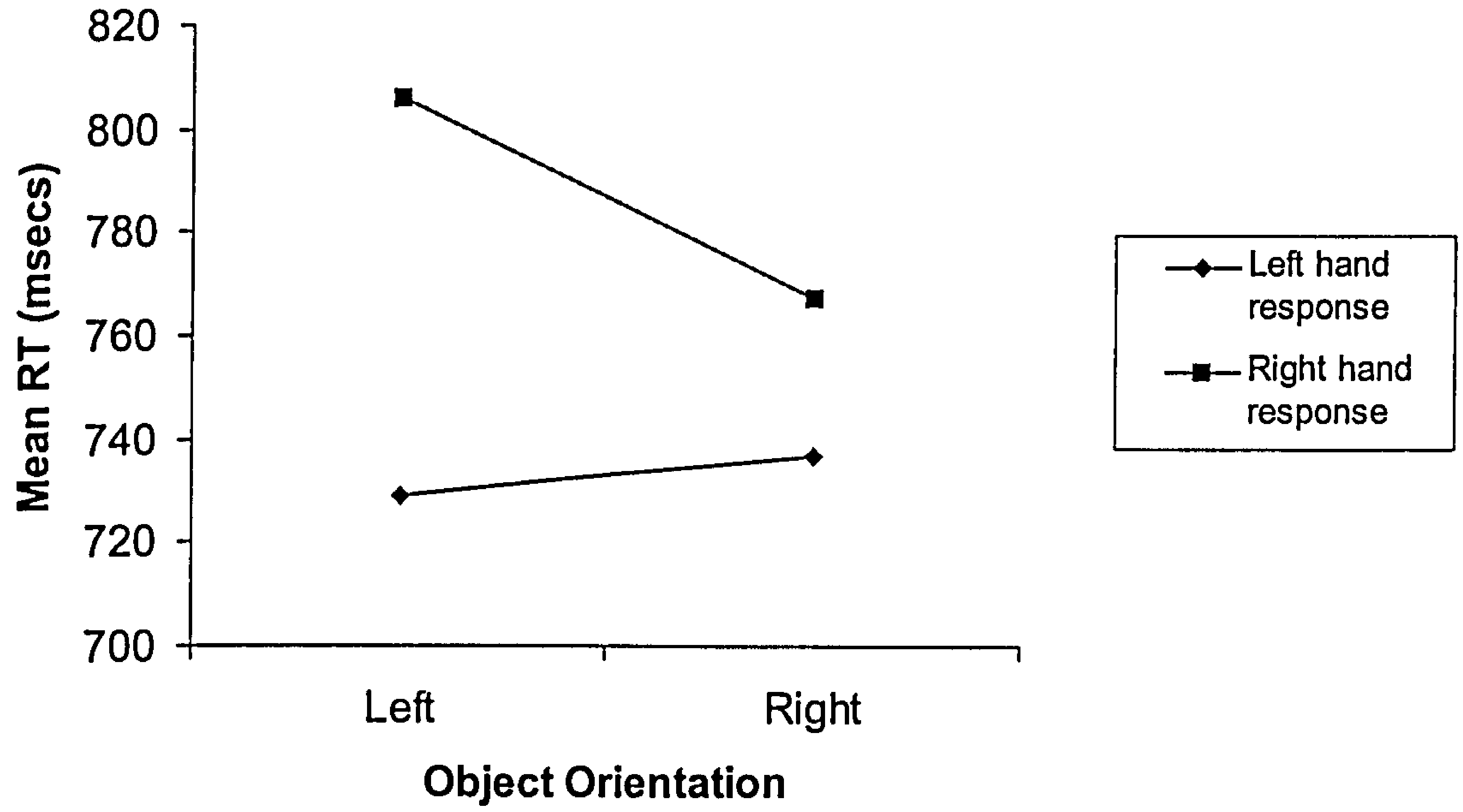

Figure 27
Mean Response Times for Left and Right Hand Responses to Left and Right-oriented Objects

Also of note was the non-significant three-way interaction between Stimulus Position, Object Orientation and Hand of Response [F(3,37) = .143, p = .934]. The absence of a significant three-way interaction suggests that the compatibility effect observed in the

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[23] Note: in order to analyse the 'Yes' responses, the 'Hand of Response' factor becomes a between participants factor.

data was unaffected by the position of the oriented object during presentation of the trial stimuli.

All other effects were shown to be non-significant.

Error Data

The error data from the trials on which participants were asked to respond 'Yes' to a named oriented object are summarised in Table 21 (Appendix CC) and were subjected to a two-way ANOVA (Appendix DD) with the within participants factor of Object Orientation (left and right) and the between participants factor of Hand of Response (left and right)[24].

The analysis revealed a significant main effect of Object Orientation [F(1,35) = 7.092, p = .012], but no main effect of Hand of Response [F(1,35) = .018, p = .893]. In respect of the main effect of Object Orientation the analysis revealed that more errors were made to left-oriented objects (m = 3.19) than to right-oriented objects (m = 2.30). This effect is consistent with the trend in the response data that found that responses to right-oriented objects are executed faster than responses to left-oriented objects.

Importantly, the analysis revealed no interaction between Object Orientation and Hand of Response [F(1,35) = .018, p = .893].

6.2.3.3 Analysis Two

The data were subjected to a second three-way mixed ANOVA (Appendix EE) with the within participants factors of Object Orientation (left and right) and Experiment Half (First and Second halves of the experiment), and the between participants factor of Hand of Response (left and right). A summary of the data can be seen in Table 22 (Appendix FF).

The aim of the analysis this time was to compare the interaction between Hand of Response and Object Orientation both at the beginning and end of the experiment.

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[24] The within participant factor of Stimulus Position was excluded from the analysis on the Error Data as there were insufficient data points for each cell of the design

The analysis revealed a significant main effect of Experiment Half [F(1,37) = 33.98, p<.0001], but once again no significant main effects of Object Orientation [F(1,37) = .007, p = .923] or Hand of Response [F(1,37 = .915, p = .345].

The main effect of Experiment Half revealed that responses in the second half of the experiment were executed significantly faster (m = 710.68 msecs) than responses executed in the first half of the experiment (m = 813.94 msecs). This finding is unsurprising and can be seen to reflect a general learning rule whereby participants' performance improves as they become familiar with the experimental procedure and stimulus set.

Interestingly, in this re-analysis of the data, the interaction between Object Orientation and Hand of Response failed to reach significance [F(1,37) = 2.67, p = .111]. However, it can be noted that in this second analysis the factor of Stimulus Position (one-four) was excluded from the analysis. Nevertheless, there was still a clear suggestion in the data that the interaction was present – right-hand responses to right-oriented objects were executed faster than right-hand responses to left-oriented objects, and left-hand responses to left-oriented objects were executed faster than left-hand responses to right-oriented objects.

Although the three-way interaction between Object Orientation, Hand of Response and Experiment Half, was also non-significant [F(1,37) = 1.15, p = .291], the mean scores for this interaction did suggest a trend in the data which could be of theoretical significance. The data suggest that the two-way interaction between Hand of Response and Object Orientation was stronger in the second half of the experiment than in the first half. The interaction is illustrated in Figures 28 and 29.

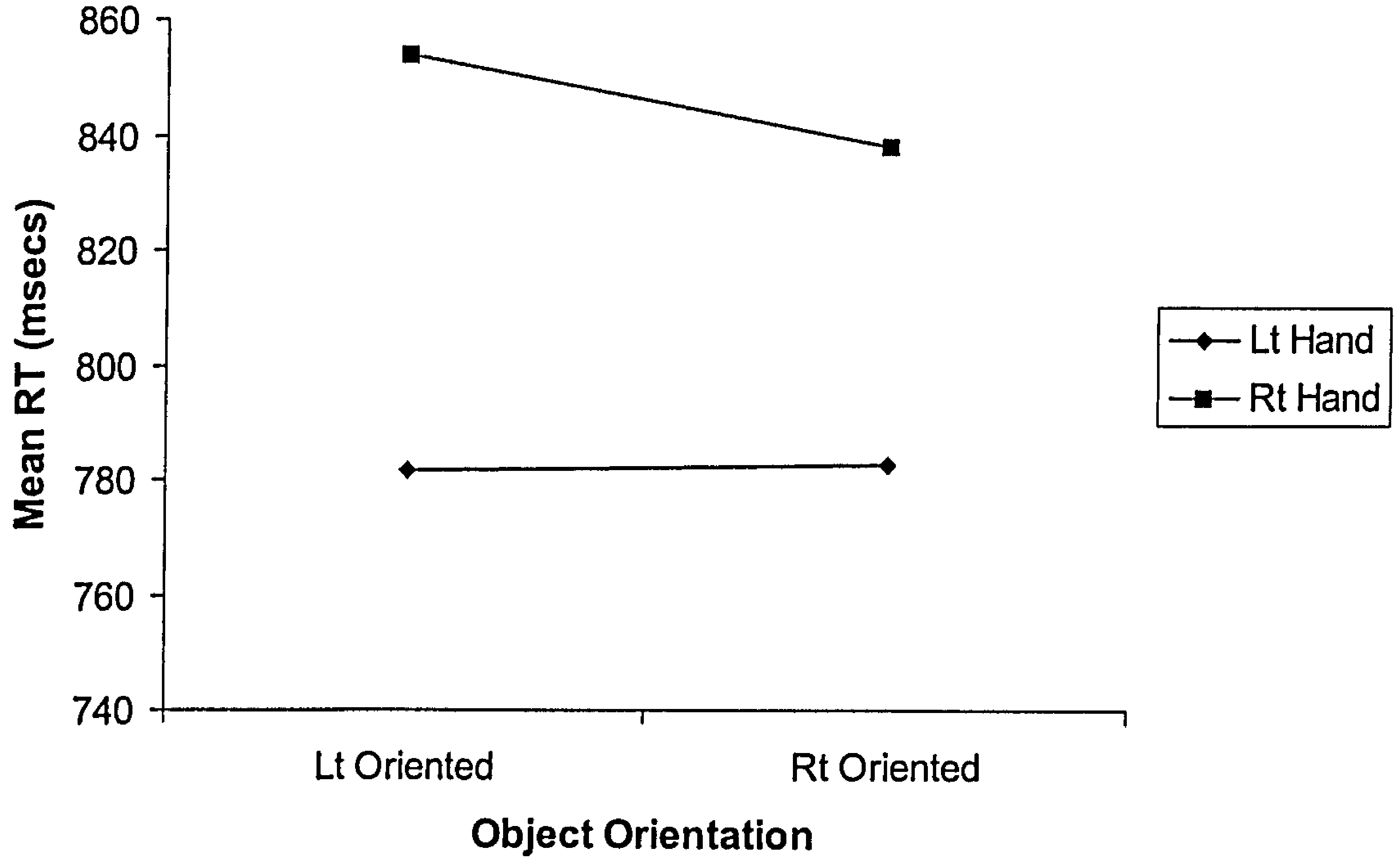

Figure 28
Mean Response Times for Left and Right Hand Responses to Left and Right-oriented Objects in the First Half of the Experiment

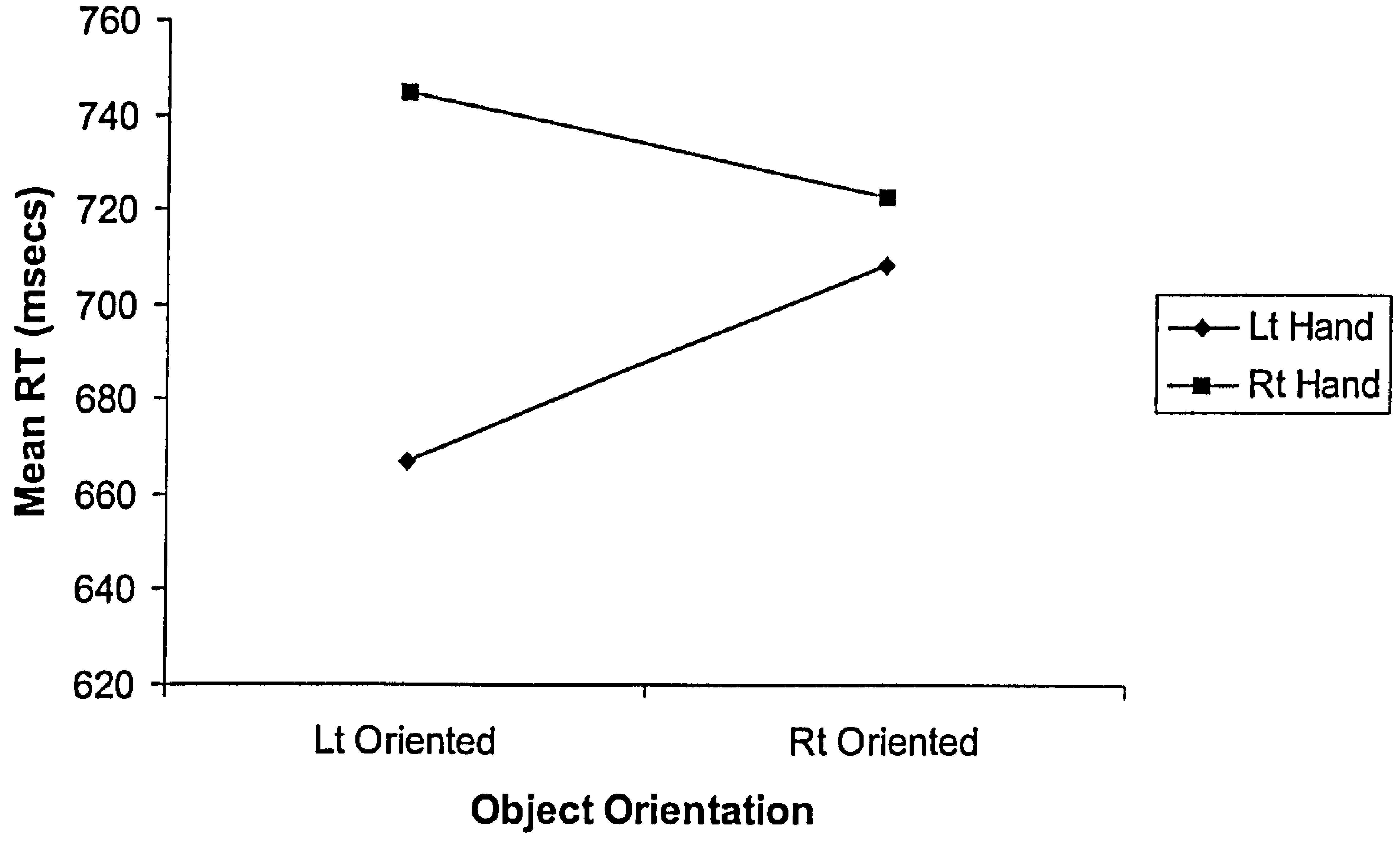

Figure 29
Mean Response Times for Left and Right Hand Responses to Left and Right-oriented Objects in the Second Half of the Experiment

Given that the main effect of Experiment Half suggests that responses in the second half of the experiment were significantly faster than those in the first half of the experiment, the trend observed in the three-way interaction between Hand of Response, Object Orientation and Response Position, could be interpreted as tentative support for Richardson et al's proposal that fast response times are associated with a compatibility effect, and slow response times with an incompatibility effect. It can be observed that where response times were at their fastest (second half of the experiment), there was the clearest indication of a compatibility effect, whereas where response times were at their slowest (first half of the experiment), there was a much weaker indication of a compatibility effect.

No other effects were found to be significant at alpha = .05. However, the two way interaction between Object Orientation and Experiment Half was found to be nearing significance [F(1,37) = 2.02, p = .164]. It can be observed that in the first half of the experiment responses to right-oriented objects were executed faster (m = 810.16 msecs) than responses to left-oriented objects (m = 817.72 msecs), but in the second half of the experiment, responses to left-oriented objects were executed faster (m = 705.71 msecs) than responses to right-oriented objects (m = 715.66). The interaction is illustrated in Figure 30.

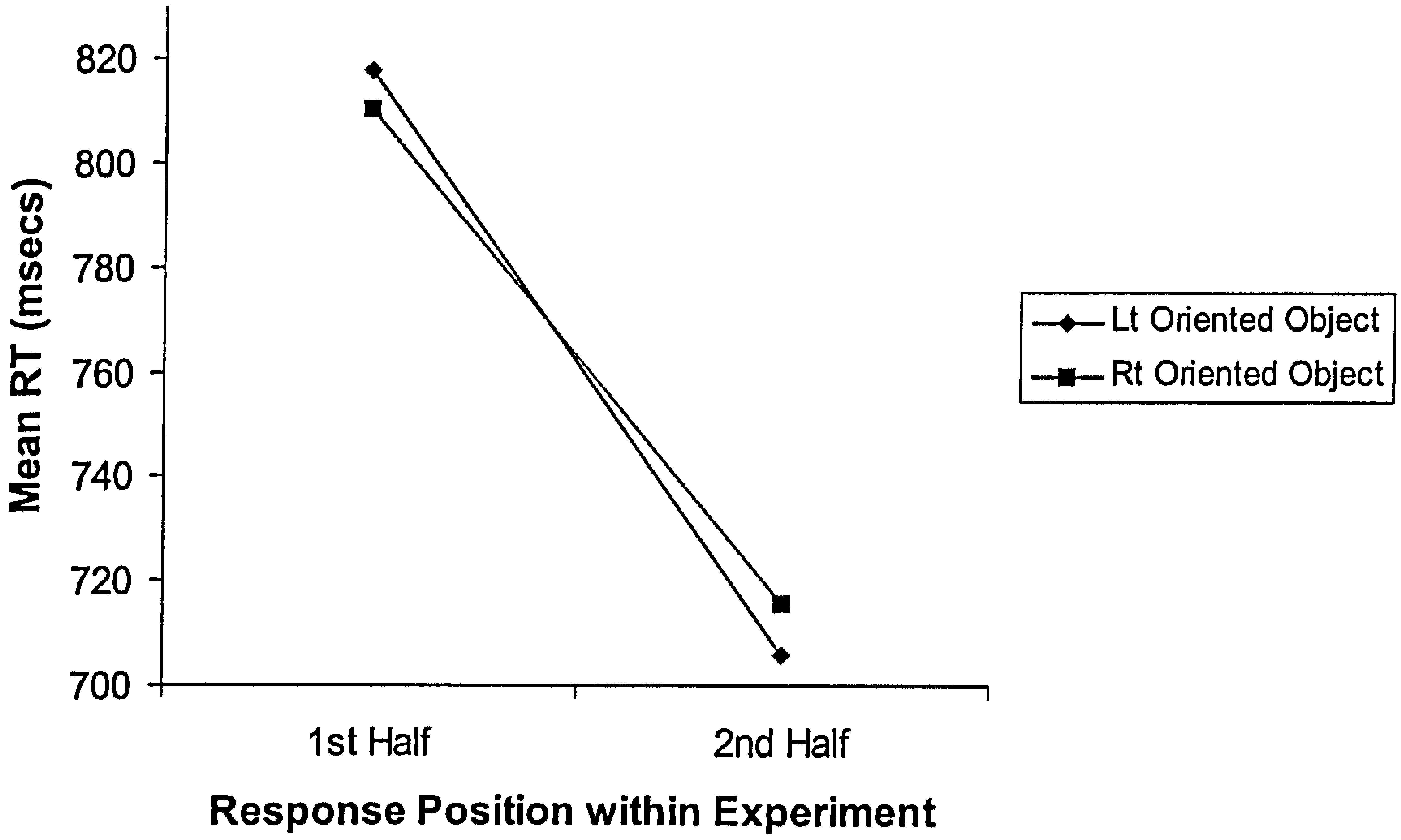

Figure 30
Mean Response Times to Left and Right-oriented Objects in the First and Second Halves of the Experiment

Although no immediate explanation can be offered for the interaction between Object Orientation and Experiment Half, the pattern of results appears to coincide with a change in other effects observed over the time-course of the experiment. Firstly, overall response times were significantly faster in the second half of the experiment than the first half, and secondly, the data suggest a stronger compatibility effect in the second half of the experiment than in the first half. We will return to a possible explanation of this interaction later in the chapter.

6.2.4 Discussion

The data from Experiment Six confirm the presence of micro-affordance effects arising from compatibility between the orientation of an optimally oriented object for grasping and hand of response, in off-line vision. Consistent with data from experiments investigating seen objects (Tucker and Ellis, 1998), the first analysis carried out on the response time data confirm that right-hand responses to right-oriented objects were executed faster than right-hand responses to left-oriented objects and left-hand responses to left–oriented objects were executed faster than left-hand responses to right-oriented objects. It was further observed that the absence of a three-way interaction in this analysis between Stimulus Position, Object Orientation and Hand of Response showed that the time between stimulus presentation and response did not appear to affect the presence of the compatibility effect. However, in contrast to the findings for seen objects, no evidence of the micro-affordance effects was observed in the error data.

The results of Experiment Six can be contrasted sharply with those of Experiments Three and Four, reported earlier in this thesis. As discussed in the introduction to this chapter it can be argued that due to the design of the earlier studies participants were not directly accessing short-term visual memory. As such it is further argued that participants were unable to utilize the viewer centred visual representations thought necessary for the expression of micro-affordance effects arising from the orientation of an object for grasping, and thought to be held in short-term visual memory.

The results of Experiment Six can also be contrasted with the results of a similar experiment reported by Richardson et al (in preparation). In that experiment an 'incompatibility' effect was observed in the data. Right-hand responses to left-oriented objects were executed faster than right-hand responses to right-oriented objects and vice versa. In that study it was argued that the incompatibility was a result of the relatively slow response times. Analysis of the data into fast and slow response times confirmed that when participants produce relatively fast response times a compatibility effect can be observed. The average response times from Experiment Six appear to support this proposal. The average response time in Experiment Six was 762.37 msecs, whereas the average response time in the Richardson et al study was approximately 1500 msecs. Further evidence to support the proposal also arose from the second analysis carried out on the response time data from Experiment Six. Although non-significant the three-way interaction between Experiment Half (first and second halves of the experiment), Hand of Response and Object Orientation, did seem to suggest that the compatibility effect was more apparent in the second half of the experiment, where response times were significantly faster, than in the first half of the experiment.

A second point of interest to arise from Experiment Six was the interaction between Experiment Half and Object Orientation. Although non-significant the data seemed to suggest that in the first half of the experiment responses to right-oriented objects were executed faster than responses to left-oriented objects, but in the second half of the experiment the pattern was reversed. This finding is of interest as elsewhere in this thesis it has been argued that participants may have encodings of prototype-oriented objects in long-term memory that could give rise to main effects of object orientation. It was further argued that for predominately right-hand individuals this prototype would reflect a right-orientation superiority effect. The analysis of the data from Experiment Six seems to support this view as right-oriented objects were responded to both faster and more accurately than left-oriented objects. However, the finding that left-oriented objects appeared to be responded to faster in the second half of the experiment suggests that just as compatibility and incompatibility effects are affected by response times so might the expression of the main effect of object orientation. Surprisingly, the superiority effect for right-oriented objects appears to be associated with slow response times (first half of the experiment) whereas the superiority effect for left-oriented objects is associated with faster response times (second half of the experiment). Discussion of possible causes for the reversal of the orientation effects is reserved until later in this chapter.

Although the compatibility effect observed in Experiment Six could be attributed to a difference in overall average response times between this study and the Richardson et al experiment, the two experiments differ in a number of other ways. Firstly, participants in Experiment Six were presented with four object images on each trial, whereas in the Richardson et al study participants were presented with eight object images on each trial. Secondly, participants in Experiment Six viewed each object for a period of one second, whereas in the Richardson et al study, each object was viewed for a period of 200 milliseconds.

In order to explore further the potential effect of these two factors, participants in Experiment Seven were again presented with four object images on each trial, but this time with a stimulus processing time of 200 msecs for each image.

6.3 Experiment Seven

6.3.1 Introduction

In the last experiment, evidence was presented for micro-affordance effects arising from the compatibility of an oriented object for grasping and hand of response when participants made a response to the short term visual memory, or the visual mental image, of an object. In this experiment further evidence is sought for this effect. However, this time evidence is also sought to establish whether or not stimulus-processing time affects the expression of these effects. As we saw in the last experiment, participants viewed each object image for a period of one second, whereas in this experiment participants view each image for a period of 200 milliseconds.

Experiment Seven again aims to identify the presence of the micro-affordance effects over the time course of the experiment, by comparing responses made in the first half of the experiment with those made in the second half of the experiment. In addition, the experiment also aims to examine the presence of micro-affordances over a longer time period. In order to achieve this aim Experiment Seven is run in conjunction with Experiment Eight. Half the participants are presented with Experiment Seven immediately before Experiment Eight and half the participants with Experiment Seven immediately after Experiment Eight. It should be noted that although Experiment Eight differs from experiment Seven in terms of the number of object images presented on each trial, all other factors remain constant.

Finally, Experiment Seven also seeks to establish whether or not viewing an oriented object on each trial affects participant responses to named objects which are not optimally oriented for grasping by either hand and participant responses to named objects which do not appear in the object array on each trial. In order to investigate this idea data is collected and analysed for both trials on which participants respond to a named non-oriented object, and those on which participants make a "no" response to declare that the named object was not present. It is argued that in order to make a correct response participants must access the visual memory for all objects presented on a trial.

6.3.2 Method

Participants

Sixty participants from the University of Plymouth took part in the experiment. All participants had normal motor function in both hands and normal or corrected to normal vision. Each received course credit for participating in the experiment.

Apparatus and Materials

The stimulus set was identical to that used in Experiment Six (see Appendix x for a list of all objects). The pictures were viewed on a 19" monitor at a distance of approximately 50 cms. The objects subtended an angle of between 6.3 and 18.18 degrees (Appendix B).

Participants' responses the reaction time tasks were recorded on the specially designed hand device used in the previous experiments.

Design

The experiment comprised 200 trials. On each trial participants were presented with four photographs. Three of the photographs depicted objects from the list of objects with no optimal orientation for grasping by a particular hand, and one photograph that depicted an object from the list of 50 orientated objects. No object appeared twice on the same trial. The object images used for inclusion on each trial were taken at random from the object lists according to the above criteria.

Participants were shown the named 'target' object on half the trials. This resulted in 100 occasions on which the participants responded "Yes" (object present) to the task, and 100 trials on which the participants responded "No" (object not present). Of the 100 trials on which the named target object was present, 40 trials identified an object with no specific orientation for grasping by a particular hand, and 60 trials identified an object with an optimal orientation for grasping by a particular hand. Of the 60 trials where the object had an optimal orientation for grasping, 30 pictures contained objects oriented to be optimally compatible with a left-hand grasp and 30 pictures contained objects oriented to be optimally compatible with a right-hand grasp. This resulted in 30 trials where there was a compatibility relationship between orientation of the object and hand of response and 30 trials in which there was an incompatible relationship between orientation of the object and hand of response.

In order to ensure a balanced design the order of presentation of "trial type" (target object present/ target object not present/orientated object/non-orientated object) was randomised independently for each participant. In addition, half the participants were assigned to a mapping condition in which they responded with their left-hand for "Yes" responses (object present) and right hand for "No" responses (object not present) and the remaining participants to a mapping condition with the reverse instructions. Experiment Seven was run in conjunction with Experiment Eight, therefore half the participants completed Experiment Seven before Experiment Eight, and half completed Experiment Seven after Experiment Eight.

Procedure

On each trial participants were presented with a message informing them to prepare for presentation of the stimulus. After 200 milliseconds the message disappeared and a series of four pictures were presented on the screen, each for a period of 200 msecs. After the fourth picture was removed from the screen a blank screen appeared. After a further one second the name of an object appeared in the middle of the screen. Participants then pressed either the switch held in their left-hand or in their right-hand depending on whether or not they remembered seeing the named object. Error trials resulted in a bleep from the computer

Having made a response participants were instructed to prepare for the next trial. All participants were presented with written instructions (Appendix GG) and completed five practice trials before commencement of the main experiment.

6.3.3 Results

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment. The mean error rate was calculated at 40.95[25] (St Dev 13.93). Four participants were excluded from the analysis on the basis of this criterion. The data generated in Experiment Seven was separated into three data sets for analysis. The first data set comprised "Yes" (object present) responses for which participants responded to a named object which was optimally oriented for grasping by either a left or right-hand grasp. This data set is comparable to the data set analysed in Experiment Six. As in Experiment Six this data set was subjected to two separate analyses. Once again the aim of the first analyses was to seek evidence for micro-affordance effects arising from the relationship between an oriented object for grasping and hand of response and to see whether this was affected by position of stimulus presentation (first, second, third and last image presented). In addition, the analysis also aimed to identify the effect of presenting the experiment after another similar experiment (Experiment Eight) to see whether or not familiarity over time with the stimulus set and procedure would affect the expression of micro-affordance effects. Similarly, as in Experiment Six, the aim of the second analyses was to investigate the expression of the micro-affordance effects over the time course of the experiment (first and second halves of the experiment).

The second data set comprised "Yes" (object present) responses for which participants responded to a named object viewed on each trial that had no optimal

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[25] Number of errors in 200 trials

orientation for grasping by either hand. The aim of the analysis carried out on this data set was to investigate whether the oriented object present on each trial had an effect on responses to non-oriented objects on each trial.

Finally, the third data set comprised "No" (object not present) responses to a named object whose image does not appear on that trial[26]. As with the data from the second data set above, the aim of the analyses carried out on this data was to investigate whether or not the oriented object present on each trial had an effect on responses to named objects that were not present on each trial.

6.3.1.1 Analysis of "Yes" Responses to named Oriented Objects

The data from the "Yes" trials in which participants were asked to respond to an oriented object were separated from the rest of the data for analysis. Error trials and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Error trials accounted for 20.3 % of response trials, while reaction times greater than two standard deviations accounted for 2.3% of response trials. The data was subjected to two separate sub-analyses (see above).

6.3.1.1.1 Analysis One

Response Time Data

The data were subjected to a four-way mixed ANOVA (Appendix HH) with the within participants factors of Object Orientation (left and right) and Order of Stimulus Position (one to four), and the between participants factors of Hand of Response (left and right) and Order of Experiment Presentation (Exp7-Exp8 / Exp8-Exp7)[27]. A summary of the data can be seen in Table 23 (Appendix II).

The analysis revealed a significant main effect of Stimulus Position [F(3,156) = 9.71, p<.0001], but no main effects of: Object Orientation [F(1,52) <.001, p = .986]; Hand of Response [F(1,52) = .357, p = .553]; or Order of Experiment Presentation [F(1,52) = .102,

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[26] All named objects come from the same stimulus list.

p = .751]. As in Experiment Six, the main effect of Stimulus Position suggests the presence of a primacy and recency effect. The data show that responses to the final images presented on each trial (position four) were executed faster (m = 726.27 msecs) than responses to images at position three (m = 786.09 msecs) and responses to images presented at position one were executed slightly faster (m = 810.39 msecs) than responses to images presented at position two (m = 822.57 msecs). However, consistent with the findings of Experiment Six a follow-up analysis (Appendix JJ) revealed that only the recency effect is significant (T(156) = 55.29, p<.05). Again this finding is consistent with the one item recency effect observed in other short-term visual memory experiments (Phillips and Christie, 1977).

Importantly, the analysis revealed no significant interactions between: Hand of Response and Object Orientation [F(1,52) = .483, p = .490].

The only significant interaction was observed between Object Orientation and Order of Experiment Presentation [F(1,52) = 4.23, p = .045]. It can be observed that when Experiment Seven was run before Experiment Eight, responses to right-oriented objects were executed faster (m = 783.41) than responses to left-oriented objects (m = 805.06). However, when Experiment Seven was run after Experiment Eight, responses to left-oriented objects were executed faster (m = 767.41) than responses to right-oriented objects (m = 789.45). The interaction can be observed in Figure 31. It can be seen that this interaction reflects a similar pattern of interaction observed over the time course of Experiment Six. In that experiment it was observed that when data from the first and second halves of the experiment were compared, responses to right-oriented objects were executed faster than responses to left-oriented objects in the first half of the experiment, but in the second half of the experiment the effect was reversed – responses to left-oriented objects were executed faster than responses to right-oriented objects.

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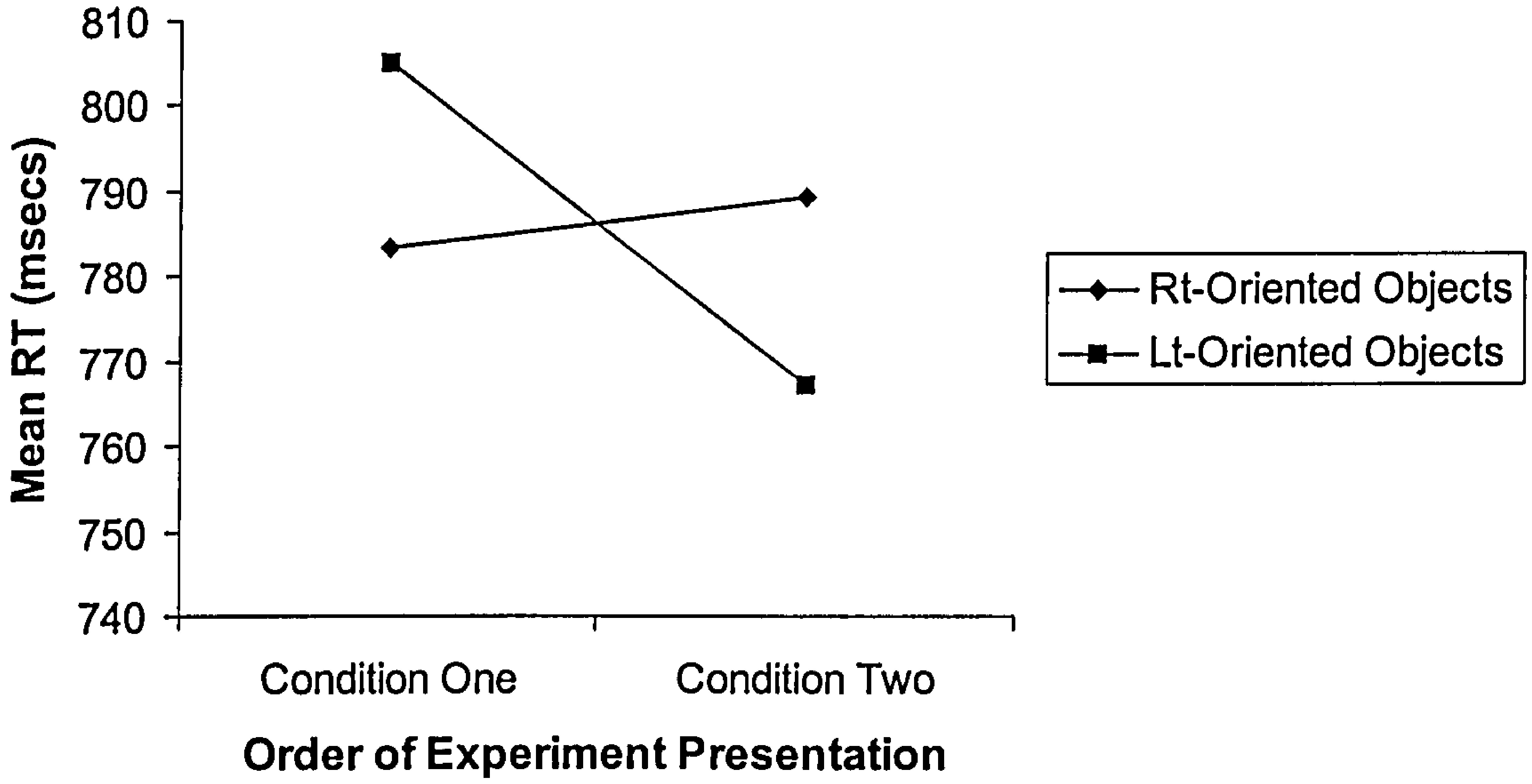
[27] Experiment Seven was run alongside Experiment Eight. Half the participants received Experiment Seven followed by Experiment Eight with the remaining participants receiving the reverse order of presentation.

A possible explanation for this effect is reserved until the General Discussion at the end of this chapter.



Condition One = Experiment Seven followed by Experiment Eight
Condition Two = Experiment Eight followed by Experiment Seven

Figure 31
Mean Response Times to Right and Left-oriented Objects when Experiment Seven was run both Before and After Experiment Eight

Error Data

Due to the limited number of errors, the Stimulus Position factor was left out of the analysis. Analysis of the error data, which examines the Hand of Response, Object Orientation and Order of Experiment Presentation factors, is reported at the end of Section 6.3.1.1.2, below.

6.3.1.1.2 Analysis Two

The data were subjected to a four-way mixed ANOVA (Appendix KK) with the within participants factors of Object Orientation (left and right) and Experiment Half (first and second halves of the experiment) and the between participants factors of Hand of Response (left and right) and Order of Experiment Presentation (Exp7-Exp8 / Exp8-Exp7). A summary of the data can be seen in Table 24 (Appendix LL).

Once again the analysis revealed no significant main effects of Hand of Response [F(1,52) = .144, p = .706], Object Orientation [F(1,52) = .161, p = .690] or Order of Experiment Presentation [F(1,52) = .208, p = .651]. However, the analysis did reveal a significant main effect of Experiment Half (First and Second halves of the experiment) [F(1,52) = 10.76, p = .002]. The data show that participants' responses were executed significantly faster in the second half of the experiment (m = 760.70) compared to the first half of the experiment (m = 807.82). As in Experiment Six, this result is unsurprising and can be explained with reference to a general learning effect whereby participants' performance improves as they become more familiar with the task procedure and stimulus set.

Importantly, the analysis again revealed no significant interactions between Hand of Response and Object Orientation [F(1,52) = .938, p = .337] .

The only significant interactions to arise from the analysis were observed between Order of Experiment Presentation and Experiment Half [F(1,52) = 6.51, p = .014] and again between Object Orientation and Order of Experiment Presentation [F(1,52) = 5.49, p = .023].

The interaction between Object Orientation and Order of Experiment Presentation is consistent with that observed in the first analysis carried out on this data set. Responses to right-oriented objects were executed faster when Experiment Seven was run before Experiment Eight, but responses to left-oriented objects were executed faster when Experiment Seven was run after Experiment Eight.

In respect of the significant interaction between Order of Experiment Presentation and Experiment Half, the data reveal a bigger decrease in response times between the first and second halves of the experiment when Experiment Seven was run before Experiment Eight (First Half: m = 837.86 – Second Half: m = 754.09), than when it was run after (First Half: m = 777.78 – Second Half: m = 767.31). This interaction can be seen to reflect the general learning rule whereby the rate of learning decreases over time as it reaches asymptote.

No other interactions were found to be significant. However, the three-way interaction between Object Orientation, Order of Experiment Presentation and Experiment Half was nearing significance [F1,52) = 2.13, p = .150]. The data suggest that when Experiment Seven was run before Experiment Eight a two-way interaction occurred between Object Orientation and Experiment Half. In the first half of the experiment responses to right-oriented objects were executed faster (m = 819.65) than responses to left-oriented objects (m = 856.07). However in the second half of the experiment the reverse is the case, responses to left-oriented objects were executed slightly faster (m = 752.68) than responses to right-oriented objects (m = 755.50). However, when Experiment Seven was run after Experiment Eight, no two-way interaction between Object Orientation and Experiment Half appeared to be present. In both halves of the experiment responses to left-oriented objects were executed faster (m= 762.46 and m=758.90, respectively) than responses to right-oriented objects (m= 793.10 and m= 775.72, respectively). The three-way interaction is illustrated in Figures 32 and 33. It can be seen that the two-way interaction between Object Orientation and Experiment Half which occurred when Experiment Seven was run before Experiment Eight is consistent with the interaction between Object Orientation and Experiment Half observed over the time-course of Experiment Six.

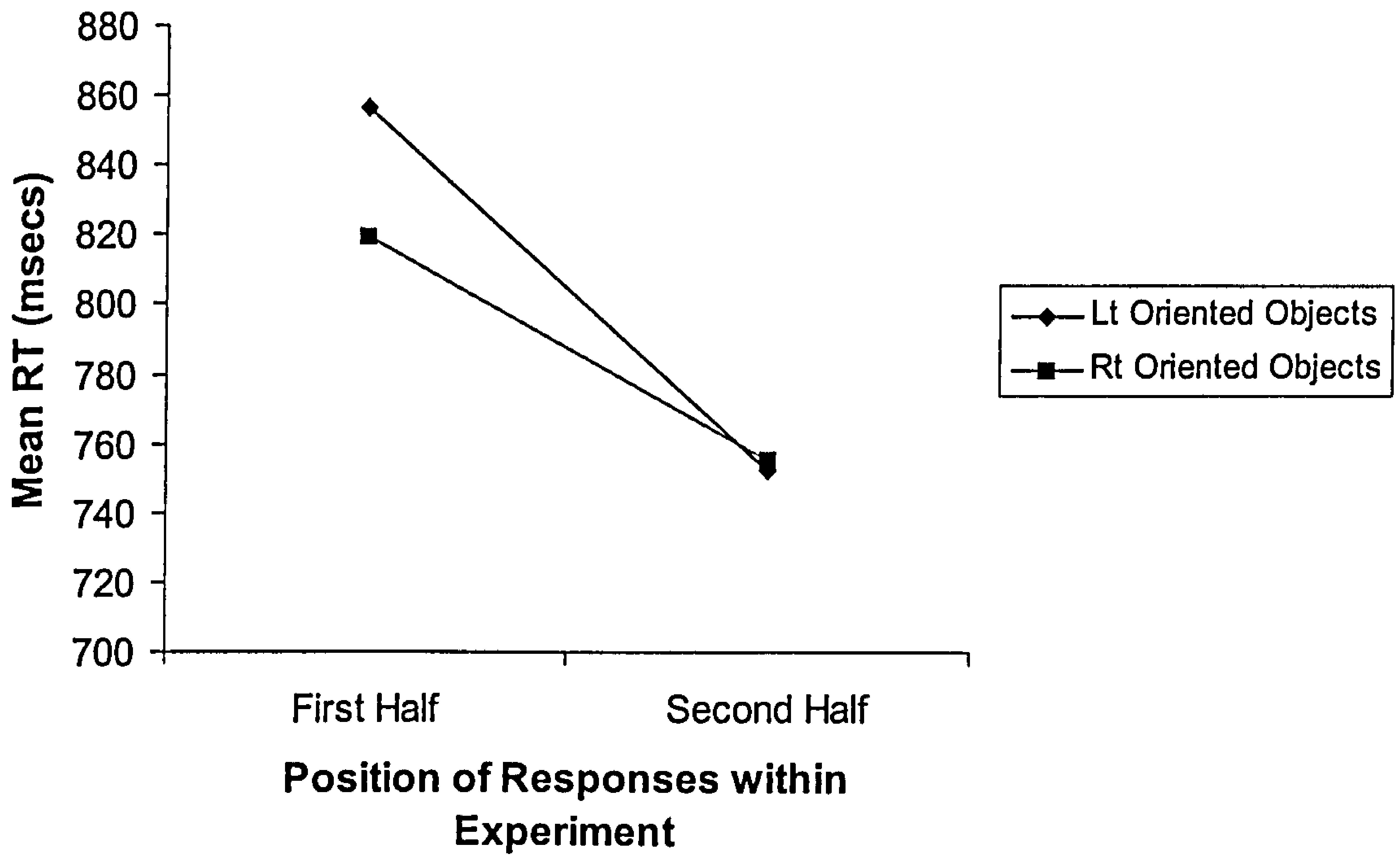


Figure 32
Mean Response Times to Left and Right-oriented Objects in the First and Second Halves of the Experiment when Experiment Seven was run before Experiment Eight

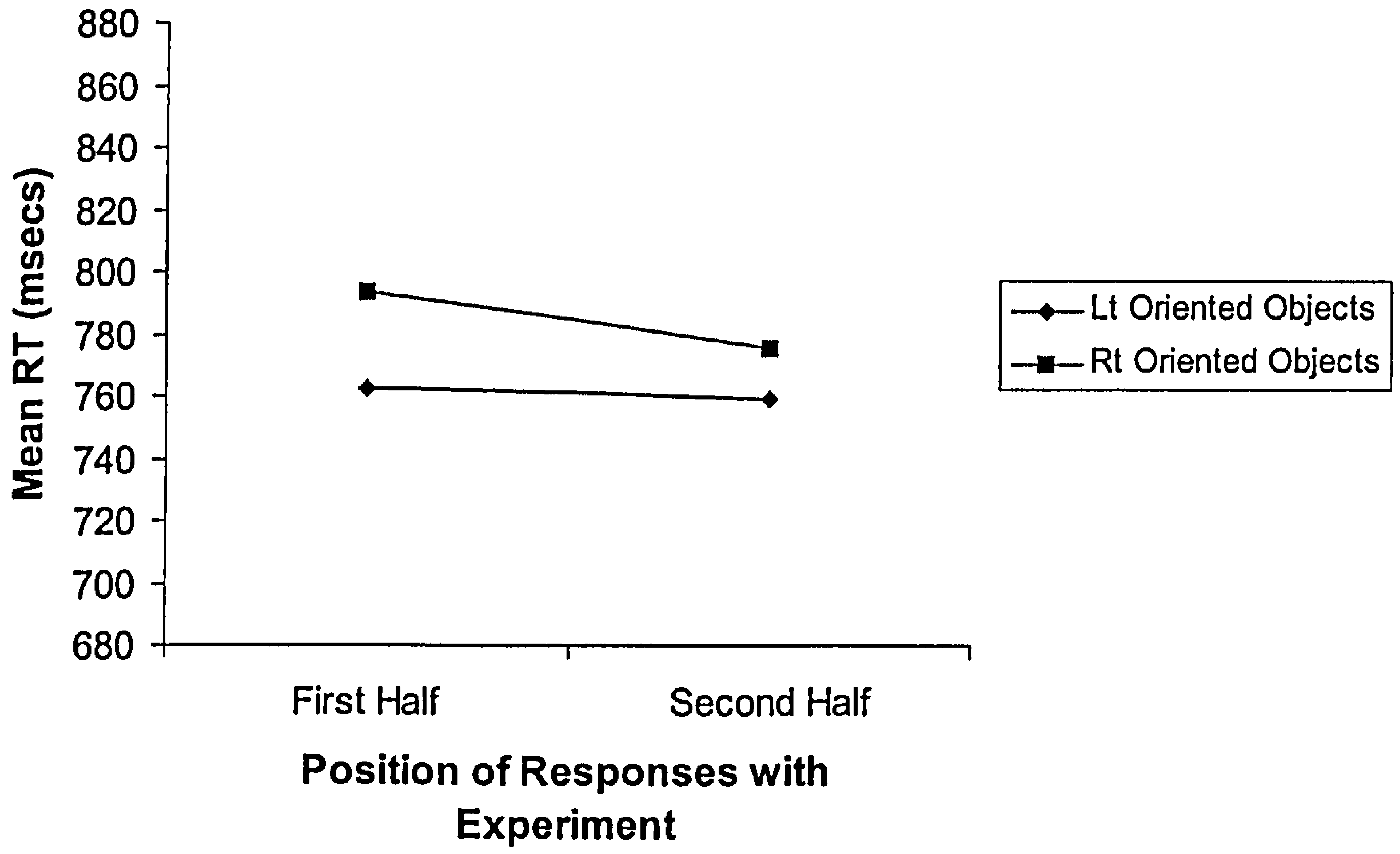


Figure 33
Mean Response Times to Left and Right-oriented Objects in the First and Second Halves of the Experiment when Experiment Seven was run after Experiment Eight

Error Data

The error data for "Yes" responses to oriented objects were subjected to a four-way mixed ANOVA (Appendix MM) with the within participant factors of Object Orientation (left and right) and Experiment Half (first and second halves of the experiment), and the between participant factors of Hand of Response (left and right), and Order of Experiment (Exp7-Exp8 /Exp8-Exp 7)[28]. A summary of the data is shown in Table 25 (Appendix NN).

The analysis revealed no significant main effects in any of the data: Object Orientation [F1,51) = .103, p = .750]; Hand of Response [F(1,51) = .393, p = .533]; Experiment Half [F(1,51) = 1.12, p = .295] and Order of Experiment Presentation [F(1,51) = 1.50, p = .226].

Importantly, the analysis revealed no significant interaction between Hand of Response and Object Orientation [F(1,51) = 2.22, p = .142], although the data suggest the presence of an incompatibility effect. In the right-hand response condition more errors were made to right-oriented objects (m = 3.23) than to left-oriented objects (m = 2.82). But in the left-hand response condition slightly more errors were made to left-oriented objects (m = 3.51) than to right-oriented objects (m = 3.24). The interaction is illustrated in Figure 34.

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[28] As in Experiment Six the Stimulus position factor was excluded from the analysis as there were insufficient errors for each cell of the design.

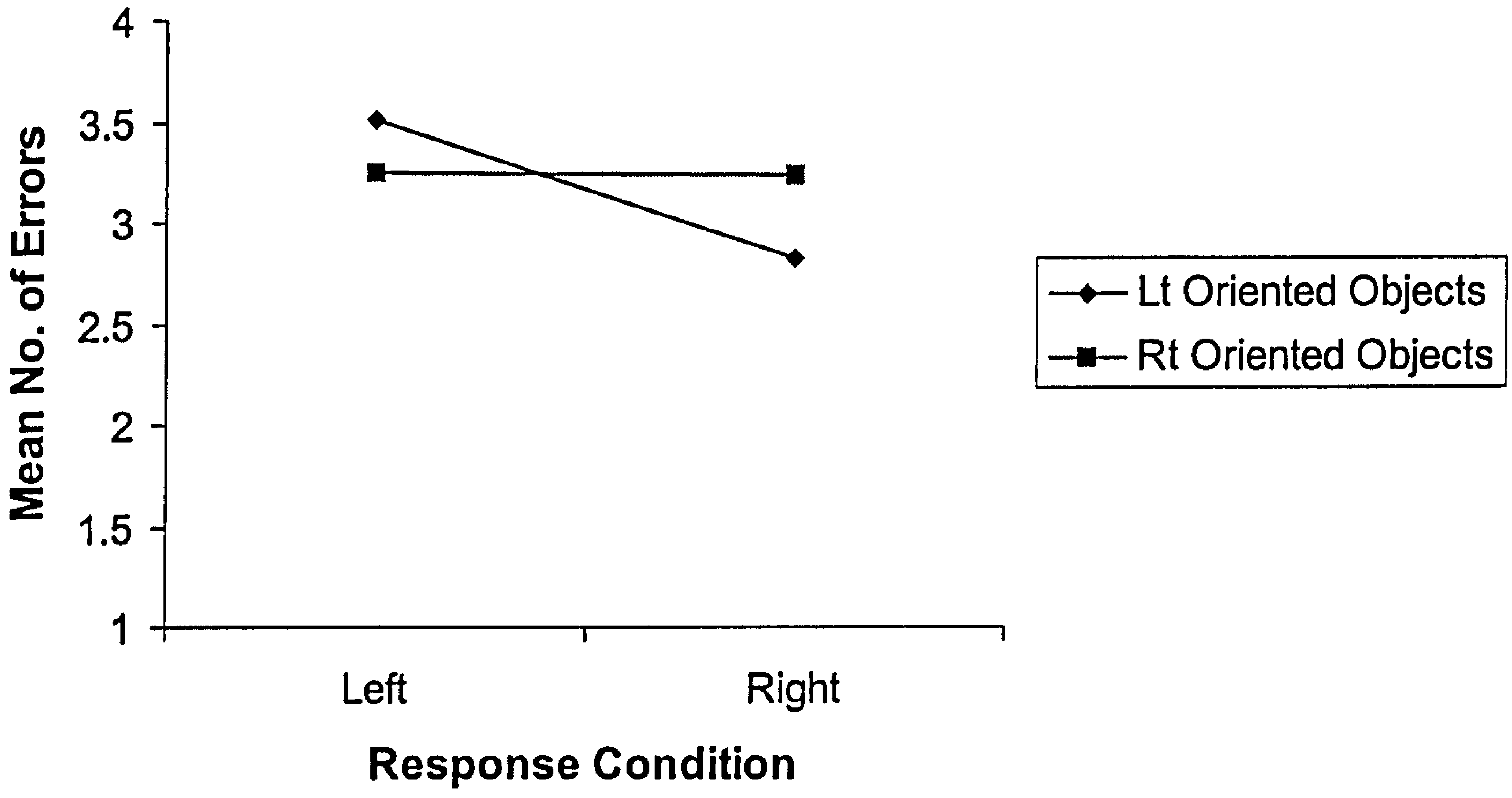

Figure 34
Mean Number of Errors for Left and Right Hand Responses to Left and Right-oriented Objects

The only effect to reach significance was an interaction between Experiment Half (First and Second halves of the experiment) and Hand of Response [F(1,51) = 4.82, p = .033]. The analysis revealed that in the first half of the experiment the left-hand response condition produced more errors (m = 3.53) than the right-hand response condition (m = 2.57), but in the second half of the experiment right-hand response condition produced slightly more errors (m = 3.48) than left-hand response condition (m = 3.21). The presence of this interaction can be interpreted as an effect of right-hand dominance in the majority of participants. Due to right-hand dominance of participants, responses in the first half of the experiment would be faster than left-hand responses. However, at the same time they could also be more inaccurate resulting in more errors in the left-hand response condition. However, later in the experiment (second half of the experiment) practice effects would mean that right-hand responses would become more accurate, while at the same time left-hand responses would become faster due to practice effects but also more inaccurate.

All other effects were found to be non-significant.

6.3.1.2 Analysis of "Yes" Responses to Named Non-oriented Objects

The aim of this analysis was to look at the effects of having an oriented object in the stimulus set when participants made a "Yes" response to the name of a non-oriented object contained in the stimulus set.

The data from the trials in which participants were asked to respond to a non-oriented object were separated from the rest of the data for analysis. Error trials and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Error trials accounted for 20.38% of response trials, while reaction times greater than two standard deviations accounted for 4.1% of response trials.

Response Time Data

The data were subjected to a three-way mixed ANOVA (Appendix OO) with the within participants factor of Object Orientation[29] (left and right) and the between participants factors of Hand of Response (left and right) and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 26 (Appendix PP).

The analysis revealed no significant effects in any of the data. However, mean response times did suggest an incompatibility effect between Hand of Response and Object Orientation. Left-hand responses to trials containing right-oriented objects were executed faster (m = 795.30 msecs) than left-hand responses to trials containing left-oriented objects (m = 810.23 msecs), and right-hand responses to trials containing left-oriented objects were executed slightly faster (m = 828.52 msecs) than right-hand responses to trials containing right-oriented objects (m = 830.12 msecs), [F(1,52) = 1.11, p = .297]. Although this effect is clearly non-significant, the result is highlighted as the suggested trend is seen to re-occur across analyses for the experiments and data sets described in this chapter. Further, the effect is of theoretical importance as it suggests that the presence of an

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[29] One object in each trial was positioned at an optimal orientation for either a left or right hand grasp.

oriented object on a trial on which participants respond to a non-oriented object could affect participants' action responses.

Error Data

The error data were subjected to a three-way mixed ANOVA (Appendix QQ) with the within participants factor of Object Orientation (left and right) and the between participants factors of Hand of Response and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 27 (Appendix RR).

Consistent with the analysis of the response time data, the mean number of errors suggested an incompatibility effect between Hand of Response and Object Orientation. In the left-hand response condition slightly more errors were made on trials containing left-oriented objects (m = 4.19) than on trials containing right-oriented objects (m = 4.17), and in the right-hand response condition more errors were made on trials containing right-oriented objects (m = 4.80) than on trials containing left-oriented objects (m = 3.93). However, the effect was again shown to be non-significant [F(1,52) = .885, p = .351]. No other effects were found to be significant.

6.3.1.3 Analysis of "No" Responses

The data from the "No" trials were separated from the rest of the data for analysis. Error trials and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Error trials accounted for 16.77 % of response trials, while reaction times greater than two standard deviations accounted for 4.45% of response trials.

Response Time Data

The data were subjected to a three-way mixed ANOVA (Appendix SS) with the within participants factor of Object Orientation (left and right) and the between participants factors of Hand of Response and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 28 (Appendix TT).

The analysis revealed no significant effects in any of the data (alpha = .05). However, it is interesting to note the pattern of data for the three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation [F(1,52) = 1.91, p = .173]. The data suggest that when Experiment Seven was run before Experiment Eight, right-hand responses to trials containing left-oriented objects were executed faster (m = 840.70 msecs) than right-hand responses to trials containing right-oriented objects (m = 843.91 msecs), and left-hand responses to trials containing right-oriented objects were executed faster (m = 902.06 msecs) than right-hand responses to trials containing left-oriented objects (m = 911.70 msecs). When Experiment Seven was run after Experiment Eight the reverse pattern could be observed. Right-hand responses to trials containing right-oriented objects were executed faster (m = 828.15 msecs) than right-hand responses to trials containing left-oriented objects (m = 839.66 msecs) and left-hand responses to trials containing left-oriented objects were executed faster (m = 854.84 msecs) than left-hand responses to trials containing right-oriented objects (m = 862.23 msecs). The three-way interaction is illustrated in Figures 35 and 36.

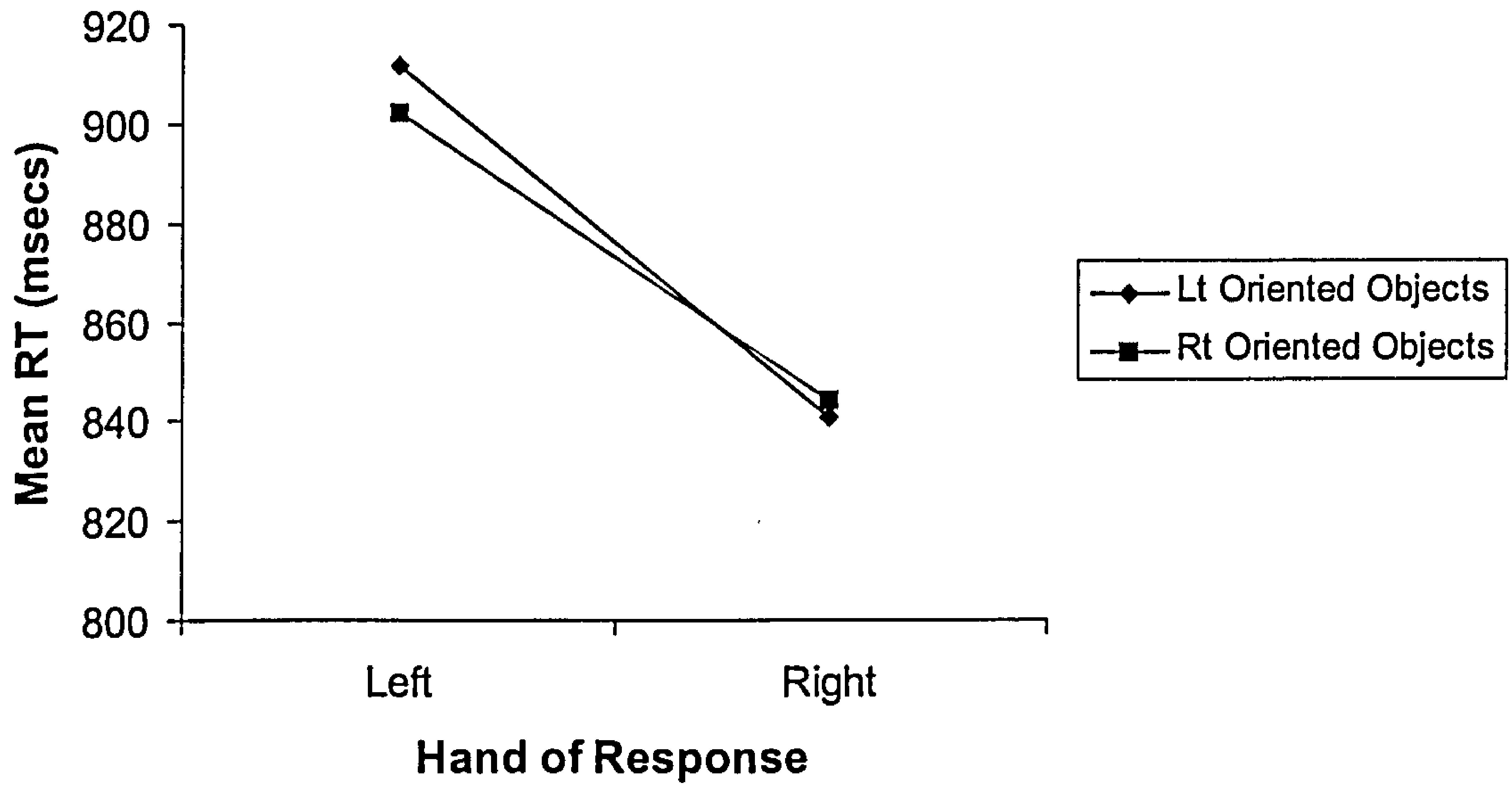

Figure 35
Mean Response Times for Left and Right Hand Responses to Left and Right-oriented Objects when Experiment Seven was run before Experiment Eight

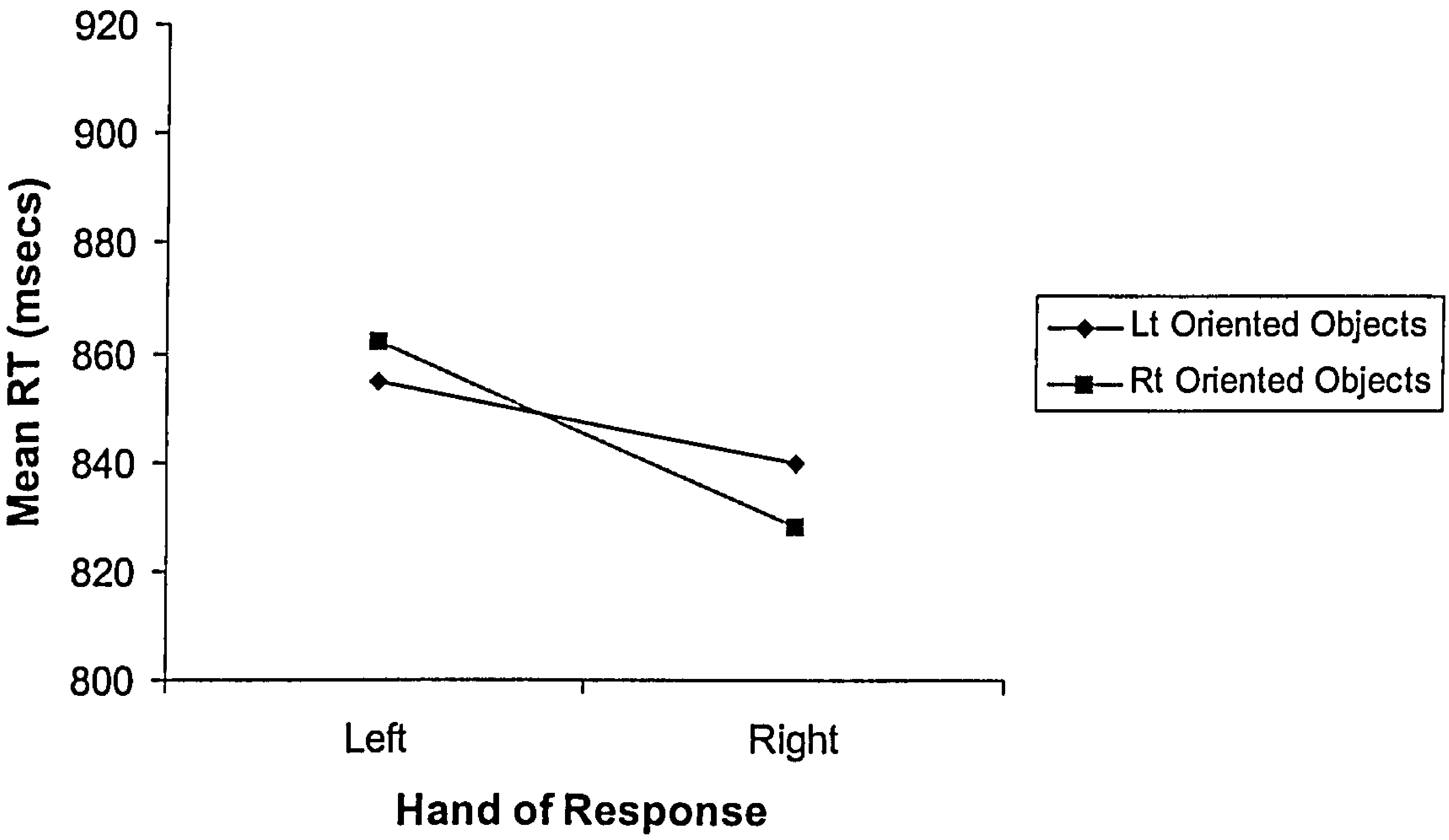

Figure 36
Mean Response Times for Left and Right Hand Responses to Left and Right-oriented Objects when Experiment Seven was run after Experiment Eight

The three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation can be interpreted as an incompatibility effect when Experiment Seven was run before Experiment Eight and a compatibility effect when it was run after Experiment Eight. Once again this effect is clearly non-significant, but the trend cannot be ignored as it is repeated in analyses across experiments and data sets reported in this chapter. Further, the results are of theoretical importance as they suggest that the presence of an oriented object on a trial on which participants were making a "No, object not present response" could affect the participant's action response.

Error Data

The error data was subjected to a three-way mixed ANOVA (Appendix UU) with the within participants factor of Object Orientation (left and right) and the between participants factors of Hand of Response and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 29 (Appendix VV).

Importantly, the analysis revealed no interactions between Object Orientation and Response Condition [F(1,52) = .213, p = .647] or between Object Orientation Response Condition and Order of Experiment Presentation [F(1,52) = .067, p = .796]. All other effects were found to be non-significant.

6.3.4. Discussion

The most important result to arise from analysis of the data from "Yes" responses to oriented objects was the absence of any micro-affordance effects in the response time data. This result can be contrasted with the results of Experiment Six where a significant compatibility effect was observed. However, analysis of the error data did suggest a trend in the data. In contrast to Experiment Six the analysis suggested an incompatibility effect. Responses to left-oriented objects in the right-hand response condition were more accurate than responses to right-oriented objects, and responses to right-oriented objects in the left-hand response condition were more accurate than responses to left-oriented objects. The absence of the compatibility effect in Experiment Seven could suggest that the reduction in stimulus processing time from one second to 200 milliseconds was an important factor in the expression of micro-affordance effects in off-line vision. However, it is also possible that response times were significantly different between the two experiments. Unfortunately, a direct comparison between the two experiments could not be carried out because the two experiments differed in one other important way. Having presented the series of photographs in Experiment Six there was a 100 millisecond delay before presentation of the written name, however in Experiment Seven there was a one second delay before presentation of the named object. Although a significant difference in response times between the two experiments cannot be ruled out as a cause for the absence of significant micro-affordance effects in Experiment Seven a preliminary review of the mean response times for each experiment suggests that this may not be the cause. The mean response time for Experiment Six was (763 msecs) and the mean response time for Experiment Seven was (785 msecs).

The second result of note to arise from the analysis was the absence of significant interactions between Hand of Response and Object Orientation in both the data for "Yes" responses to non-oriented objects and "No" responses. The absence of these effects at first seem to suggest that the presence of an oriented object on trials where participants either make a "Yes" response to a named non-oriented object present on the trial or a "No" response to a named object not present on the trial does not give rise to mirco-affordance effects. However, given that no significant effects were observed in the data for "Yes" responses to oriented objects, perhaps this is not surprising. Interestingly, there was a trend in the data similar to that observed for the analysis of error data to oriented objects. Analysis of both the response time data and error data for "Yes" responses to non-oriented objects suggested the presence of an incompatibility effect. Right-hand responses to left-oriented objects were faster and more accurate than right-hand responses to right-oriented objects and vice versa. Similarly in the response time data for "No" responses an incompatibility effect was observed when experiment Seven was run before Experiment Eight. However, when Experiment Seven was run after Experiment Eight the data suggested the presence of compatibility effect.

The most important significant effect to arise from the analysis of Experiment Seven was the interaction between Object Orientation and Order of Experiment Presentation in the response time data for "Yes" response to oriented objects. This effect suggested that when Experiment Seven was run before Experiment Eight responses to right-oriented objects were executed faster than responses to left-oriented objects, but when they were run in the reverse order responses to left-oriented objects were executed faster than responses to right-oriented objects. Importantly, the three-way interaction between Object Orientation Order of Experiment Presentation and Experiment Half suggested that the interaction between Object Orientation and Order of Experiment Presentation occurred during the time course of Experiment Seven when it was run before Experiment Eight. The data suggested that in the first half of the experiment responses to right-oriented objects were executed faster than responses to left-oriented objects but in the second half of the experiment responses to left-oriented objects were executed faster than responses to right-oriented objects. When Experiment Seven was run after Experiment Eight no interaction could be observed between Object Orientation and Experiment Half. Responses to left-oriented objects were executed faster in both the first and second halves of the Experiment. The presence of the interaction between Object Orientation and Order of Experiment Presentation reflects the same pattern of interaction observed in Experiment Six. In the first half of that experiment responses to right-oriented objects were executed faster than responses to left-oriented objects and vice versa in the second half of the experiment.

As discussed in Experiment Six this interaction is of interest as it appears to coincide with a change in the interaction between Object Orientation, Hand of Response, over the time course of the experiments. In Experiment Seven this change in the interaction was observed as a three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation in the response time data for "No" responses. When Experiment Seven was run before Experiment Eight there was a trend toward an incompatibility effect, but when the experiments were run in the reverse order there appeared to be a trend toward a compatibility effect. Similarly in Experiment Six the interaction between Object Orientation and Experiment Half coincided with a weak compatibility effect in the first half of the experiment and a stronger compatibility effect in the second half of the experiment. A possible explanation for this and other similar trends is reserved until the General Discussion at the end of this chapter.

6.4 Experiment Eight

6.4.1 Introduction

The aim of Experiment Eight is to provide further evidence for the micro-affordance effects observed in Experiments Six and Seven in an experiment in which participants are presented with eight object images on each trial for a period of 200 msecs each followed by a one second retention interval. As with Experiment Seven this experiment also aims to: (1) examine the expression of compatibility effects across the time course of the experiment (by comparing data collected in the first half of the experiment with that collected in the second half of the experiment) and across a longer time period by comparing the data collected when Experiment Eight is run both before and after Experiment Seven, and (2) seek evidence of micro-affordance effects arising from the presentation of one oriented object on each trial when participants make "Yes" responses to named non-oriented objects and when they make "No" responses to named objects not viewed on a trial

6.4.2 Method

Participants

The same sixty participants took part in Experiment Eight as took part in Experiment Seven.

Apparatus and Materials

All apparatus and materials were identical to those used in Experiment Seven

Design

The design of Experiment Eight was identical to that of Experiment Seven with the exception that on each trial participants viewed eight object images on each trial. One object image depicted an object optimally oriented for grasping by a particular hand (left and right) and seven object images depicted objects with no optimal orientation for grasping by either hand. Experiment Eight was run in conjunction with Experiment Seven, therefore half the participants completed Experiment Eight before Experiment Seven, and half completed Experiment Eight after Experiment Seven.

Procedure

The procedure was identical to that used in Experiment Seven with the exception that participants were presented with eight object images on each trial instead of four (see Appendix GG for a copy of the instructions).

6.4.3 Results

A maximum error rate of two standard deviations above the mean (error rate) was fixed for inclusion of participant data in this experiment. The mean error rate was calculated at 59.75[30] (St Dev 13.95). Five participants were excluded from the analysis based on this criterion. In addition, three participants failed to finish the experiment.

The data generated in Experiment Eight was subjected to a similar profile of analyses to that carried out on the data for Experiment Seven. The data generated in Experiment Eight was first separated into three data sets. The first data set comprised "Yes" (object present) responses for which participants responded to a named object which was either optimally oriented for a left or right-hand grasp. This data set was then subjected to three separate sub-analyses. Once again, the aim of the first sub-analyses was to seek evidence for micro-affordance effects arising from the relationship between an oriented object for grasping and hand of response and to see whether this was affected by stimulus position (first to eighth image presented). In addition, the analysis also sought to establish the effect of presenting the experiment after another similar experiment (Experiment Seven) to see whether or not familiarity over time with the stimulus set and procedure would affect the expression of the micro-affordance effects.

A second sub-analysis was then carried out on the data that collapsed the data across stimulus position. This analysis was undertaken as data from several participants had data missing from cells in the design of the first sub-analysis.

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[30] Number of errors out of 200 trials

Similarly, as in Experiments Six and Seven, the aim of the third analyses was to investigate the expression of the micro-affordance effects over the time course of the experiment by comparing responses from the first and second halves of the experiment.

The second data set comprised "Yes" (object present) responses for which participants responded to a named object viewed on each trial that had no optimal orientation for grasping by either hand. The aim of the analysis carried out on this data set was to investigate whether the oriented object present on each trial had an effect on responses to non-oriented objects on each trial.

Finally, the third data set comprised "No" (object not present) responses to a named object which did not appear on the trials[31]. As with data from the second data set above, the aim of the analyses carried out on this data set was to investigate whether the oriented object present on each trial had an effect on responses to named objects that were not present on each trial.

6.4.3.1 Analysis of "Yes" Responses to Named Oriented Objects

The data from the "Yes" trials in which participants were asked to respond to an oriented object were separated from the rest of the data for analysis. Error trials and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Error trials accounted for 28.3 % of response trials, while reaction times greater than two standard deviations accounted for 3.73% of response trials.

The data for all "yes, oriented object" trials were subjected to three separate sub-analyses.

6.4.3.1.1 Analysis One

The data were subjected to a four-way mixed ANOVA (Appendix WW) with the within participants factors of Object Orientation (left and right) and Stimulus Position, and the between participants factors of Hand of Response (left and right) and Order of

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[31] All named objects came from the stimulus list.

Experiment Presentation (Exp7-Exp8 / Exp8-Exp7). A summary of the data can be seen in Table 30 (Appendix XX).[32]

The analysis revealed a significant main effect of Stimulus Position [F(7,336) = 10.69, p<.0001], but no main effects of Object Orientation [F(1,48) = .053, p = .818], Hand of Response [F(1,48) = .834, p = .367] or Order of Experiment Presentation [F(1,48) = 1.66, p = .203].

In respect of the main effect of Stimulus Position, the data suggest both a primacy and a recency effect. The data show that responses to images at position one were executed faster (m = 894.02 msecs) than responses to images at position two (m = 910.34 msecs), and responses to images at position eight were executed faster (m = 760.59 msecs) than responses to images at position seven (m = 847.33 msecs). However in a follow-up analysis (Appendix YY) only the recency effect was found to be significant (T(336) = 59.51, p<.05). In addition, all other comparisons were found to be non-significant. Consistent with the findings of both Experiments Six and Seven, the follow-up analysis supports the observation of a one item recency effect reported elsewhere in the short-term visual memory literature (Phillips and Christie, 1977).

Importantly, no significant interaction was observed between: Object Orientation and Hand of Response [F(1,48) = .023, p = .881]. Although the interaction between Object Orientation, Hand of Response and Order of Experiment Presentation was also non-significant [F(1,48) = 1.81, p = .184], the result is of interest as the pattern of data reflects that observed for the analysis of the "No" responses in Experiment Seven. As with that analysis the data show that when Experiment Eight was run before Experiment Seven (the reverse order for the analysis in Experiment Seven) there was an incompatibility effect between hand of response and object orientation. However, when the two experiments were run in reverse order a compatibility effect could be observed. The data show that

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[32] In this analysis approximately half the participants had data missing for at least one cell of the design. In order to include as much data as possibly in the analysis it was decided to replace all missing cells with the mean response score for each participant across all conditions.

when Experiment Eight was run before experiment Seven right-hand responses to left-oriented objects were executed faster (m = 886.55 msecs) than right-hand responses to right-oriented objects (m = 891.37 msecs), and left-hand responses to right-oriented objects were executed faster (m = 896.94 msecs) than left-hand responses to left oriented objects (m = 900.59 msecs). However, when Experiment Eight was run after experiment Seven right-hand responses to right-oriented objects were executed faster (m = 909.60 msecs) than right-hand responses to left-oriented objets (m = 922.16 msecs), and left-hand responses to left-oriented objects were executed faster (m = 780.31 msecs) than left hand responses to right-oriented objects (m = 798.41 msecs). The interaction is illustrated in figures 37 and 38.

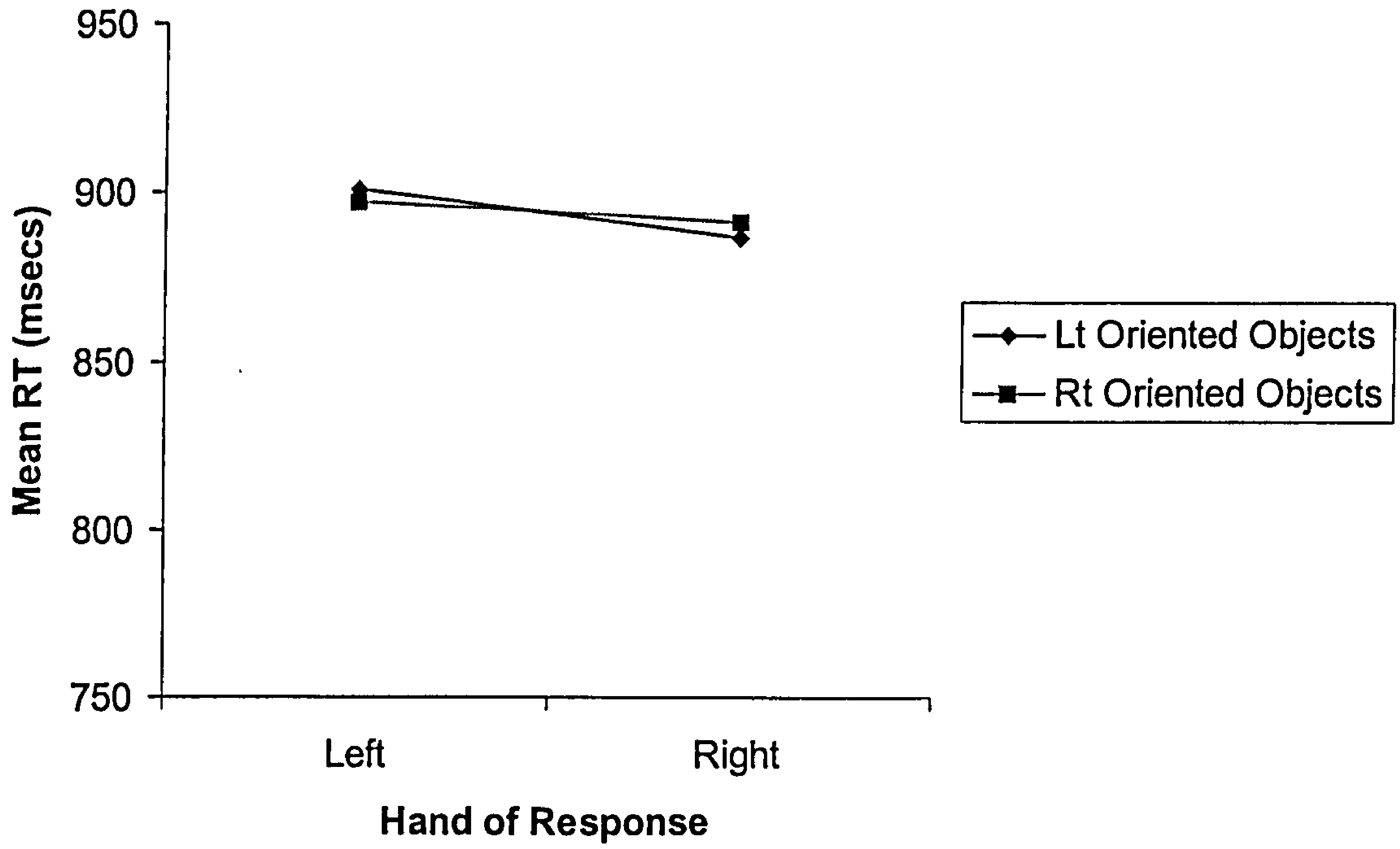


Figure 37
Mean Response Times for Left and Right Hand Responses to Left and Right-oriented Objects when Experiment Eight was run before Experiment Seven

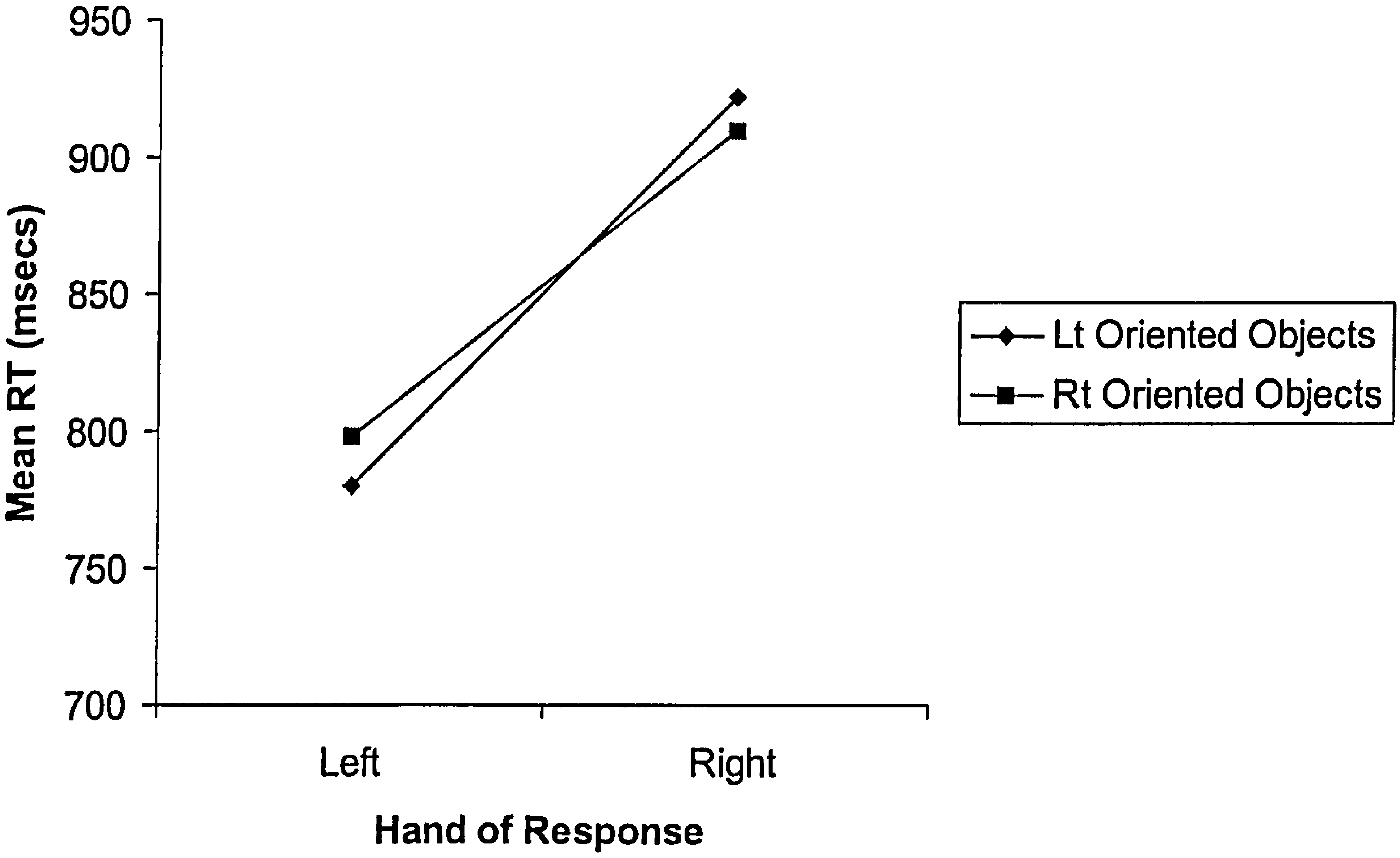
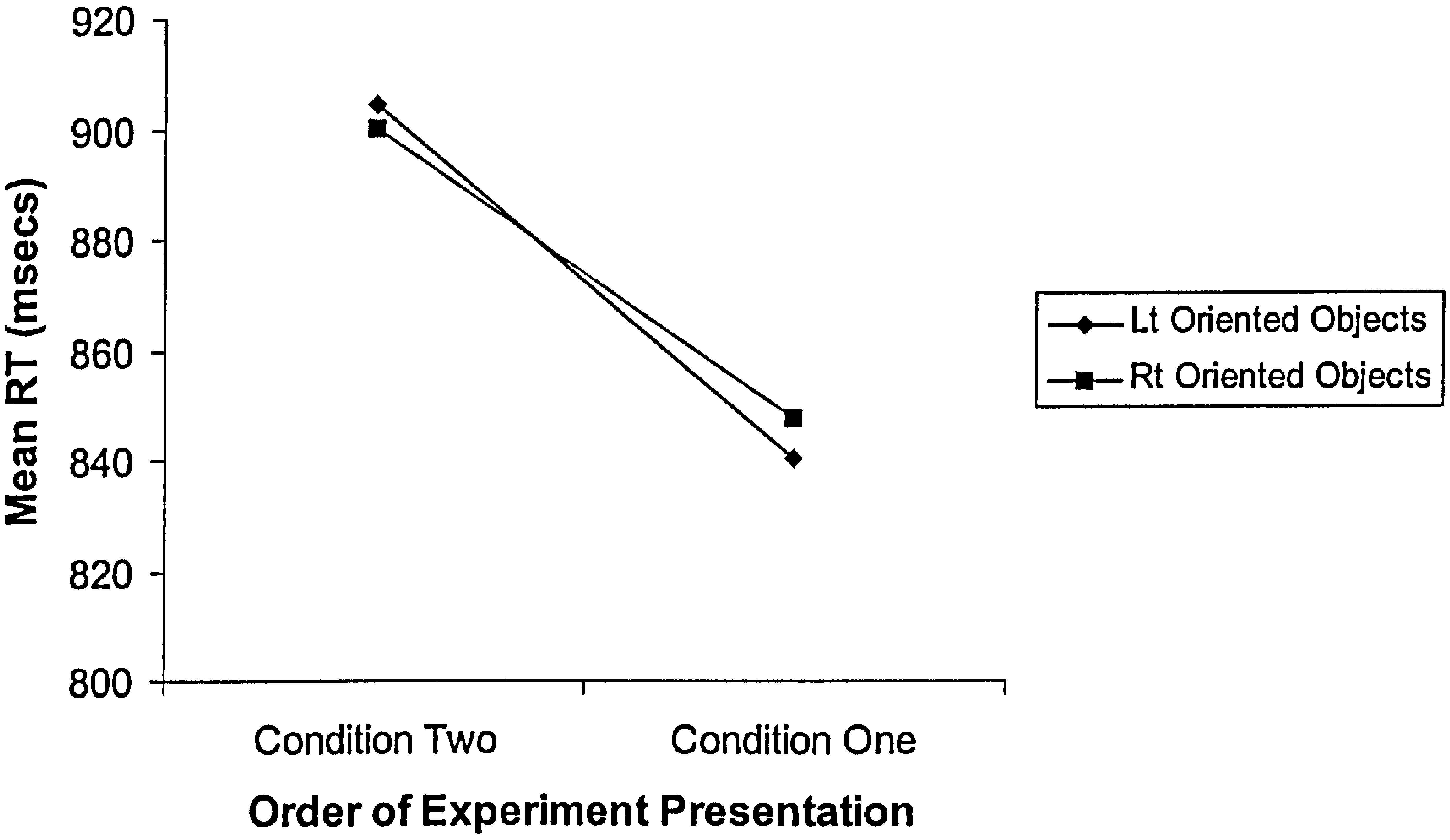


Figure 38
Mean Response Times for Left and Right Hand Responses to Left and Right-oriented Objects when Experiment Eight was run after Experiment Seven

The interaction between Object Orientation and Order of Experiment Presentation was also clearly non-significant [F(1,48) = .585, p = .448], but once again the pattern of means is of interest in the light of the findings from Experiment Seven where similar trends were observed. As was the case with Experiment Seven, the data from this experiment suggest that when Experiment Eight was run before Experiment Seven (the reverse order for Experiment Seven), responses to right-oriented objects were executed slightly faster (m = 900.48 msecs) than responses to left-oriented objects (m = 904.36 msecs), but when Experiment Eight was run after Experiment Seven, responses to left-oriented objects were executed slightly faster (m = 840.45 msecs) than responses to right-oriented objects (m = 847.68 msecs). This interaction is illustrated in Figure 39.



Condition Two = Experiment Eight followed by Experiment Seven
Condition One = Experiment Seven followed by Experiment Eight

Figure 39
Mean Response Times for Left and Right-oriented Objects when Experiment Eight was run both before and after Experiment Seven

In respect of the remaining analysis, the only significant effect was the two-way interaction between Object Orientation and Stimulus Position [F(5.56,266.69) = 2.78, p = .015][33]. No clear explanation can be provided for this interaction.

Error Data

The error data for "Yes" responses to oriented objects were subjected to a three-way mixed ANOVA (Appendix ZZ) with the within participant factor of Object Orientation (left and right), and the between participant factors of Hand of Response (left and right), and Order of Experiment Presentation (Exp7-Exp8 /Exp8-Exp 7). A summary of the data is shown in Table 31 (Appendix aa).

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[33] Due to a violation of the sphrecity assumption, the significance values were adjusted using the Greenhouse-Geisser correction.

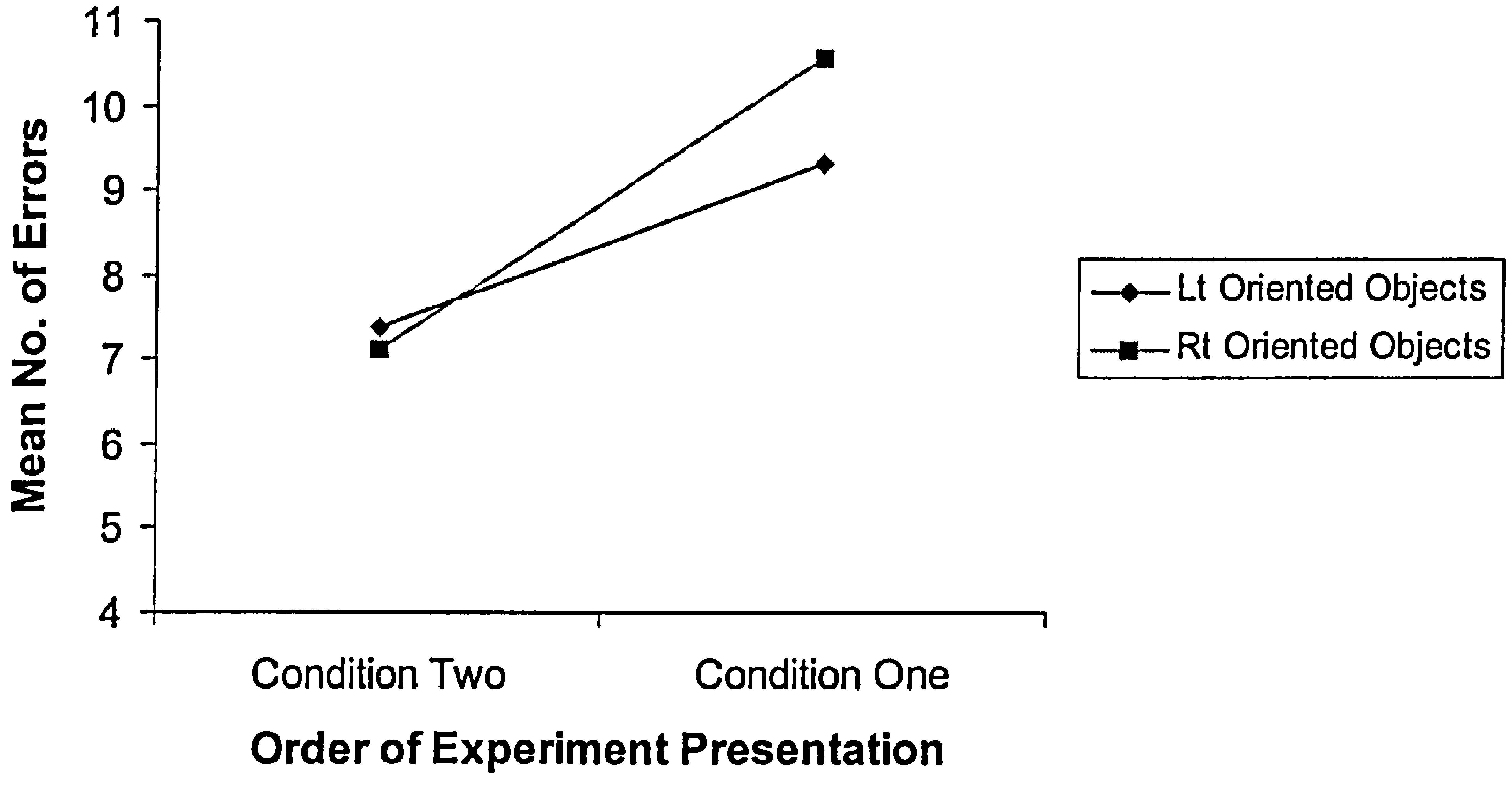
The analysis revealed a significant main effect of Order of Experiment Presentation [F(1,48) = 8.35, p = .006], but no main effects of either Object Orientation [F(1,48) = 1.22, p = .274], or Hand of Response [F(1,48) = .139, p = .711].

The main effect of Order of Experiment Presentation revealed that participants were more accurate when Experiment Eight was run before Experiment Seven (m = 7.23), than when the two experiments were run in the reverse order (m = 9.23).

Importantly, the analysis revealed no significant interactions between Object Orientation and Hand of Response [F(1,48) = .115, p = .695].

Although non-significant at alpha = .05, both the interaction between Object Orientation and Order of Experiment Presentation [F(1,48) = 2.17, p = .103] and the interaction between Hand of Response and Order of Experiment Presentation [F(1,48) = 3.75, p = .059] were nearing significance.

In respect of the interaction between Object Orientation and Order of Experiment Presentation the data suggest that when Experiment Eight was run before Experiment Seven, more errors were made to left-oriented objects (m = 7.37) than to right-oriented objects (m = 7.10). However, when Experiment Eight was run after Experiment Seven, more errors were made to right-oriented objects (m = 10.55) than to left-oriented objects (m = 9.29). The interaction is illustrated in Figure 40.



Condition Two = Experiment Eight followed by Experiment Seven
Condition One = Experiment Seven followed by Experiment Eight

Figure 40
Mean number of Errors to Left and Right-oriented Objects when Experiment Eight was run before and after Experiment Seven

The interaction between Object Orientation and Order of Experiment Presentation in this analysis reflects the same pattern of results observed in the response time data for this data set. In the analysis of that data it was observed that responses to right-oriented objects were executed faster than responses to left-oriented objects when Experiment Eight was run before Experiment Seven but responses to left-oriented oriented objects were executed faster than responses to right-oriented objects when the experiments were run in the reverse order.

In respect of the interaction between Hand of Response and Order of Experiment Presentation the data suggest that when Experiment Eight was run before Experiment Seven more errors were made in the left-hand response condition (m = 7.96) than in the right-hand response condition (m = 6.50). However, when Experiment Eight was run after Experiment Seven more errors were made in the right-hand response condition (m = 11.00) than in the left-hand response condition (m = 8.85). This interaction reflects a similar interaction observed in the response time data of Experiment Seven across the time course of that experiment. In that analysis it was observed that early in the experiment the left hand response condition produced more errors than the right-hand response condition, but this was reversed in the second half of the experiments. As suggested in that section this interaction can be interpreted as an effect of the right-hand dominance of the majority of the participants whereby there is a trade-off between fast right-hand responding and inaccurate responding.

6.4.3.1.2 Analysis Two

Response Time Data

The data were subjected to a three-way mixed ANOVA (Appendix bb) with the within participants factors of Object Orientation (left and right) and the between participants factors of Hand of Response (left and right) and Order of Experiment Presentation (Exp7-Exp8 / Exp8-Exp7). A summary of the data is displayed in Table 32 (Appendix cc).

As with the first sub-analysis, this second analysis revealed no significant main effects of: Object Orientation [F(1,48) = .093, p = .761]; Hand of Response [F(1,48) = .698, p = .408]; and Order of Experiment Presentation [F(1,48) = 1.98, p = .166].

Importantly, the analysis again revealed no significant interaction between Object Orientation and Hand of Response [F(1,48)>.001, p = .989]. However, although non-significant at alpha = .05, it is worth noting that the three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation was nearing significance and [F(1,42) = 3.35, p = .054].

As in the first analysis carried out on this data set, the three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation, suggests that when Experiment Eight was run before Experiment Seven there was an incompatibility effect between Object Orientation and Hand of Response, but when Experiment Eight was run after Experiment Seven there was a compatibility effect. The analysis revealed that right-hand responses to left-oriented objects were executed faster (m = 889.87 msecs) than right-hand responses to right-oriented objects (m = 896.27 msecs), and left-hand responses to right-oriented objects were executed faster (m = 902.82 msecs) than left-hand responses to left-oriented objects (m = 933.15 msecs). However, when Experiment Eight was run after Experiment Seven the interaction reversed. Left-hand responses to left-oriented objects were executed faster (m = 776.91 msecs) than left-hand responses to right-oriented objects (m = 801.34 msecs), and right-hand responses to right-oriented objects were executed faster (m = 885.61 msecs) than right-hand responses to left-oriented objects (m = 897.39 msecs). The interaction is illustrated in Figures 41 and 42. This interaction can be seen to reflect a similar interaction to the trend observed in the response time data for "No" responses in Experiment Seven.

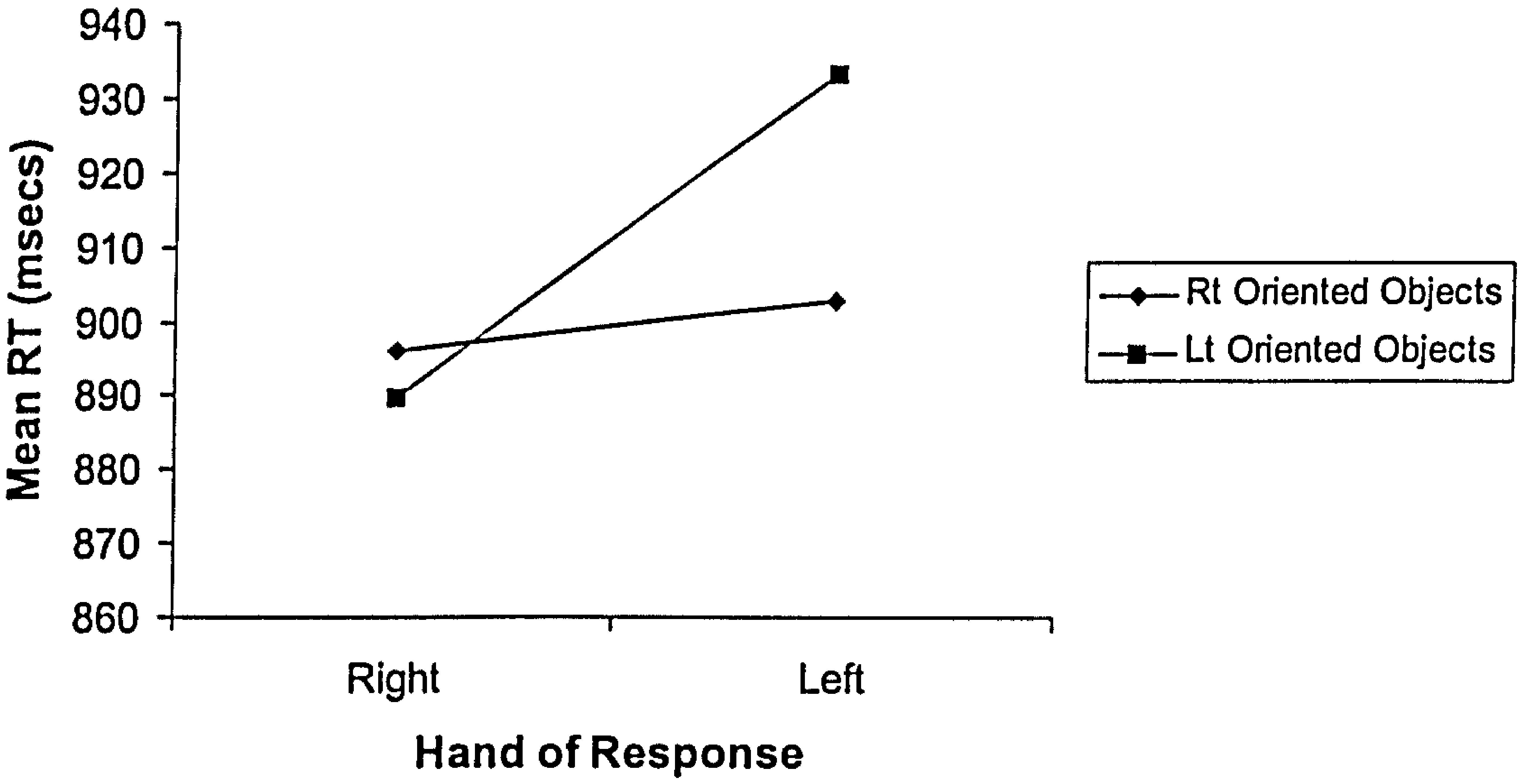


Figure 41
Mean Response Times for Right and Left Hand Responses to Right and Left-oriented Objects when Experiment Eight was run before Experiment Seven

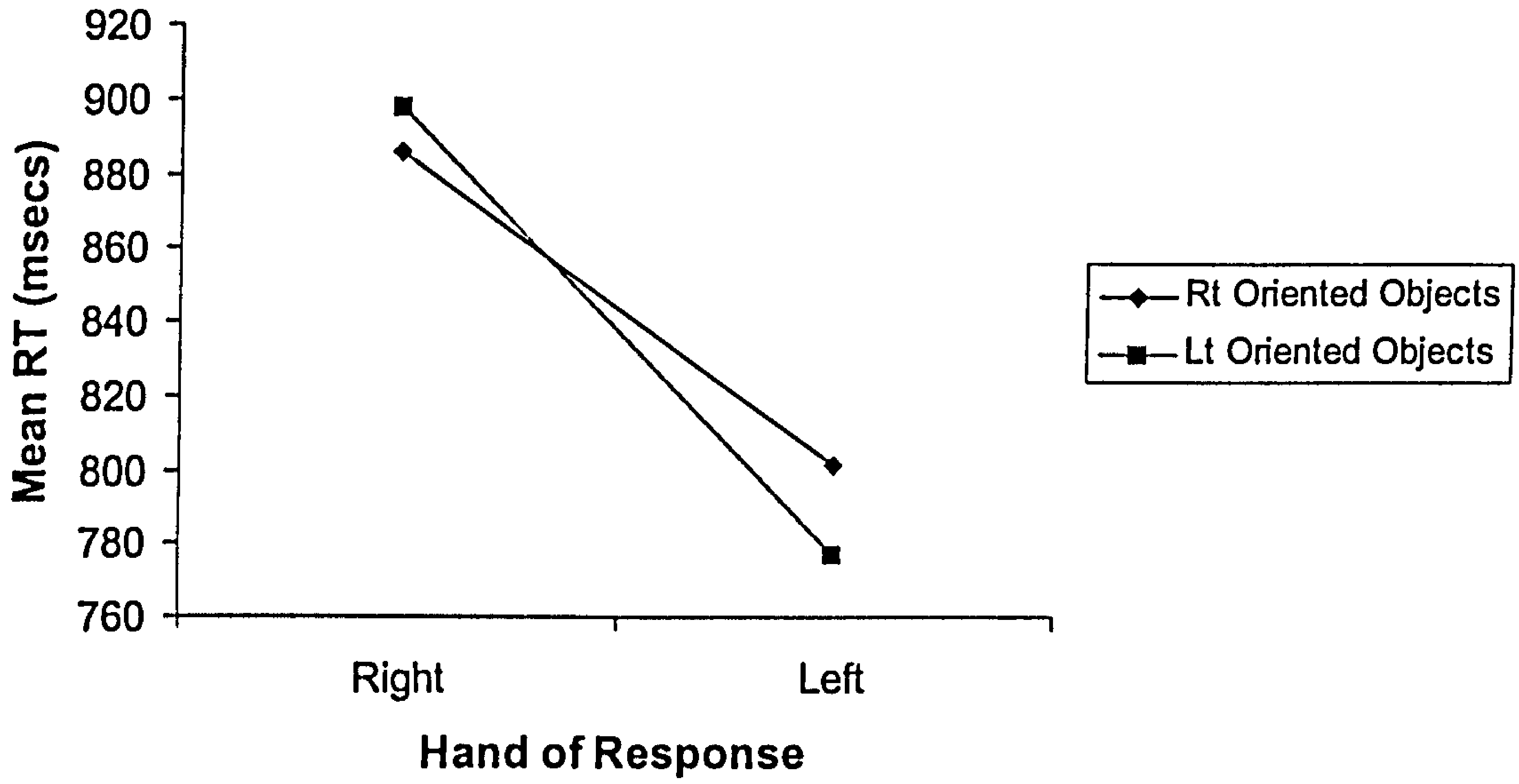


Figure 42
Mean Response Times for Right and Left Hand Responses to Right and Left-oriented Objects when Experiment Eight was run after Experiment Seven

No other effects were found to be significant.

6.4.3.1.3 Analysis Three

The data were subjected to a third ANOVA (Appendix dd) with the within participants factors of Object Orientation (left and right) and Experiment Half (first and second halves of the experiment) and the between participants factors of Hand of Response (left and right) and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 33 (Appendix ee).

The analysis revealed a significant main effect of Experiment Half [F(1,48) = 17.65, p<.0001], but once again no main effects of Object Orientation [F(1,48) = .323, p = .572] or Hand of Response [F(1,48) = .426, p = .517] or Order of Experiment Presentation [F(1,48) = 2.32, p = .134].

In respect of the main effect of Experiment Half the data suggest that participant responses were executed significantly faster in the second half of the experiment (m = 834.52 msecs) compared to the first half of the experiment (m = 903.49 msecs). As was the case with Experiments Six and Seven the effect of Experiment Half can be seen to reflect a general learning effect over the time course of the experiment.

Importantly, the analysis once again revealed no significant interaction between Object Orientation and Hand of Response [F(1,48) = .111, p = .740].

Although all other effects were found to be non-significant, the pattern of data for the interaction between Object Orientation and Experiment Half is of interest [F(1,48) = .994, p = .324]. Consistent with the analysis carried out on the response time data of Experiment Six, the data show that in the first half of the experiment responses to right-oriented objects were executed faster (m = 902.09 msecs) than responses to left-oriented objects (m = 904.89 msecs), but in the second half of the experiment the reverse pattern could be observed. Responses to left-oriented objects were executed faster (m = 826.34 msecs) than responses to right-oriented objects (m = 842.70 msecs). Again discussion of this effect is reserved until the General Discussion at the end of this chapter.

6.4.3.2 Analysis of "Yes" Responses to Named Non-Oriented Objects

The data from the "Yes" trials in which participants were asked to respond to a non-oriented object were separated from the rest of the data for analysis. Error trials and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Error trials accounted for 28.91% of response trials, whilst reaction times greater than two standard deviations from the participants' means accounted for 4.24% or response trials.

Response Time Data

The remaining data were subjected to a three-way mixed ANOVA (Appendix ff) with the within participants factor of Object Orientation (left and right) and the between participants factors of Hand of Response and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 34 (Appendix gg).

The analysis revealed no significant main effects of Object Orientation [F(1,48) = 1.69, p = .199], Hand of Response [F(1,48) = 2.48, p = .122] or Order of Experiment Presentation [F(1,48) = 3.23, p = .079], although this effect was nearing significance. In respect of the main effect of Order of Experiment Presentation the data suggest a practice effect. When Experiment Eight was run after Experiment Seven responses were executed faster (m = 899.20 msecs) than when Experiment Eight was run before Experiment Seven (m = 990.59 msecs). Once again this effect can be seen to reflect a general learning rule whereby participants' performance improves as they become familiar with the experimental procedure and stimulus set.

Importantly, the analysis revealed no significant interaction between Object Orientation and Hand of Response [F(1,48) = .017, p = .898].

All other effects were found to be non-significant.

Error Data

The error data was subjected to a three-way mixed ANOVA (Appendix hh) with the within participants factor of Object Orientation (left and right) and the between participants factors of Hand of Response and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 35 (Appendix ii).

The analysis revealed no significant effects in any of the data. However, the interactions between Object Orientation and Hand of Response and Object Orientation, Hand of Response and Order of Experiment Presentation were both nearing significance [F(1,48) = 3.42, p = .071] and [F(1,48) = 3.13, p = .083] respectively. In respect of the two-way interaction between Object Orientation and Hand of Response the data suggest a compatibility effect. The data show that in the right-hand response condition more errors were made on trials containing left-oriented objects (m = 6.33) than on trials containing right-oriented objects (m = 4.95), but in the left-hand response condition more errors were made on trials containing right-oriented objects (m = 6.23) than on trials containing left-oriented objects (m = 6.06).

In respect of the three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation the data suggest that the two-way interaction between Object Orientation and Hand of Response is confined to the data collected when Experiment Eight was run before Experiment Seven. The data show that when Experiment Eight was run before Experiment Seven there were more errors on trials containing right-oriented objects in the left-hand response condition (m = 7.00) than on trials containing left-oriented objects (m = 5.58), and more errors on trials containing left-oriented objects in the right-hand response condition (m = 6.23) than on trials containing right-oriented objects (m = 4.61). However, when Experiment Eight was run after Experiment Seven no two-way interaction was observed. In both the left and right-hand response condition responses on trials containing right-oriented objects were more accurate (m = 5.46 and 5.29, respectively) than responses on trials containing left-oriented objects (m = 6.54 and 6.53, respectively). This three-way interaction therefore suggests the presence of a compatibility effect when experiment Eight was run before Experiment Seven, but no effect when Experiment Eight was run after Experiment Seven. The three-way interaction is illustrated in Figure 43 and Figure 44. At first sight this trend appears to contradict other trends observed in the analyses of this experiment. In those other analyses a trend was seen for an incompatibility effect when Experiment Eight was run before Experiment Seven and a compatibility effect when Experiment Eight was run after Experiment Seven. However, the above effect does not contradict these findings as only a compatibility effect is observed. Although this occurs when Experiment Eight is run before Experiment Seven, no effect or trend is observed in the data when the two experiments were run in the reverse order.

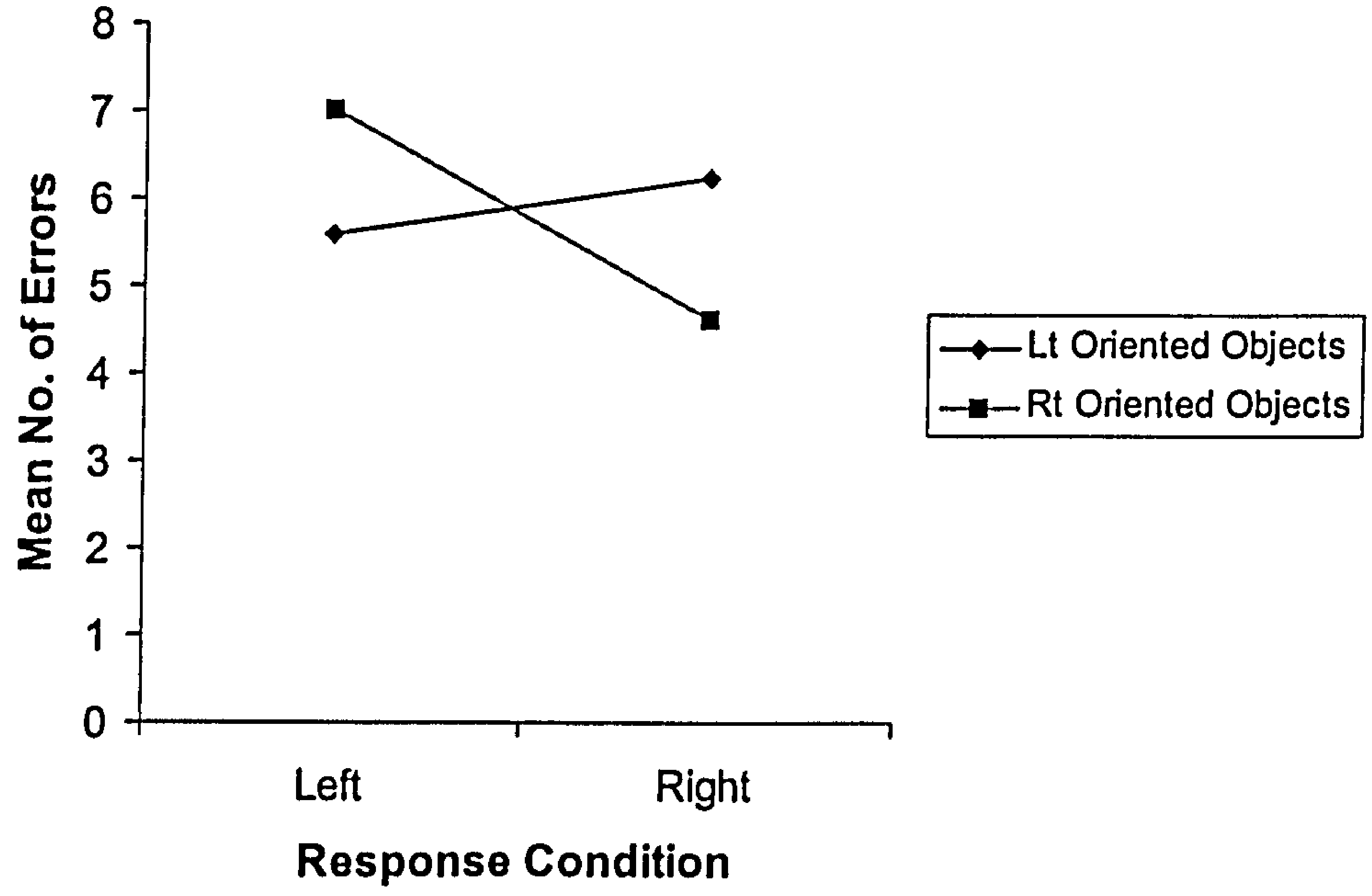


Figure 43
Mean Number of Errors in the Left and Right Hand Response Conditions when Experiment Eight was run before Experiment Seven

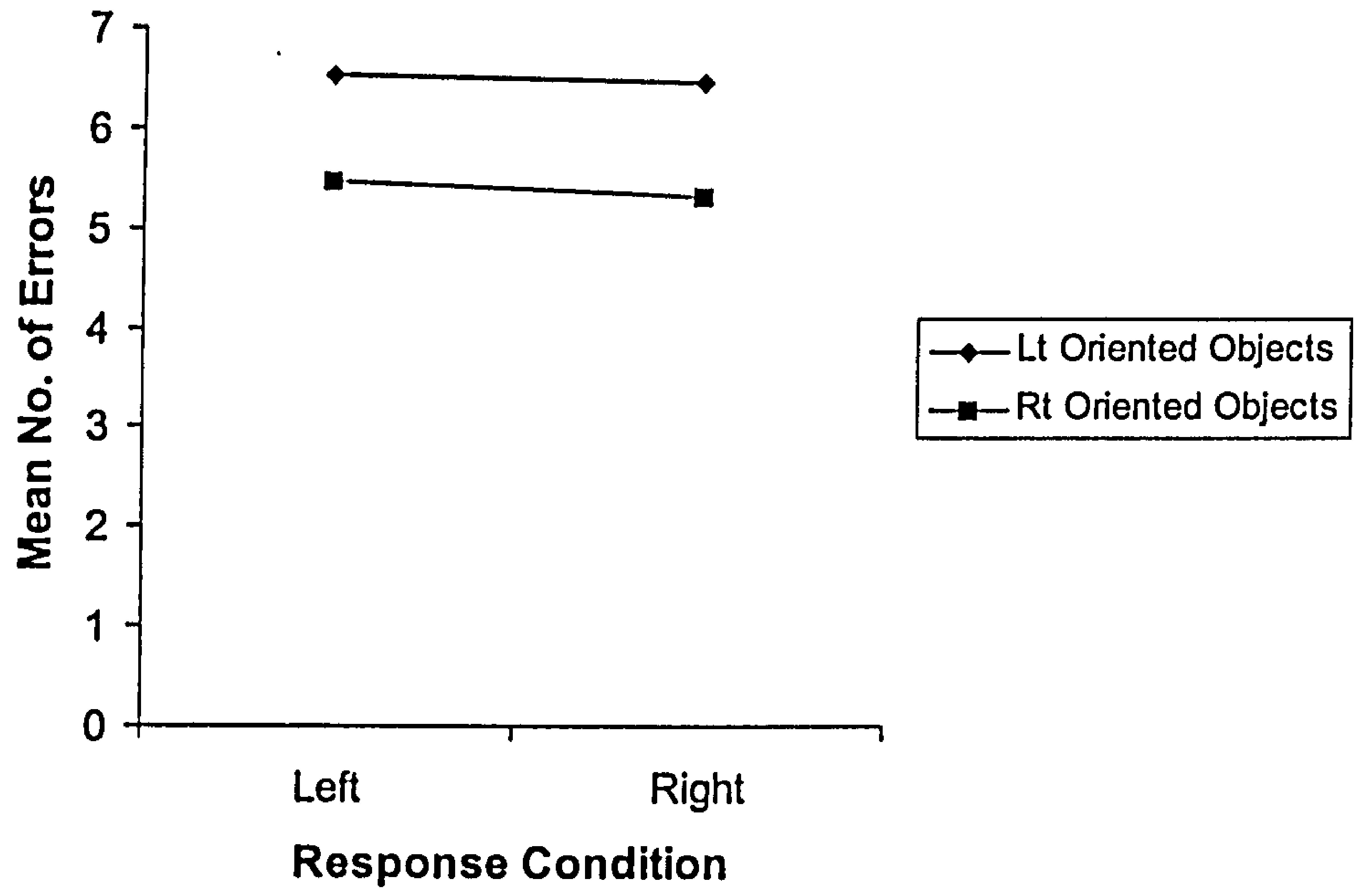


Figure 44
Mean Number of Errors in the Left and Right Hand Response Conditions when Experiment Eight was run after Experiment Seven

All other effects were found to be non-significant.

6.4.3.3 Analysis of "No" Responses

The data from the "No" trials in which participants were asked to respond to an object not present in the stimulus set were separated from the rest of the data for analysis. Error trials and reaction times more than two standard deviations from the participants' means were excluded from the analysis. Error trials accounted for 24.43% of response trials, whilst reaction times greater than two standard deviations from the participants' means accounted for 4.60% or response trials.

Response Time Data

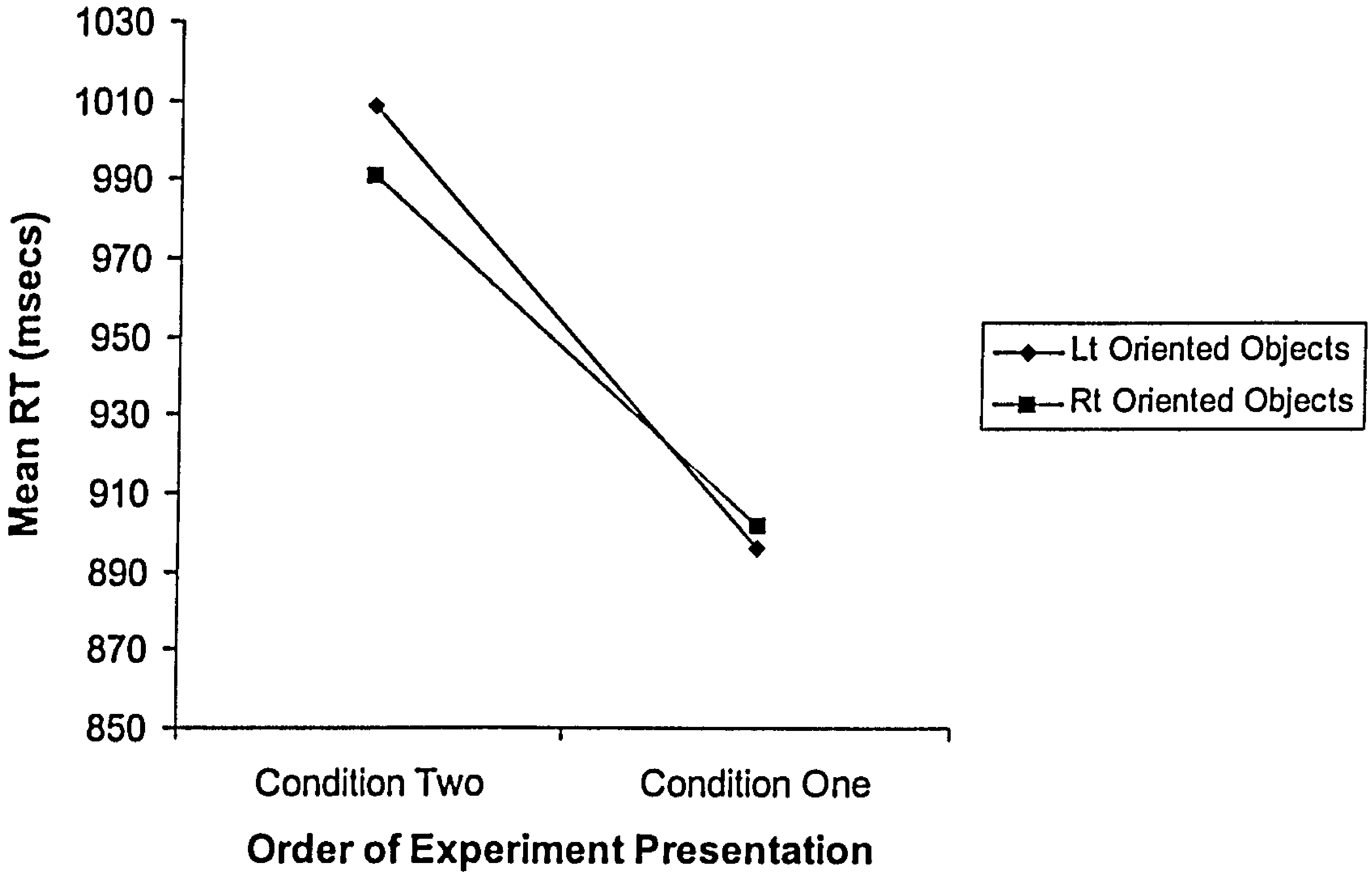
The data were subjected to a three-way mixed ANOVA (Appendix jj) with the within participants factor of Object Orientation (left and right) and the between participants factors of Hand of Response and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 36 (Appendix kk).

The analysis revealed no significant main effects of Object Orientation [F(1,48) = .852, p = .361], Hand of Response [F(1,48) = .325, p = .571] or Order of Experiment Presentation [F(1,48) = 3.24, p = .078] although this main effect was nearing significance. In respect of the main effect of Order of Experiment Presentation the data suggest that responses were executed faster when Experiment Eight was run after Experiment Seven (m = 899.00 msecs), than in the reverse order (m = 999.78 msecs). As in previous analyses reported in this chapter, this main effect can be seen to reflect a general practice effect over the time course of the two experiments whereby participants' performance improves with increased familiarity with the task procedure and stimulus set.

Importantly, the analysis revealed no significant interaction between Object Orientation and Hand of Response [F(1,48) = .272, p = .605].

Although the interaction between Object Orientation and Order of Experiment Presentation was also non-significant at alpha =.05, the effect was nearing significance [F(1,48) = 2.96, = .092]. The pattern of data for the interaction suggests a similar pattern to the trend observed in the response time data for responses to oriented objects. The data shows that when Experiment Eight was run before Experiment Seven responses to trials containing right-oriented objects were executed faster (m = 990.96 msecs) than responses to trials containing left-oriented objects (m = 1008.60 msecs). However, when Experiment Eight was run after Experiment Seven responses to trials containing left-oriented objects were executed faster (m = 896.34 msecs) than responses to trials containing right-oriented objects (m = 901.66 msecs). The interaction is illustrated in Figure 45.

Figure 45
Mean Response Times to Right and Left-oriented Objects when Experiment Eight was run both before and after Experiment Seven



Error Data

The data was subjected to a three-way mixed ANOVA (Appendix ll) with the within participants factor of Object Orientation (left and right) and the between participants factors of Hand of Response and Order of Experiment Presentation (Exp7-Exp8/Exp8-Exp7). A summary of the data can be seen in Table 37 (Appendix mm).

The analysis revealed no significant main effects of Hand of Response [F(1,48) = 1.26, p = .268] or Order of Experiment Presentation [F(1,48) = .894, p = .349]. Although the main effect of Object Orientation was also non-significant at alpha = .05, it was nearing significance [F(1,48) = 3.08, p =.085]. The data show that more errors were made on trials containing left-oriented objects (m = 13.64) than on trials containing right-oriented objects (m = 12.58). This main effect of object orientation reflects a similar effect reported in Experiment Six for both the response time data and the error data.

Importantly, no interaction was observed between Hand of Response and Object Orientation [F(1,48) = 1.218, p = .275). However, the interaction between Object Orientation, Hand of Response and Order of Experiment Presentation was shown to be significant [F(1,48) = 4.05, p = .05].

In respect of the interaction between Order of Experiment Presentation, Object Orientation and Hand of Response, the data suggest that when Experiment Eight was run before experiment Seven there was a two-way interaction between Hand of Response and Object Orientation. The data show that more errors were made on trials containing left-oriented objects in the right-hand response condition (m = 15.42) than were made on trials containing right-oriented objects in the right-hand response condition (m = 11.67), and the same number of errors were made on trials containing right-oriented objects in the left-hand response condition (m = 13.92) as were made on trials containing left-oriented objects in the left-hand response condition (m = 13.92).

However, when experiment Eight was run after Experiment Seven, the reverse pattern of interaction could be observed. The data show that slightly more errors were made on trials containing right-oriented objects in the right-hand response condition (m = 14.31) than were made on trials containing left-oriented objects in the right-hand response condition (m = 14.00), and more errors were made on trials containing left-oriented objects in the left-hand response condition (m=11.21) than were made on trials containing right-oriented objects (m = 10.43) in the left-hand response condition. This interaction can therefore be interpreted as an incompatibility effect when Experiment Eight is run before Experiment Seven but a compatibility effect when Experiment Eight was run after Experiment Seven. The three-way interaction is illustrated in Figures 46 and 47.

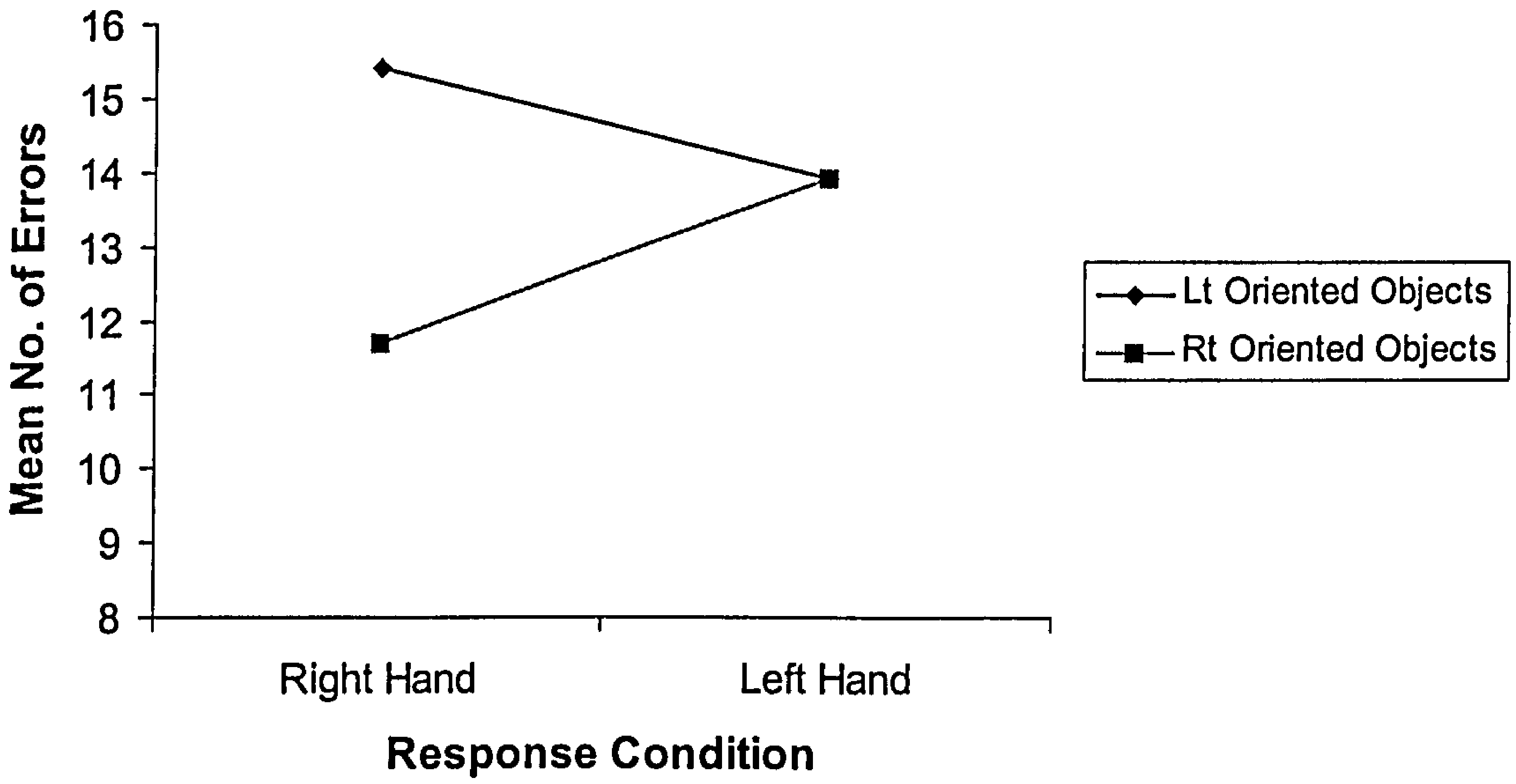


Figure 46
Mean Number of Errors for Right and Left Hand Response Conditions to Right and Left-oriented Objects when Experiment Eight was run before Experiment Seven

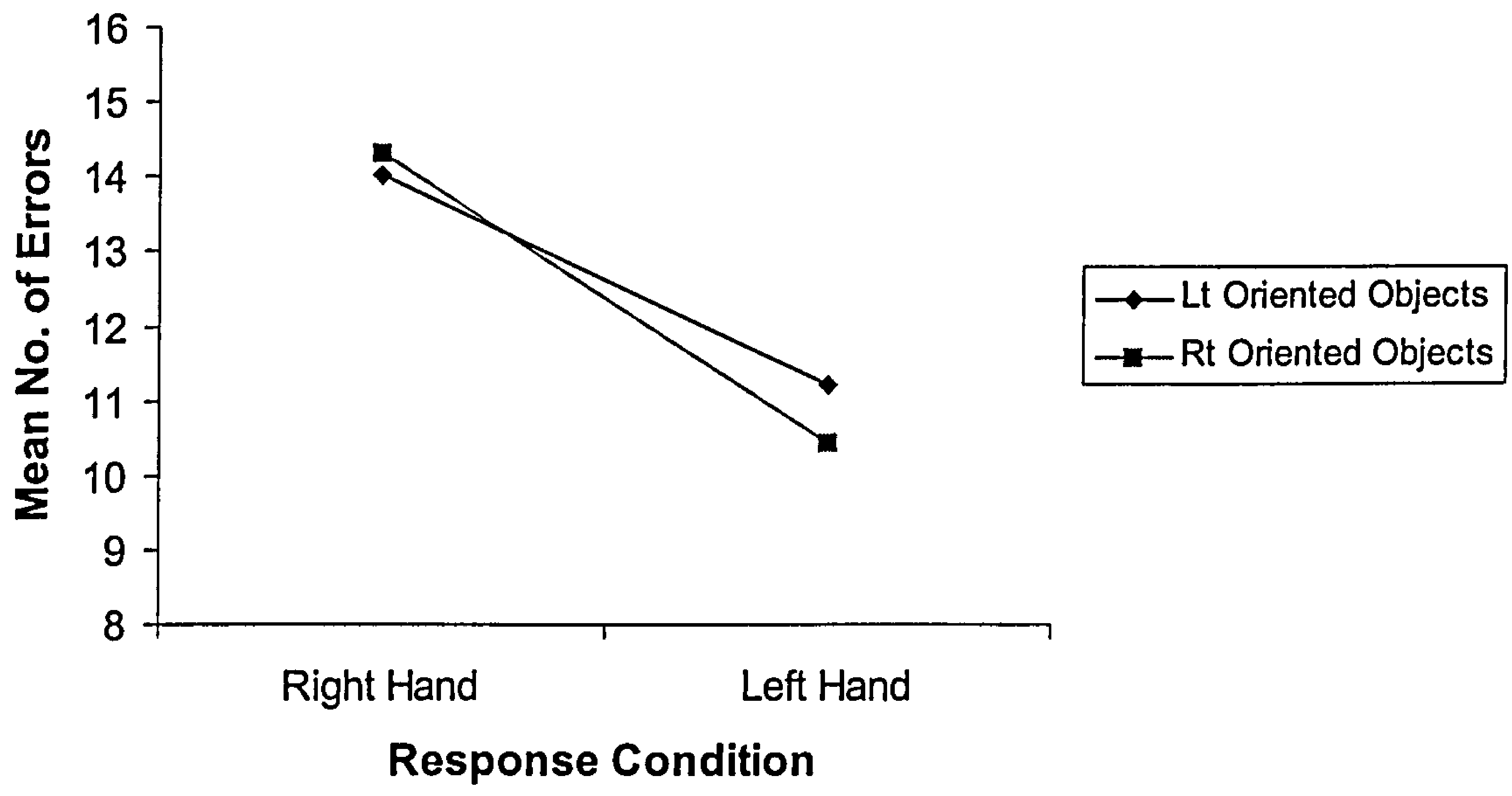


Figure 47
Mean Number of Errors for Right and Left Hand Response Conditions to Right and Left-oriented Objects when Experiment Eight was run after Experiment Seven

6.4.4 Discussion

The most important result to arise from Experiment Eight was the absence of any micro-affordance effects in the data set for "Yes" responses to oriented objects. However, as with the analyses carried out on Experiment Seven the data did suggest a trend. In the first two analyses carried out on the response time data there was a suggestion of a three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation. The data suggest the presence of a compatibility effect when Experiment Eight was run before Experiment Seven and an incompatibility effect when Experiment Eight was run after Experiment Seven. This pattern of data reflects a similar pattern to that observed in the analysis of Experiment Seven.

Although non-significant the data again suggested that responses times were slower when experiment Eight was run before Experiment Seven than when Experiment Eight was run after Experiment Seven. This finding was again consistent with Richardson et al's proposal that incompatibility effects are associated with relatively slow reaction times and compatibility effects with relatively fast response times. However, no trends were observed in the error data for "Yes" responses to oriented objects.

Consistent with the findings of Experiment Seven, no micro-affordance effects were observed in the response time data for either the "Yes" responses to non-oriented objects or the "No" responses. However, analysis of the error data for the "No" responses did provide evidence of an effect. The data show that when experiment Eight was run before Experiment Seven there was an incompatibility effect in the data but when Experiment Eight was run after Experiment Seven there was a compatibility effect. This pattern of data reflects the same pattern of interaction observed in the response time data to oriented objects (reported above) and to that of the "No" responses in Experiment Seven. The presence of this significant effect is important as it provides evidence that the presence of an oriented object on trials on which participants make a "No" response to a named object not present on that trial can affect participants action responses.

Analysis of the error data for "Yes" responses to <u>non-oriented</u> objects also suggested a trend. In contrast to the error data for the "No" responses the data suggest the presence of a compatibility effect when Experiment Eight was run before Experiment Seven but no effect when the Experiment Eight was run after Experiment Seven.

Another important result to arise from the analyses carried out on Experiment Eight were the interactions between Object Orientation and the time course of the experiments (both Order of Experiment Presentation and Experiment Half). In the analyses of the response time data and analysis of the error data for "Yes" responses to <u>oriented</u> objects a trend in the data suggested that when Experiment Eight was run before Experiment Seven responses to right-oriented objects were executed faster and more accurately than responses to left-oriented objects. However, when Experiment Eight was run after Experiment Seven responses to left-oriented objects were executed faster and more accurately than responses to right-oriented objects. Although again non-significant, this pattern of interaction was repeated in analysis of the response time data for "No" responses. The analysis revealed that trials containing right-oriented objects were executed faster than trials containing left-oriented objects when Experiment Eight was run before

Experiment Seven, but when Experiment Eight was run after Experiment Seven trials containing left-oriented objects were executed faster than trials containing right-oriented objects.

Similarly, in the third analysis carried out on the response time data a trend was observed in the data to suggest an interaction between Object Orientation and Experiment Half. Responses to right-oriented objects were executed faster in the first half of the experiment than responses to left-oriented objects. However, in the second half of the experiment responses to left-oriented objects were executed faster than responses to right-oriented objects.

Although the interactions between object orientation and the time course of the experiments (Experiment Half and Order of Experiment Presentation) were all non-significant, the trends are consistent with those observed in the analyses carried out in Experiments Six and Seven

6.5 Summary of Experimental Design and Results for Experiments Six, Seven and Eight

Design

In each of the three experiments reported in this chapter participants were presented with a series of trials on which they viewed a number of object images (one after another) followed by the name of an object written in the middle of the computer screen. Participants then had to respond as to whether or not they remembered seeing the named object by pressing a left and right positioned key. However, each experiment varied in the following ways:

<u>Experiment Six</u>

- four images presented on each trial
- stimulus processing time for each image – one second
- 100 msecs retention interval

Experiment Seven

- four images presented on each trial
- stimulus processing time for each image – 200 msecs
- one second retention interval

Experiment Eight

- eight images presented on each trial
- stimulus processing time for each image – 200 msecs
- one second retention interval

Results

The following represent a summary of the most important results to arise from the analyses carried out on experiments Six, Seven and Eight.

Stimulus Position Curve

In each of the three experiments analysis of the response time data for "Yes" responses to oriented objects suggested the presence of both a primacy and a recency effect. However, in follow-up analyses only the recency effects were found to be significant. Moreover, the analyses suggested the presence of a one item recency effect in each experiment. This finding is consistent with literature that suggests that a characteristic of short-term visual memory is the one item recency effect (Phillips and Christie, 1977).

Analysis of data sets for "Yes" responses to non-oriented objects and "No" responses

Data sets for "Yes" responses to non-oriented objects and "No" responses to named objects not present on the trial were collected for Experiments Seven and Eight. The only significant compatibility effect observed in these two data sets was a three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation in the error data for "No" responses in Experiment Eight. This interaction suggested the presence of an incompatibility effect when Experiment Eight was run before Experiment Seven and a compatibility effect when Experiment Eight was run after Experiment Seven.

Although no other compatibility effects were found to be significant in these two data sets, a number of trends were observed in the data which were consistent across data sets and considered of theoretical importance. These are reported below.

Compatibility and Incompatibility Effects

A combination of significant interactions and trends were observed across all experiments and all data sets, as follows:

- A significant compatibility effect was observed in the response time data of Experiment Six. This was expressed as an interaction between Object Orientation and Hand of Response.
- A trend in the error data for "Yes" responses to oriented objects of Experiment Seven suggested the presence of an incompatibility effect. The effect was expressed as an interaction between Object Orientation and Hand of Response.
- A trend in the response time data for "Yes" responses to non-oriented objects in Experiment Seven suggested the presence of an incompatibility effect. The effect was expressed as an interaction between Object Orientation and Hand of Response.
- A trend in the error data for "Yes" responses to non-oriented objects in Experiment Seven suggested the presence of an incompatibility effect. The effect was expressed as an interaction between Object Orientation and Hand of Response.
- A trend in the response time data for "No" responses in Experiment Seven suggested the presence of both a compatibility effect and an incompatibility effect. The effect was expressed as an interaction between Object Orientation, Hand of Response and Order of Experiment Presentation. The data suggested that when Experiment Seven was run before Experiment Eight an incompatibility was present but when Experiment Seven was run after Experiment Eight a compatibility effect was present.

- A trend in the response time data for "Yes" responses to oriented objects in Experiment Eight suggested the presence of both a compatibility and an incompatibility effect. The effect was expressed as an interaction between Object Orientation, Hand of Response and Order of Experiment Presentation. The data suggested that when Experiment Eight was run before Experiment Seven an incompatibility effect was present but when Experiment Eight was run after Experiment Seven a compatibility effect was present.
- A trend in the error data of "Yes" response to non-oriented objects in Experiment Eight suggested the presence of a compatibility effect. The effect was expressed as an interaction between Object Orientation and Hand of Response.
- Both a significant compatibility effect and an incompatibility effect were observed in the error data of the "No" responses in Experiment Eight. The effects were expressed as an interaction between Object Orientation, Hand of Response and Order of Experiment Presentation. The data suggested that when Experiment Eight was run before Experiment Seven an incompatibility effect was present, but when Experiment Eight was run after Experiment Seven an incompatibility effect was present.

Interactions between Object Orientation and the Time Course of the Experiments

The interactions between Object Orientation and the time course of the experiments were expressed as both interactions between Object Orientation and Experiment Half, and Object Orientation and Order of Experiment Presentation. As with the compatibility and incompatibility effects these were a combination of significant interactions and trends across all data sets.

- A trend in the response time data of Experiment Six suggested the presence of an interaction between Object Orientation and Experiment Half. The data suggested that in the first half of the experiment responses to right-oriented objects were executed faster than responses to left-oriented objects, but in the second half of the experiment responses to left-oriented objects were executed faster than responses to right-oriented objects.

- A significant interaction was observed between Object Orientation and Order of Experiment Presentation in the response time data for "Yes" responses to oriented objects in Experiment Seven. The data suggested that when Experiment Seven was run before Experiment Eight responses to right-oriented objects were executed faster than responses to left-oriented objects, but when Experiment Seven was run after Experiment Eight responses to left-oriented objects were executed faster than responses to right-oriented objects.
- A trend in the response time data for "Yes" responses to oriented objects in Experiment Seven suggested the presence of an interaction between Object Orientation, Experiment Half and Order of Experiment Presentation. The data suggested that when Experiment Seven was run before Experiment Eight responses to right-oriented objects in the first half of the experiment were executed faster than responses to left-oriented objects and responses to left-oriented objects in the second half of the experiment were executed faster than responses to right-oriented objects. However, when the experiments were run in the reverse order no interaction between Object Orientation and Experiment Half was observed.
- A trend in the response time data for "Yes" responses to oriented objects in Experiment Eight suggested an interaction between Object Orientation and Order of Experiment Presentation. The data suggested that when Experiment Eight was run before Experiment Seven responses to right-oriented objects were executed faster than responses to left-oriented objects. However, when Experiment Eight was run after Experiment Seven responses to left-oriented objects were executed faster than responses to right-oriented objects.
- A trend in the error data for "Yes" responses to oriented objects in Experiment Eight suggested an interaction between Object Orientation and Order of

Experiment Presentation. The data suggested that when Experiment Eight was run before Experiment Seven more errors were made to left-oriented objects than to right-oriented objects, but when Experiment Eight was run after Experiment Seven more errors were made to right-oriented objects than to left-oriented objects.

- A trend in the response time data for "Yes" responses to oriented objects in Experiment Eight suggested an interaction between Object Orientation and Experiment Half. The data suggested that in the first half of the experiment responses to right-oriented objects were executed faster than responses to left-oriented objects and in the second half of the experiment responses to left-oriented objects were executed faster than responses to right-oriented objects.
- A trend in the response time data for "No" responses in Experiment Eight suggested an interaction between object Orientation and Order of Experiment Presentation. The data suggested that when Experiment Eight was run before Experiment Seven responses to right-oriented objects were executed faster than responses to left-oriented objects. However, when Experiment Eight was run after Experiment Seven responses to left-oriented objects were executed faster than responses to right-oriented objects.

6.6 General Discussion

The main aim of the three experiments described in this chapter was to identify micro-affordance effects arising from the relationship between the orientation of an object for grasping and hand of response in a short-term visual memory task. In each of the three experiments participants were shown a series of object images, one after another on a computer screen, for varying durations, followed by the name of an object written in the middle of the computer screen. Participants were then asked to press a left or right positioned key with their left and right hands to declare whether or not they remembered seeing the named object in the series of object images just viewed. In each series of object images participants were presented with one object that was maximally compatible with either a left or right-hand power grasp and the remaining objects which were neither optimally compatible with a left or right-hand grasp.

The response data for trials on which participants made a response to an oriented object was separated from the rest of the trials for analysis on each of the three experiments. Analysis of this data set for Experiment Six suggested the presence of micro-affordance effects. The results revealed a significant compatibility effect between hand of response and orientation of an object for grasping. In contrast, analysis of the same data sets for experiments Seven and Eight revealed no significant micro-affordance effects. However, in both these experiments the data did suggest trends. Unlike Experiment Six, the data from Experiment Seven suggested the presence of an incompatibility effect between hand of response and orientation of an object for grasping. Similarly, in Experiment Eight the data again suggested the presence of an incompatibility effect between hand of response and orientation of an object for grasping, but this time the trend was only present when Experiment Eight was run before Experiment Seven. When the two experiments were run in reverse order a trend in the data suggested the presence of a compatibility effect.

For experiments Seven and Eight, analyses were also carried out on the data sets for responses to non-oriented objects and responses to named objects not present on a trial, i.e. the "No" response trials. The most important finding to arise from these analyses was a significant three-way interaction between Object Orientation, Hand of Response and Order of Experiment Presentation in the error time data for "No" responses in Experiment Eight. The finding revealed the presence of an incompatibility effect when Experiment Eight was run before Experiment Seven but a compatibility effect when Experiment Eight was run after Experiment Seven. This interaction can be seen to mirror the trend observed in the response time data for "Yes" responses to oriented objects in Experiment Eight, and reported above. A similar trend was also observed in the response time data for "No" responses in Experiment Seven. As with the response time data for "Yes" responses to oriented objects and the error data for "No" responses in Experiment Eight, the trend in Experiment Seven suggested the presence of an incompatibility effect when Experiment Seven was run before Experiment Eight and a compatibility effect when Experiment Seven was run after Experiment Eight.

Analyses carried out on the data set for "Yes" responses to non-oriented objects in Experiment Seven also revealed consistent trends with those observed in the analyses carried out on "Yes" responses to oriented objects in Experiment Seven. The data suggested the presence of an incompatibility effect in both the response time data and the error data, and this effect can be seen to mirror the incompatibility effect observed in the response time data for "Yes" responses to oriented objects in Experiment Seven.

The significant interaction in the error data for "No" responses in Experiment Eight, together with trends observed in the other data sets for both "No" responses and "Yes" responses to non-oriented objects, reported above, have two important implications.

Firstly, the effects lend support to results of analyses on data from "Yes" responses to oriented objects carried out on all three experiments. Secondly, the effects suggest that the presence of an object on a trial on which participants are responding to a non-oriented object, or making a "No" response to a named object not present on the trial, have the potential to both produce and inhibit micro-affordance effects in the viewer.

The difference in results between experiments Six, Seven and Eight can be explained with reference to a number of design differences between the three experiments. Firstly, Experiment Six differed from Experiments Seven and Eight in that stimulus duration for the presentation of each object image in Experiment Six was one second, whereas in Experiments Seven and Eight it was 200 msecs. In addition, the interval between presentation of the last object image and presentation of the response cue was 100 msecs in Experiment Six and one second in experiments Seven and Eight. Experiment Seven also differed from Experiment Eight in that in Experiment Seven participants were presented with four images on each trial, whereas in Experiment Eight participants were presented with eight object images on each trial.

Due to a confound between the stimulus retention period and the stimulus processing time in experiments Six and Seven it is difficult establish exactly which of these factors were responsible for the difference in results between Experiment Six and the other two experiments. However, it seems reasonable to assume that either or both these factors could influence participants' ability to form and maintain visual representations.

Returning to the analysis of the data for "Yes" responses to oriented objects in Experiment Six, it can be seen that the results clearly demonstrate the presence of micro-affordance effects arising from the relationship between hand of response and orientation of an object for grasping in off-line visual processing. The results of Experiment Six can be contrasted with a similar experiment carried out by Richardson et al, and reported in Chapter Two. Although the results of that experiment also provided evidence of an interaction between hand of response and orientation of an object for grasping in off-line vision, the results of that experiment showed evidence for the inhibition of afforded actions. These inhibition or 'incompatibility' effects are therefore more consistent with the results of experiments Seven and Eight. It should be noted that Richardson et al's experiment did differ from the three experiments reported here in that participants were presented with eight object images on each trial for a period of 200 msecs each, followed by a verbally presented object name. However, this design was very similar to that used in Experiment Eight.

Consistent with Richardson et al's predictions, the expression of compatibility and incompatibility effects do appear to be dependent on the mean response times in each experiment. The analysis carried out on Experiment Six revealed much faster response times on average (750 msecs approximately) than the Richardson et al experiment (1500 msecs approximately). However, an alternative explanation for the difference in results is also possible.

In experiments Seven and Eight, trends in the data suggested that incompatibility effects were associated with either responses carried out early in each experiment (first half of experiment) or when the experiment was the first experiment run in series (order of experiment presentation). In both cases the data suggest that responses were slower in the first half of experiments or when the experiment was the first experiment run in series (order of experiment presentation). However, just as response times were slower in the first half of the experiments and or when one experiment was run before another experiment, exposure to the stimuli producing the effects was also shorter. Participants would have viewed the stimuli twice as often by the end of an experiment than when they were halfway through the experiment. Moreover, this effect would be more profound in Experiment Six. In that experiment participants viewed each object image for a period of one second and therefore would have processed the images for a longer period early on in the experiment. By contrast, in Experiments Seven and Eight participants viewed each object image for a period of only 200 msecs. It is interesting to note therefore that in the experiments in which the object images would have been processed for the least amount of time, experiments Seven and Eight, only a hint of a compatibility effect was observed at the end of Experiment Eight. In the experiment in which the object images would have been processed for the most amount of time, Experiment Six, a compatibility effect was observed throughout the experiment. It is recognised, of course, that this effect could also have been due to the stimulus retention period which also differed between Experiment Six and experiments Seven and Eight. In Experiment Six the stimulus retention period was 100 msecs and in experiments Seven and Eight, one second. Further study would be required to tease apart these factors and investigate the alternative explanation presented here for the expression of compatibility and incompatibility effects.

The results of Experiment Six can also to be contrasted with those of Experiments Three and Four reported earlier in this thesis. In both those experiments participants were asked to carry out reaction time tasks whilst forming visual mental images. However, the results of these two experiments found no significant micro-affordance effects arising from the relationship between the orientation of an object for grasping and hand of response. By contrast, the results of Experiment Six did find evidence for this type of micro-affordance effect. The results of this experiment therefore seems to demonstrate that the representations held in short-term visual memory can facilitate micro-affordance effects arising from compatibility between the orientation of an object for grasping and hand of response. In addition, the trends observed in experiments Seven and Eight also appear to demonstrate that the representations held in short-term visual memory can lead to the inhibition of this type of micro-affordance effect. To further support the claim that it was the representations held in short-term visual memory that gave rise to the results of experiments Six, Seven and Eight, a one-item recency effect was observed in all three experiments – an effect which is considered a property of short-term visual memory (Phillips and Christie, 1977).

Another major finding to arise from the analyses of the data sets in which participants made responses to oriented objects, was a significant interaction between object orientation and order of experiment presentation in Experiment Seven. The interaction showed that when Experiment Seven was run before Experiment Eight responses to right-oriented objects were executed faster than responses to left-oriented objects, but when Experiment Seven was run after Experiment Eight responses to left-oriented objects were executed faster than responses to right-oriented objects. Although this significant effect was not repeated for Experiment Eight, the data from Experiment Eight did suggest a similar trend in both the response time data and the error data. Interestingly, further trends, in the data from experiments Seven and Eight, and Experiment Six, suggested an interaction between Object Orientation and Experiment Half (first and second halves of the experiment).

The data suggested that in the first half of the experiment responses to right-oriented objects were executed faster than responses to left-oriented objects, but in the second half of the experiments responses to left-oriented objects were executed faster than responses to right-oriented objects. The same pattern of interaction was repeated in Experiment Eight. In Experiment Seven the data showed a three-way interaction between Object Orientation, Experiment Half and Order of Experiment Presentation. When Experiment Seven was run before Experiment Eight responses to right-oriented objects were executed faster than responses to left-oriented objects in the first half of the experiment, but responses to left-oriented objects were executed faster than responses to right oriented-objects in the second half of the experiment. When the experiments were run in reverse order no interaction was observed between object orientation and experiment half. In both halves of the experiments responses to left-oriented objects were executed faster than responses to right-oriented objects.

As was the case with the expression of the micro-affordance effects and incompatibility effects, analysis of the response time data for "No" responses in Experiment Eight gave support to the above findings. The data revealed a trend between Object Orientation and Order of Experiment Presentation which mirrored that observed in analysis of the response time data for "Yes" responses to oriented objects. The data suggested that when Experiment Eight was run before Experiment Seven responses to right-oriented objects were executed faster than responses to left-oriented objects. However, when Experiment Eight was run after Experiment Seven, responses to left-oriented objects were executed faster than responses to right-oriented objects.

As suggested in previous chapters, the presence of orientation effects in these experiments could be taken as evidence to support the proposal that participants have prototypical object representations containing orientation information held in long-term memory. The proposal is that orientation effects are observed because there is a processing advantage for viewed objects when there is a correspondence between the orientation of a viewed object and the orientation of a prototypical object representation stored in long-term memory. In addition, the consistency across participants for the advantage of one object orientation over another can be accounted for in terms of the handedness (left or right) of participants.

If the proposal that orientation effects are a result of a processing advantage arising from a correspondence between the orientation of a prototype object and a seen object is correct, then the question arises as to why the initial advantage for faster responses to right-oriented objects observed over the time course of the three experiments reported in this chapter, reverses and becomes an advantage for left-oriented objects.

The first point to note in trying to find an explanation for the reversal of orientation effects is that it coincides with the change over time in the expression of the compatibility and incompatibility effects observed in experiments Six, Seven and Eight. In all the experiments and across the majority of data sets, it was observed that either early in the experiments (first half of the experiments) or when an experiment was the first experiment run in a series of two experiments, either trends towards incompatibility effects or weak compatibility effects were observed. However, late in the experiments (second half of the experiments) or when an experiment was the second experiment run in a series of two experiments, either trends toward compatibility effects or strong compatibility effects were observed. Similarly, it was observed that either early in the experiments (first half of the experiments) or when an experiment was the first experiment run in a series of two experiments the data suggested faster response times to right-oriented objects than to left-oriented objects. However, late in the experiments (second half of the experiments) or when an experiment was the second experiment run in a series of two experiments, the data suggested faster response times to left-oriented objects than to right-oriented objects.

As reported above, Richardson et al propose that compatibility effects are observed when participants produce relatively fast response times and incompatibility effects are observed when participants produce relatively slow response times. As reported in Chapter Two this proposal is based on Stoet and Hommel's (1999) Theory of Event Coding. According to this theory, perception and actions are coded in a shared medium. Following presentation of an object image, features of the viewed object can facilitate compatible or overlapping responses, e.g. a left-oriented object and a left-hand grasp. However, having attended to the object for a certain period of time, the features codes that give rise to the compatible responses become incorporated in an 'event file'. This event file is said to consist of a temporal binding of the feature codes and action codes that originally facilitated compatible responses. Once this binding occurs the codes are no longer available for the planning and control of other actions and therefore an incompatibility effect is observed.

Unlike compatibility and incompatibility effects, orientation effects are believed to represent a processing advantage for the particular orientation of a seen object because the prototype of that object used for object recognition shares the same orientation. Importantly, this processing advantage is not dependent on the hand of response of the viewer and therefore does not give rise to particular action codes. It seems unlikely, therefore, that the Theory of Event Coding can be employed to explain the reversal of the orientation effects. However, the reversal of the orientation effects may still be explained with reference to the presence of compatibility and incompatibility effects.

One explanation to be explored is the possibility that reversal of the orientation effects arises due to a combining of the response time advantage for orientation effects with the response time advantage for affordance effects. However, on closer inspection this proposal does not appear credible. To illustrate, it can be observed in Figure 48 that when a compatibility effect occurs there is a speed of response advantage from the affordance effects for left-hand responses to left-oriented objects and for right-hand responses to right-oriented objects. In addition, the presence of orientation effects (given a right-handed population) would suggest that there is also an advantage for right-oriented objects irrespective of the hand of response.

Compatibility Effects			
		Object Orientation	
		Left	Right
Hand of Response	Left	Δ	Π
	Right		ΔΠ

Δ = Response Time Advantage to arise from Affordance Effects
Π = Response Time Advantage to arise from Orientation Effects

Figure 48
Table to illustrate the combining of response time advantages for compatibility effects and orientation effects.

At first glance this proposal suggests that right-oriented objects have a double processing advantage over left-oriented objects and should result in an orientation effect in favour of right-oriented objects. However, as we saw from the data in this chapter, the advantage for right-oriented objects co-occurred with the incompatibility effect and not the compatibility effect. In addition, if one observes the situation when an incompatibility effect co-occurs with an orientation effect the proposal becomes even less likely. To illustrate, it can be observed in Figure 49 that when an incompatibility effect occurs there is a response time advantage from the affordance effects for left-hand responses to right-oriented objects and for right-hand responses to left-oriented objects. In addition, the presence of orientation effects (given a right-handed population) would again suggest that there is an added response time advantage for right-oriented objects irrespective of the hand of response.

Incompatibility Effects

		Object Orientation	
		Left	Right
Hand of Response	Left		ΔΠ
	Right	Δ	Π

Δ = Response Time Advantage to arise from Affordance Effects
Π = Response Time Advantage to arise from Orientation Effects

Figure 49
Table to illustrate the combining of response time advantages for incompatibility effects and orientation effects.

Therefore, once again, there appears to be an added processing advantage for right-oriented objects over left-oriented objects. Although in this instance the situation would be consistent with the experimental findings, that right-oriented objects have a processing advantage over left-oriented objects, the situation with the presence of an incompatibility effect does not differ from the presence of a compatibility effect. In order to account for reversal of the orientation effects further investigation is required.

Chapter Seven

This chapter is divided into three sections. In the first section a summary of the major experimental findings to arise from this study are reported. In the second section of the chapter, these findings are discussed further in relation to their theoretical implications. Finally in section three, a number of unanswered questions to arise from the study are addressed together with ideas for future research.

7.1 Major Experiment Findings

There are three main areas of interest to arise from the experimental findings reported in this thesis: (1) micro-affordance effects in off-line visual processing; (2) Simon Effects in off-line visual processing, and (3) orientation effects in off-line visual processing. In this section of this chapter these findings are reported together with a discussion of the differences that exist between different off-line visual processes and the methodologies employed to investigate these processes.

Micro-affordance Effects in Off-line Visual Processing

Based on evidence for micro-affordance effects in on-line vision (Tucker and Ellis, 1998; Ellis and Tucker, 2000 and Tucker and Ellis, 2001), two types of micro-affordance effects in off-line vision were investigated. These are (1) the compatibility of an object for grasping with the power and precision component of the reach-to-grasp action, and (2) the compatibility between the orientation of an object for grasping and hand of response.

In the first experiment reported in this thesis a new experimental design was employed in an effort to identify micro-affordance effects arising from the power and precision component of the reach-to-grasp action. On each experimental trial participants were shown an array of four objects which were a combination of naturally formed objects and manufactured objects. The objects varied in regard to their compatibility to be grasped by either a power or precision grasp. While viewing the array of objects, an arrow appeared in the middle of the computer screen directing attention toward one of the four objects. Participants then had to decide whether or not the object being pointed at was 'naturally formed' or 'manufactured' by making either a precision response action or a power response action, depending on the mapping rule given. Using the new design, evidence was sought for micro-affordance effects in on-line vision. Consistent with the findings of earlier studies seeking evidence for micro-affordance effects in on-line vision compatibility effects were observed between the power and precision component of the reach-to-grasp action and the compatibility of the object for grasping, in both the response time data and the error data.

Having confirmed the efficacy of the new experimental design in on-line vision, the design was then used in Experiment Two in an effort to identify micro-affordance effects in a visual mental imagery experiment. In order to use the experimental design in a visual mental imagery task, identification of the target object was delayed until after the array of objects were removed from view. The arrow used to identify the target object appeared on a blank screen pointing towards the position previously occupied by one of the objects in the array. In this way participants were required to remember and recall the array of objects and their spatial positions to complete the task. Consistent with the findings of Experiment One, compatibility effects were again revealed in both the response time data and the error data.

Micro-affordance effects arising from the power and precision component of the reach-to-grasp action in off-line vision were again investigated in Experiment Five. Once again, an experimental design was employed in which participants were asked to form a visual mental image whilst carrying out a response time task. However, the design of Experiment Five differed from that used in Experiment Two. In this experiment on each of four blocks of trials participants were shown the image of one object that was either compatible with a power or precision grasp and placed on either the left or right side of the computer screen. Having memorised the image participants then completed a series of trials in which they responded with a power and precision response action to a high and low pitched tone whilst conjuring a visual mental image of the previously viewed object.

Unlike the findings of Experiment Two, no evidence of micro-affordance effects was observed in Experiment Five.

The absence of effects in Experiment Five suggests an effect of experimental design. In contrast to the design employed in Experiment Two, participants in Experiment Five did not have to carry out a categorisation task based on the objects viewed. In addition, participants only had to remember one object image on each trial instead of the four presented to participants in Experiment Two. Importantly, it can be argued that participants in Experiment Five did not have to form visual mental images in order to complete the task, but instead only had to respond to the high and low pitched tones. Participants' compliance with the instructions to form a visual mental image was totally reliant on their motivation. By contrast, in Experiment Two participants had to make a categorisation decision based on the memory of which object was present at the position identified by the arrow.

In Experiment Three evidence was sought for micro-affordance effects arising from the relationship between the orientation of an object for grasping and hand of response. Having identified micro-affordance effects for the power and precision component of the reach to grasp action in Experiment Two the same experimental design was used in Experiment Three. However, unlike Experiment Two no effects were observed in the data.

Although no micro-affordance effects were observed in Experiment Three a trend was observed in the data that was of theoretical importance as it did suggest that participants may have been utilising off-line visual representations of the recently viewed objects to complete the task. Although the result just failed to reach significance it was observed that for objects positioned at the top of the screen, left-oriented objects were responded to faster than right-oriented objects and for objects positioned at the bottom of the screen, right-oriented objects were responded to faster than left-oriented objects. As we will see later in this section, trends observed in experiments Four, Six, Seven and Eight suggest both the presence of main effects of object orientation and interactions between object orientation and the time course of the experiments.

In order to investigate further micro-affordance effects arising from the orientation of an object for grasping and hand of response in off-line vision, a second experiment, Experiment Four, was carried out. The design of the experiment was similar to that used in Experiment Five and described above. In the experiment participants completed four blocks of trials. At the start of each block of trials participants viewed a photograph containing two objects, each optimally oriented for grasping by a particular hand (left and right) and positioned one to the right and one to the left of the computer screen. Participants were then asked to complete a number of trials in which they viewed one or other of the objects viewed in the target photograph. The objects this time were positioned in the centre of the screen at a relatively neutral orientation[34]. Participants responded with a left or right key press to the two objects (depending on the mapping rule given), whilst at the same time trying to form a visual mental image of the same object as it had appeared in the target photograph. As in Experiment Five, compliance to the instructions to form a visual mental image were reliant on participants' motivation to adhere to the instructions, and, as with Experiment Five, no evidence of micro-affordance effects were observed.

Having failed to identify micro-affordance effects arising from the orientation of an object for grasping in two experiments employing a visual mental imagery task it was decided to look for the effects in a study using a short-term visual memory task. Although the visual mental imagery tasks used in the two studies reported above could be assumed to utilise short-term visual memory, it is recognised that visual mental imagery and short-term visual memory are not synonymous. As such a third experimental design was used in experiments Six, Seven and Eight.

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[34] The objects were positioned at 90° to the horizontal so that they were neither optimally compatible with a left-hand grasp or a right-hand grasp

The design of the experiments this time did not require participants to engage in visual mental imagery but instead aimed to tap short-term visual memory. In all three experiments participants completed a number of trials in which they were presented with a series of object images in succession followed by the name of an object printed in the middle of the computer screen. Participants then had to decide whether or not the named objects was one of the objects just viewed. Participants made 'yes' and 'no' responses by pressing keys positioned on the left and right of the keyboard (depending on the mapping rule given). Although it cannot be ruled out that participants were engaging in visual mental imagery, participants were only required to decide whether or not they had seen a named object in a previously seen series of object images. In contrast to results of experiments Three and Four, Experiment Six provided evidence of micro-affordance effects. Consistent with earlier experiments using seen objects a compatibility effect was observed between the orientation of an object for grasping and hand of response.

In contrast to results of Experiment Six, the results of experiments Seven and Eight found no evidence of compatibility effects. However, the data from these experiments did suggest evidence of trends towards incompatibility effects. The suggestion of incompatibility effects were of particular interest as similar effects were reported in a study carried out by Richardson et al (in preparation) which implemented a similar experimental design to the three experiments reported here.

Simon Effects

An additional effect to arise from the experiments carried out in this thesis was evidence of spatial Simon Effects (Simon, 1969) in off-line visual processing. Typically, the spatial Simon Effect is observed when a right-hand response results in faster response times to a right positioned stimulus than to a left positioned stimulus, and a left-hand response results in faster response times to a left positioned stimulus than to a right positioned stimulus. Although Experiment Three failed to find any evidence of micro-affordance effects in off-line visual processing, the experiment did find evidence of Simon

Effects. However, whether or not the spatial positioning of objects in the object array were responsible for the effects or the arrows used to direct attention to the position once occupied by the objects is a subject for debate. Research has shown that prior to the onset of an action response merely viewing left and right facing arrows produces patterns of brain activation normally associated with left and right action responses (Eimer, 1993; 1995).

In experiments Four and Five the spatial Simon effect was again observed in the data, although as reported above neither experiment found evidence of micro-affordance effects. In these experiments no arrow or other overt cue was used to direct participants attention to the position occupied by the previously viewed objects, so the effects could be assumed to arise from off-line visual processing of the recently viewed images. The presence of Simon Effects in visual mental imagery is not a new phenomenon as they had previously been reported by Tluaka and McKenna (1998). However, the presence of Simon Effects in these experiments, particularly Experiments Four and Five, were of particular interest as they suggest that participants were adhering to the instructions and trying to form some type of visual mental image or spatial representation based on the previously viewed objects whilst carrying out the response time task. Moreover, the presence of the Simon Effect combined with the absence of micro-affordance effects suggests spatial representations do not code for orientation.

Orientation Effects

Orientation effects manifested themselves as main effects of object orientation in those experiments investigating micro-affordance effects arising from the orientation of an object for grasping and hand of response. The presence of orientation effects suggested that one object orientation was more salient than another orientation because response times to objects oriented in one direction were faster than response times to objects oriented in the opposite direction. Although in most of the experiments the orientation effects failed to reach significance, in many instances the effects were nearing significance. Importantly, the observed trends seemed to be consistent across experiments.

The first indication of orientation effects was observed in Experiment Three. As reported in the last section an interaction, which just failed to reach significance, was observed between object orientation and position of the object image. The data suggested that for objects positioned at the top of the screen, left-oriented objects were responded to faster than right-oriented objects and for objects positioned at the bottom of the screen, right-oriented objects were responded to faster than left-oriented objects. Although no obvious explanation could be offered for the presence of the effect, it is considered of theoretical importance as it suggests participants were encoding the object arrays and using these representations whilst carrying out the response time task.

In Experiment Four there was again an indication of an orientation effect. The effect this time, which again just failed to reach significance, was a main effect of object orientation in favour of right-oriented objects. As in Experiment Three the effect was considered of methodological importance as it suggested that participants were encoding the recently viewed objects and using these representations in the response time task. In addition, the presence of orientation effects could be used to support the proposal for the existence of prototypical object representations that contain orientation information and are held in long-term memory.

In experiments Six, Seven and Eight, orientation effects were again observed. This time they were observed as interactions between object orientation and the time course of the experiments. Although the majority of evidence for orientation effects in these three experiments failed to reach significance[35], the trends were consistent across all three experiments. In each case the data suggested that during the early stages of the response time task, either during the first half of the experiment, or the first run experiment (when experiments Seven and Eight were run consecutively), responses to right-oriented objects were executed faster than responses to left-oriented objects. However, during the second half of the experiments, or the second run experiment, responses to left-oriented objects were executed faster than responses to right-oriented objects.

7.2 Theoretical Implications

In this section, the theoretical implications for each of the three main areas of experimental findings reported in the last section will be addressed. These are: (1) micro-affordances in off-line visual processing, (2) orientation effects in off-line visual processing and, (3) Simon Effects in off-line visual processing.

Micro-affordance Effects in Off-line Visual Processing

The main aim of this thesis was to develop our understanding of micro-affordance effects in off-line visual processing. As we saw in Chapter One a large body of evidence already exists for a number of types of micro-affordance effects in on-line vision and an understanding of the time-course of these effects (Tucker and Ellis, 1998; Ellis and Tucker, 2000; and Tucker and Ellis, 2001). However, only one study has provided evidence for micro-affordance in off-line vision (Richardson et al [in preparation]).

In achieving its aim this thesis has tried to clarify the position in regard to two explanations put forward to reconcile the Marrian and Gibsonian theories of visual perception. It was argued in Chapter One that the presence of micro-affordance effects in off-line vision is more consistent with an argument put forward by Ellis and Tucker (1998) to reconcile the Marrian and Gibsonian theories than an argument put forward by Goodale and Humphrey (1998). To recall the arguments reported in Chapter One, Goodale and Humphrey propose that the Gibsonian and Marrian theories of visual perception are reconcilable on the grounds that those sympathetic to the Gibsonian theory are concerned with visual abilities that are primarily under the remit of the dorsal stream, such as affordance effects. Whereas, the theory proposes that those sympathetic to the Marrian

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[35] A significant interaction was observed between object orientation and order of experiment presentation in Experiment Seven.

approach to vision, are mainly concerned with visual abilities that are under the remit of the ventral system. Importantly, the authors also propose that the dorsal stream is important for visuomotor co-ordination, which they consider an 'on-line' property of visual processing. This approach therefore emphasises the relative independence of the two visual streams.

By contrast Ellis and Tucker (1998) put forward an approach that both emphasises the mutual dependence of the two visual systems and suggests the involvement of other cortical areas. According to this argument, object representation in the brain is the coupling or binding of visual responses with action related responses. It follows from this argument, that Marrian and Gibsonian approaches to vision cannot be independently attributed to the two visual pathways and affordance effects primarily to an on-line, visuomotor co-ordination system.

From the evidence presented in this thesis it has been shown that two micro-affordance effects can be observed without the aid of on-line visual processing. Evidence was provided for two types of micro-affordance effects in off-line vision: the compatibility of an object for grasping by either a power or precision grasp, and the orientation of an object for grasping by a particular hand. This evidence is therefore more consistent with the arguments put forward by Ellis and Tucker. Although the evidence does not rule out the role of the dorsal system in on-line motor co-ordination it does suggest that affordance effects are not a product of on-line motor co-ordination. In distancing affordance effects from an on-line visuomotor co-ordination system it either suggests that the dorsal system does have a role to play in off-line visual processing or that other areas and not the dorsal system are responsible for handling action encodings. As we saw in Chapter Two, the former view is consistent with evidence that has shown that the dorsal system is implicated in visual mental imagery tasks that require a spatial component (Farah, 2000; Uhl et al, 1990), tasks which clearly do not rely on on-line visual processing.

In providing evidence for micro-affordances in off-line vision, various aspects of the ecological theories of affordance can also be challenged. As we saw in Chapter One, various authors have put forward evidence for the existence of visual affordances (Warren, 1984; Todd, 1981; Lee et al, 1982; Warren et al, 1986). However, these authors all support the notion that affordances are directly detected by the visual system and do not require the existence of mental representations. In providing evidence for micro-affordance effects in off-line vision, it is difficult to account for the effects without presuming the existence of some sort of memory representation. Although it could be suggested that the effects occurred during the on-line visual processing of stimuli and persisted over the time course of the response time tasks, there are two reasons for thinking that this is not the case. Firstly, in the experiments that reported the effects, participants were unaware of the target objects that gave rise to the micro-affordance effects until after they had been removed from the screen. Secondly, the results of a study carried out by Tucker and Ellis, (2001) and reported in Chapter One, showed that micro-affordance effects normally terminate once an object is removed from view. It was only in the experiments reported here that when asking a participant to conjure up the mental image of an object, or to remember whether or not they had seen the image of an object, that the micro-affordance effects were again observed.

The evidence for micro-affordance effects in off-line vision, is also able to highlight differences which exist between two types of the micro-affordance effects – the compatibility of an object for grasping with either a power or precision grasp, and the orientation of an object for grasping by a particular hand (left and right).

It became apparent during the course of this study that different experimental designs were required to elicit these two types of micro-affordance effects in off-line vision. Although an experimental design aimed at inducing visual mental imagery was sufficient to elicit micro-affordance effects arising from the power and precision component of the reach-to-grasp action, the same design was not sufficient to elicit micro-affordance effects arising from the orientation of an object for grasping.

The difference in results obtained for these two effects led to an examination of the object attributes that are thought to give rise to the effects. It was recognised that the object attributes most likely to underlie the power and precision component of the reach-to-grasp action are 'object size' and 'object weight'. It was further recognised that object size could form both an 'extrinsic' and an 'intrinsic' object attribute, and object weight an intrinsic object attribute. For example, in a normal setting, due to size constancy cues (see Marr, 1982) an object such as a peanut would have a 'small' perceived size – an extrinsic object attribute. However, it would also be known to be small and light, as the viewer would have semantic knowledge about a peanut's attributes – an intrinsic object attribute. Given this observation it was recognised that in principle micro-affordance effects arising from the power and precision component of the reach-to-grasp action could have arisen as a result of extrinsic object attributes, intrinsic object attributes, or even a combination of both. Importantly, if the effects were found to have arisen from intrinsic object attributes then this would have implications for the type of representation necessary to elicit the effects. For example, it would suggest that the necessary representations need not be visual in nature but could instead be semantic. In the experiments reported here the effects could have arisen from verbal name labels given the objects during the encoding stage of the task and recalled during the response time task.

In contrast to the power and precision component of the reach-to-grasp action, micro-affordance effects arising from the 'orientation of an object for grasping' are judged to be dependent on an extrinsic object property, that of object orientation. It was argued in Chapter Four that in order for an optimally oriented object to potentiate compatible actions in the viewer, the viewer must process a viewer-centred representation of the object. During on-line vision this is the generally recognised situation, the visual system constructs a viewer-centred representation for further processing (Marr, 1982). However, when considering the type of representations available during off-line visual processing the situation becomes slightly more complicated.

Although one experiment reported in this thesis found clear evidence for micro-affordance effects arising from the orientation of an object for grasping in off-line visual processing, two experiments did not. It is argued that the reason for this finding was that the experiment in which the effects were observed was tapping a different off-line visual process to the two experiments that reported no effects. In the experiment that reported the effects the experimental design was such that it was believed to be directly accessing short-term visual memory. In contrast the two experiments that reported no effects were believed to be accessing visual mental imagery abilities. It has been recognised that unlike short-term visual memory, visual mental imagery can draw on several different cognitive processes, for example, long-term visual memory and semantic memory (Logie, 1995; Pearson et al 1999). In the one experiment that reported the micro-affordance effects it can be assumed that participants were accessing a viewer-centred visual object representation based on the recently viewed object and that this representation was held in short-term visual memory. However, in the two experiments that did not report effects it is possible that participants were drawing on cognitive resources in addition to, or instead of, short-term visual memory to complete the task.

For example, it could have been the case that participants were not utilising any type of off-line visual representation. Instead of forming visual mental images participants could have been using the strategy mentioned above in which they remembered the names and positions of the objects in the stimulus array and then recalled these to complete the task. However, if we are to assume that participants were using some form of off-line visual representation, then an alternative explanation is also available. Once again, it may have been the case that participants were remembering the object names and positions, but then using these semantic labels to construct visual mental images based on visual information held in long-term memory. One reason why participants might use this strategy would be to reduce the cognitive load involved in remembering an array of four visual objects. If participants did use this strategy then one may not expect to see micro-affordance effects arising from the orientation of an object for grasping, as the visual representations purported to be held in long-term memory and accessed by the semantic labels, may not have the same orientation information to the task stimuli. Although this argument is only speculation, there were a number of trends in the data that could be used to develop the argument.

As we will see in the next section, the trends of interest are those that demonstrate main effects of object orientation, and interactions between object orientation and stimulus position or the time course of the experiment.

Orientation Effects in Off-line Visual Processing

It was argued in Chapters Four and Five that the presence of main effects of object orientation could be taken to suggest the existence of prototype object representations held in long-term memory. These prototype object representations are purported to contain orientation information which when matched with the orientation of an object in a viewer-centred object representation[36], produce a processing advantage for the object contained in the viewer-centred representation, which is then reflected as orientation effects in the response time tasks.

The existence of prototype object representations is based on the recognition that the viewer-centred object representations produced during on-line vision are not sufficient to account for the process of object recognition. Instead, the visual systems requires some form of stored representation to help carry out this task. Several authors have argued that in order to carryout the process of object recognition one must possess some sort of object-centred representation (Biederman, 1987; Marr 1982). However, one attribute of object-centred representations is that they are said <u>not</u> to contain orientation information and therefore could not account for the orientation effects observed in this thesis.

As reported in Chapters Four and Five, Edelman (1994) has put forward an argument that suggests that object-centred representations are not necessary for the process of object recognition and instead prototype object representations can be used to account for the process of object recognition. Importantly, the concept of prototype representations suggests that such representations could contain orientation information, as according to Edelman's argument a prototype object representation can be formed from a limited number of viewer-centred representations. If one is then to assume that a particular object is viewed more often in one direction than another then the prototype could contain orientation information weighted in favour of the most viewed orientation.

In order that prototype object representations can account for the existence of the orientation effects observed in the experiments reported in this thesis, it is necessary that the consistency of the orientation of prototypes across participants be accounted for. One possible factor that can be used to account for this consistency is the handiness of the participants.

For the orientation of heads on coins it has been found that right-handed individuals can remember left-facing heads more easily than right-facing heads but for left-handed individuals the case is reversed (Martins and Jones, 1999). To explain these findings the authors proposed that motor memories for the drawing of heads is stored with the representations used in recognition, and that right-handed individuals are more likely to draw a head facing left and left-handed individuals with the head facing right. However, when the study looked at the memory for objects no effects were observed. If, as argued here, prototype objects representations may be stored with a particular orientation, then

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[36] On-line or off-line

perhaps one may have expected to see evidence of a recall advantage for objects as well as the direction of heads on coins. However, as we will see below, when considering the particular objects used in the Martins and Jones study, and the reasons why an object may be viewed more often in one direction than another, this lack of effect can be easily accounted for.

It can be noted that the argument used here to suggest that a prototype representation will contain orientation information is based on Edelman's argument that prototype representations are formed from a limited number of viewer-centred representations. In addition, it is argued that the prototype object representation will only contain orientation information if the object being represented has been viewed, or interacted with more often at one orientation than another. It can be argued that right-handed individuals are more likely to have viewed and interacted with objects with a right-oriented view than with a left-oriented view and that the converse would have been the case for left-handed left- individuals. Therefore, it can be further argued that the orientation of a prototype object for a right-handed individual is more likely to be right-oriented and that for a left-handed individual to be left-oriented. However, this would only be the case for objects that have an optimal orientation for grasping by a particular hand. For example, objects such as saucepans and toothbrushes have a function to fulfil and this requires that they be held by the handle. As such, the optimal orientation for these objects would be for the handles to be pointing towards the right-hand, given a right-handed individual. There are however, many objects that do not have an optimal orientation for grasping by a particular hand, for example a shoe. In the Martins and Jones study the objects were not selected on the basis of their likelihood to have been interacted with more often in one orientation than another and therefore the study contained object images such as shoes which have no optimal orientation for grasping by a particular hand.

The main effect of object orientation, which just failed to reach significance in Experiment Four in this thesis, appears to support the argument that handedness of participants may account for the orientation effects observed in the studies. The majority of participants taking part in Experiment Four were right-handed and right-oriented objects were responded to faster than left-orientated objects. In addition, three out of the four left-handed participants (75%) revealed faster response times to left-oriented objects than right-oriented objects, whereas only 11 out 35 right-handed participants (32%) revealed faster response times to left-oriented objects. Of course, due to the limited number of left-handed individuals participating in the study, further investigation would be required to confirm this proposal.

Trends observed in the results of experiments Six, Seven and Eight could also be used to support the existence of prototype oriented objects. However, the effects of object orientation observed in these experiments were found to interact with the time-course of the experiments, a finding which also requires explanation.

The interaction between object orientation and the time course of the experiment showed that early in the experiments (first half of the experiments) or when one experiment was the first experiment run in a series of two experiments, responses to right-oriented objects were executed faster than responses to left-oriented objects. However, late in the experiments (second half of experiments) or when one experiment was the second experiment run in a series of two experiments, responses to left-oriented objects were executed faster than responses to right-oriented objects.

As in Experiment Four, the majority of participants in experiments, Six, Seven and Eight were right-handed by self-report, and the initial expression of orientation effects was for an advantage for right-oriented objects. Although this initial advantage for right-oriented objects changed over the time course of the experiments, this finding need not be a problem for the argument that orientation effects arise from the existence of prototype object representations. It can be noted that the change in the orientation effects mirrors changes observed both in the expression of micro-affordance effects, and in response times across the time course of the experiments. In all the experiments and across the majority of data sets, it was observed that either early in the experiments (first halves of the experiments) or when an experiment was the first experiment run in a series of two experiments, either trends towards incompatibility effects or weak compatibility effects were observed. However, late in the experiments (second halves of the experiments) or when an experiment was the second experiment run in a series of two experiments, either trends toward compatibility effects or strong compatibility effects were observed. In addition, it was observed that during the first half of the experiments, or when an experiment was the first experiment run in a series of two experiments, response times were slower than during the second halves of the experiments, or when an experiment was the second experiment run in a series of two experiments. It can be argued that just as the reversal in the micro-affordance effects does invalidate the arguments put forward for the existence of the effects, the reversal of the orientation effects does not invalidate the claim that orientation effects arise from the presence of prototypical object representations used for object recognition. However, as stated above the reversal of the effects does require explanation.

As reported in Chapter Two, Richardson et al (in preparation) have proposed that the presence of compatibility or incompatibility effects is dependent on response latency. Fast response times are said to be associated with a compatibility effect and slow response times with an incompatibility effect. Support for this proposal is based on a Theory of Event Coding, recently developed by Stoet and Hommel (1999). As reported in Chapters Two and Six, this theory proposes that perception and actions are coded in a shared medium. It is argued that following immediate presentation of an object image, features of the viewed object can facilitate compatible or overlapping responses, e.g. a left-oriented object and a left-hand grasp. However, once these features have been activated for a certain period of time they become incorporated in what is termed an 'event file'. The event file consists of a temporal binding together of the feature codes and action codes that originally facilitated the compatible responses thereby making them no longer available for the planning and control of other actions. Once this binding occurs it is believed that an incompatibility effect is observed in the data.

Although the theory put forward by Richardson et al is dependent on response latency and the effects observed in experiments Six Seven and Eight show an interaction with the time-course of the experiment the two effects are not mutually exclusive. Analysis of response latencies over the time course of the experiments show that response times are faster in the second halves of the experiments than in the first halves, and that when an experiment is the second experiment run in a series of two experiments response times are also faster (although not always significantly). Given this observation, it is therefore possible that the observed interaction between object-orientation and time-course is, in fact, an interaction between object orientation and response latency.

Unlike compatibility and incompatibility effects, orientation effects are believed to represent a processing advantage for the particular orientation of a viewer-centred object representation because the prototype of that object used for object recognition purposes shares the same orientation. Importantly, this processing advantage is not dependent on the hand of response of the viewer and therefore is unlikely to give rise to particular action codes. It seems unlikely, therefore, that the Theory of Event Coding can be employed to explain the reversal of the orientation effects. However, the reversal of the orientation effects may still be explained with reference to the presence of the compatibility and incompatibility effects.

Before exploring one possible cause for the reversal of the orientation effects, it is first worth noting that the Richardson et al explanation for the expression of compatibility and incompatibility effects may not be correct. From the findings of experiments Six, Seven and Eight there appears to be at least one alternative explanation to explain the presence of the compatibility and incompatibility effects.

As we saw above, trends in the data of experiments Six, Seven and Eight suggested that incompatibility effects were associated with either responses carried out early in each experiment (first half of the experiment) or when one experiment was the first experiment run in series (order of experiment presentation). In both cases the data suggest that responses were slower in the first halves of experiments or when one experiment was the first experiment run in series (order of experiment presentation). However, just as response times were slower in the first halves of the experiments and or when one experiment was run before another experiment, exposure to the stimuli producing the effects was also shorter. Participants would have been exposed to the stimuli twice as often by the end of an experiment than when they had completed only half an experiment. Moreover, the effect of exposure to the stimuli would be more profound in Experiment Six than in the other two experiments, as in Experiment Six participants viewed the stimuli for a period of one second for each image and in experiments Seven and Eight, participants viewed the images for only 200 msecs each. It is interesting to note, therefore, that in the experiments in which the object images would have been processed for the least amount of time, experiments Seven and Eight, only a hint of a compatibility effect was observed at the end of Experiment Eight. By contrast, in the experiment in which the object images would have been processed for the most amount of time, Experiment Six, a compatibility effect was observed. It is recognised, of course, that this effect could also have been due to the stimulus retention period which also differed between Experiment Six and experiments Seven and Eight. In Experiment Six the stimulus retention period was 100 msecs and in experiments Seven and Eight, one second. In order to tease apart these two factors and investigate the proposed alternative explanation for the presence of compatibility and incompatibility effects, further investigation would be required.

Returning to an explanation for the reversal of the orientation effects one obvious explanation which was explored in Chapter Six, was the possible effects of the compounding of response time advantage from orientation effects with the response time advantage from micro-affordance effects. With the aid of Figures 6.4.1 and 6.4.2 (see Chapter Six) it was argued that the compounding of the two effects was unlikely to be a cause for the reversal of orientation effects. It was shown that whether or not micro-affordance effects were observed (compatibility effect) or inhibited (incompatibility effect), the data should show a processing advantage for right-oriented objects over left-oriented objects, given a right-handed participant population and not reverse to show a processing advantage for left-oriented objects. It seems clear, therefore that further investigation is required to both clarify the cause for the production of compatibility and incompatibility effects and the reversal of orientation effects over time. One other area that also requires further clarification relates to the findings of Experiment Three in which a trend in the data suggested that object orientation also interacts with object location within the visual field.

The data from Experiment Three suggested that for objects positioned to the top right and top left of the screen, responses to left-oriented objects were executed faster than responses to right-oriented objects. However, for objects positioned to the bottom right and bottom left of the screen, responses to right-oriented objects were executed faster than responses to left-oriented objects. As discussed in Chapter Four no obvious explanation can be put forward to explain this effect although the effect does appear to bear a resemblance to the findings of a study carried out by Michaels and Schilder (1991). In that study it was observed that moving an index finger on the right hand to the right of an initial starting position resulted in faster reaction times to a visual cue positioned at the top of the screen than to a cue positioned at the bottom of the screen. However, moving an index finger on the left hand to the right of an initial starting position resulted in faster reaction times to a visual cue positioned at the bottom of the screen than to a cue positioned at the top of the screen. Conversely, moving an index finger on the right hand to the left of an initial starting position resulted in faster reaction times to a visual cue positioned at the bottom of the screen than to a cue positioned at the top of the screen. Whereas moving an index finger on the left hand to the left of an initial starting position resulted in faster reaction times to a visual cue positioned at the top of the screen than a cue positioned at the bottom of the screen. Michaels and Schilder do not provide a precise explanation for the findings of this experiment, but instead use this and other experiments within the study to illustrate the complexity of S-R relationships. In identifying this complexity they then argue against traditional approaches to the relationship between perception and action, arguing instead for an ecological approach.

Although the findings of the Michaels and Schilder study do not map directly onto the results of Experiment Three, they do provide evidence for differential compatibilities between the left and right hands when an action (associated with "left" and "right" descriptors) is paired with stimuli positioned at the top and bottom of a computer screen.

A final note in relation to the existence of prototype object representations is that, in theory, their effect should not be confined to off-line visual processing as access to these representations is also required for the process of object recognition during on-line visual processing. Indeed, recent evidence from a study carried out by Ellis, Symes and Tucker (under review) suggest that orientation effects can be observed in on-line vision.

Simon Effects in Off-line Visual Processing

The presence of Simon Effects observed in this thesis can also help shed light on the nature of micro-affordance effects. Although in many respects micro-affordance effects and the Simon Effect share similarities, it has already been recognised that compatibility effects arising from the spatial Simon Effect differ in a number of ways from micro-affordance effects. As reported in Chapter One, Simon Effects can be elicited through colour cues whereas micro-affordances are not observed (Ellis, Symes and Tucker, under review). In addition, the time course the two effects have been found to differ. For micro-affordance effects longer response latencies have been shown to be associated with stronger effects (Ellis and Tucker, 2001), whereas for Simon Effects, longer response latencies have been found to be associated with weaker effects (Simon et al, 1976).

Interestingly, the proposal that longer response latencies are associated with stronger micro-affordance effects contradicts the explanation put forward by Richardson et al to explain the existence of compatibility and incompatibility effects. As reported earlier in this chapter, Richardson et al suggest that compatibility effects are dependent on relatively short response latencies whereas incompatibility effects are dependent on relatively long response latencies. Given this contradiction, it can be argued that weight is added to the suggestion put forward in the last section that response latency is not responsible for the expression of compatibility and incompatibility effects, but instead stimulus processing time or stimulus retention time.

From the experiments carried out in this study it has also become apparent that Simon Effects can be elicited in experiments designed to investigate visual mental imagery in the absence of any micro-affordance effects. This finding highlights the most important difference between the two effects - micro-affordances appear to arise from object based representations whereas Simon Effects arise from purely spatially based representations. In Chapter One a wide range of literature was discussed that supported the notion that the ventral pathway of the visual system was primarily responsible for object representation, the "what" pathway, and the dorsal pathway for visuomotor co-ordination, the "how" pathway. A major factor in visuomotor co-ordination is the processing of spatial information. Much of the literature used to support the distinction between the ventral and dorsal pathways reported dissociations between object representation and spatial processing. Indeed the clear distinction between these two types of processing originally led the two pathways to be named 'what' and 'where' pathways (Ungerleider and Mishkin, 1982). The presence of the Simon Effect in the absence of micro-affordance effects possibly reflects this same dissociation. Further support for this proposal can be seen when closer examination is made of the similarities that exist between Simon Effects and micro-affordance effects – particularly micro-affordance effects arising from the relationship between the orientation of an object for grasping and hand of response.

When discussing each of these effects the spatial labels "right" and "left" are used. However, as discussed in Chapter Five, Baylis and Driver (1993) have proposed that there is a distinction to be had between two types of spatial relations. According to these authors, spatial relation can be both 'object' based and 'frame' based. Object based spatial relations arise from the relative position of object contours which give rise to object shape. By contrast, frame based spatial relation arise from the relative position of one object in relation to another or the surrounding area. Simon Effects therefore do not require the processing of object spatial relations and can be dissociated from the processing of object representations. Similarly, micro-affordance effects arising from the orientation of an object for grasping rely on object shape and the relative position of the object contours and can therefore be associated with object based spatial relations.

7.3 Future Developments

Although the experiments reported in this thesis have been able to shed some light on the presence of micro-affordance effects in off-line vision, three major avenues for future research have been identified: (1) the encoding of orientation information in long-term memory representations as suggested by the presence of orientation effects; (2) the reversal of orientation effects over time; and (3) the role of intrinsic and extrinsic object attributes in the expression of micro-affordance effects arising from the power and precision component of the reach-to-grasp action. Each of these three areas is discussed below:-

The encoding of orientation information in long-term memory representations as suggested by the presence of orientation effects

The presence of orientation effects in those experiments investigating the relationship between object orientation and hand of response were totally unexpected. Although the majority of these effects were observed as only trends in the data, they were observed in four out the five experiments investigating the relationship between the hand of response and orientation of an object for grasping. If, as suggested, the effects occur as a result of prototype object representations held in long-term memory for the process of object recognition, then research is required to establish why the objects are coded with specific orientations. Of particular interest in this respect is the proposal that the encoding of specific object orientations may depend on the handedness of the individuals carrying out the response time tasks.

The reversal of orientation effects over time

The reversal of the orientation effects over time was observed in Experiments Six, Seven and Eight. These effects were observed as either interactions between Object Orientation and Order of Experiment Presentation (Experiment Seven run before Experiment Eight and Experiment Eight run before Experiment Seven), or interactions between Object Orientation and Experiment Half (first and second halves of the experiments). Although the majority of these effects were observed as only trends in the data[37] they were consistent across all experiments. In all three experiments it was observed that early in the experiments or when one experiment was run first in a series of two experiments, right-oriented objects were responded to faster than left-oriented objects, but later in the experiments, or when one experiment was run second in a series of two experiments, left-oriented objects were responded to faster than right-oriented objects.

In the data collected from the three experiments it is not clear which factors are responsible for the reversal of orientation effects, however, three factors which require further investigation have been identified. Firstly, response times were found to be faster in the second halves of the experiments or when an experiment was the second experiment run in a series of two experiments than in the first halves of the experiments or when an experiments was the first experiment run in a series of two experiments. Secondly, exposure to the visual stimuli, and therefore stimulus processing time, was judged to be greater in the second halves of the experiments or when an experiment was the second experiment run in a series of two experiments than in the first halves of the experiments or when an experiment was the first experiment run in a series of two experiments. Thirdly, the reversal of the orientation effects was seen to mirror a reversal in the micro-affordance effects. The data from the three experiments seemed to suggest that in the first halves of the experiments or when an experiment was the first experiment run in a series of two experiments trends toward negative compatibility effects or weak compatibility effects were observed. However, in the second halves of the experiments or when an experiment was the second experiment run in a series of two experiments trends towards compatibility effects or strong compatibility effects were observed.

A final matter which appears to require further investigation in relation to the reversal of the orientation effects is based on the observation that the first of the two factors listed above, stimulus response time and stimulus processing time, tend to be compounded in response time experiments. It can be noted that as stimulus-processing time increases, stimulus response time decreases. This point is considered of importance as the explanation for the reversal of micro-affordance effects put forward by Richardson et al (in preparation) is based on the premise that relatively short response times produce compatibility effects and relatively long response times produce incompatibility effects. However, as response latency tends to be confounded with stimulus processing time during a standard response time task, alternative explanations for the reversal of micro-affordance effects may be possible.

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[37] With the exception of the interaction between object orientation and order of experiment presentation in

The role of 'intrinsic' and 'extrinsic' object attributes in the expression of micro-affordance effects arising from the power and precision component of the reach-to-grasp action

From the experiments carried out in this thesis it was observed that an experimental design employing a visual mental imagery task was successful at inducing micro-affordance effects arising from the power and precision component of the reach-to-grasp action. However, the same design was not successful at inducing micro-affordance effects arising from the relationship between the orientation of an object for grasping and hand of response. One possible explanation for this difference in results arises from the different object properties that are thought to give rise to the two effects.

The object properties that produce micro-affordance effects arising from the power and precision component of the reach-to-grasp action are thought to be 'object size' and 'object weight', both of which can form intrinsic object attributes. By contrast, the object property thought to produce micro-affordance effects arising from the relationship between the orientation of an object for grasping and hand of response is 'object' orientation, a purely extrinsic object attribute. Given this difference it is arguable that the micro-affordance effects arising from the power and precision component of the reach-to-grasp action may not have arisen from off-line visual processing of a visual mental image, but may have arisen from semantically represented intrinsic object attributes. Further research needs to be carried out in order to establish whether or not intrinsic, extrinsic or both types of object attributes can give rise to micro-affordance effects.

Experiment Seven.

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Appendix A

List of 40 Objects used in Experiments One and Two

Naturally Formed Objects Compatible with a Power Grip

Parsnip
Courgette
Banana
Potato
Leek
Corn on the Cob
Sweet Potato
Cucumber
Squash
Aubergine

Naturally Formed Objects Compatible with a Precision Grip

Green String Bean
Grape
Pea Pod
Peanut
Spring Onion
Mushroom
Chilli
Brussel Sprout
Lychee
Strawberry

Manufactured Objects Compatible with a Power Grip

Screwdriver
Wire brush
Mallet
Trowel
Saucepan
Clothes Brush
Kitchen Knife
Gardening Folk
Torch
Hammer

Manufactured Objects Compatible with a Precision Grip

Coin
Biro
Small Paintbrush
Key
Pencil Sharpener
Screw
Teaspoon
Clothes Peg
Pencil
Small Bulldog Clip

Appendix B

Calculation of the Visual Angles for all Objects used in all Experiments

Tan (½ Visual Angle [VA]) = ½ D/Z

D= Object Height on Computer Screen
Z= Distance from Eye to Computer Screen

Experiments 1 & 2 – Objects between 1.5 cms and 13.5 cms

D = 1.5 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan(½ VA) = 0.75 / 50
" = 0.015
½ VA = Tan (0.015)
½ VA = 0.8593722
Visual Angle = 2 x 0.8593722
Visual Angle = 1.72°

D = 13.5 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 6.75/50
" = 0.135
½ VA = Tan (0.135)
½ VA = 7.6884478
VA = 2 x 7.6884478
Visual Angle = 15.38°

Experiment 3 – Objects between 6 cms and 13 cms

D = 6cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 3/50
" = 0.06
½ VA = Tan (0.06)
½ VA = 3.4336304
VA = 2 x 3.4336304
Visual Angle = 6.87°

D = 13 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 6.5/50
" = 0.13
½ VA = Tan (0.13)
½ VA = 7.4069121
VA = 2 x 7.4069121
Visual Angle = 14.81°

Experiment 4 – Objects between 8.5 cms and 15.38 cms

D = 8.5 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 4.25 / 50
" = 0.085
½ VA = Tan (0.085)
½ VA = 4.8584629
Visual Angle = 2 x 4.8584629
Visual Angle = 9.72°

D = 11.5 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 5.75/50
" = 0.115
½ VA = Tan (0.115)
½ VA = 6.5601964
VA = 2 x 6.5601964
Visual Angle = 13.12°

Experiment 5 Objects between 2 cms and 9.5 cms

D = 2 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 1/50
" = 0.02
½ VA = Tan (0.02)
½ VA = 1.1457628
VA = 2 x 1.1457628
Visual Angle = 2.29°

D = 9.5 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 4.75/50
“ = 0.095
½ VA = Tan (0.095)
½ VA = 5.4268125
VA = 2 x 5.4268125
Visual Angle = 10.85°

Experiments 6, 7 & 8 - Objects between 5.5 cms and 16 cms

D = 5.5 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

Tan (½ VA) = 2.75/50
“ = 0.055
½ VA = Tan (0.055)
½ VA = 3.1480961
VA = 2 x 3.1480961
Visual Angle = 6.30°

D = 16 cms Z = 50 cms

Tan (½ Visual Angle [VA]) = ½ D/Z

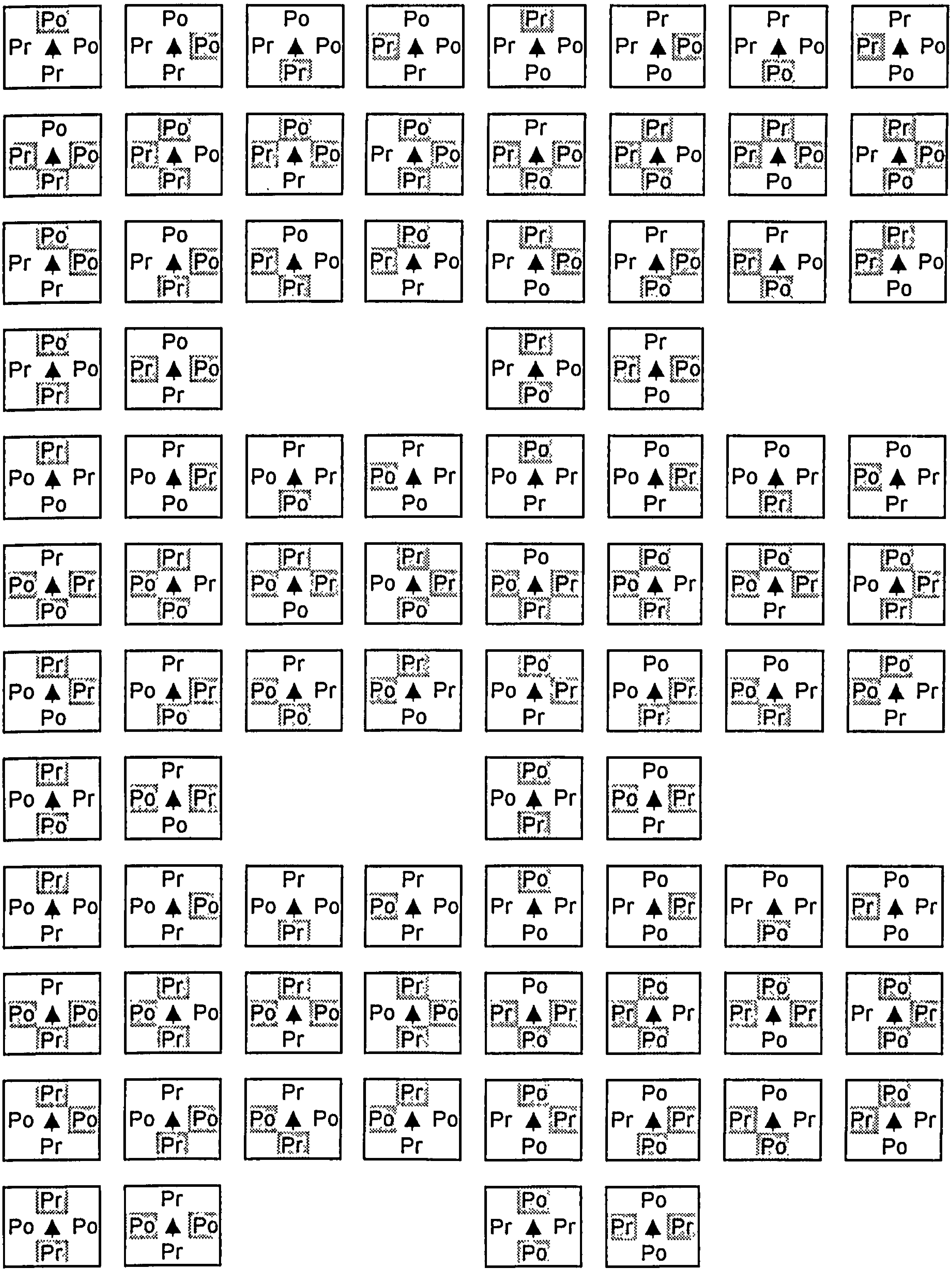
Tan (½ VA) = 8/50
“ = 0.16
½ VA = Tan (0.16)
½ VA = 9.0902769
VA = 2 x 9.0902769
Visual Angle = 18.18°

All Object Combinations for the Photographs used in Experiments One and Two

Note: each photograph would be shown four occasions with the arrow pointing to a different object on each occasion.

☐ = Manufactured Object Po = Power Graspable Object

▨ = Naturally Formed Object Pr = Precision Graspable Object



Appendix D

Instructions, Experiment One, Mapping One

In this experiment you will be presented with a series of pictures on the computer screen. Shortly after each picture appears, an arrow will appear on the screen. This arrow will point to one of four objects in the picture. Using the hand device provided, you are required to make a decision as to whether the object being pointed at is 'naturally formed' or 'manufactured'.

The hand device has two switches. One of the switches is held between your thumb and index finger and the other in the palm of your hand.

* If you decide the object being pointed at is naturally formed, please make a response by pressing the switch held between your thumb and index finger.

* If you decide the object being pointed at is manufactured, please make a response by pressing the switch held in the palm of your hand.

When you make your decision the picture will disappear and you will see an instruction asking you to get ready for the next picture. PLEASE MAKE YOUR RESPONSE AS FAST AS YOU CAN WHILST MAINTAINING ACCURACY.

If you make an error you will hear an error signal.

Before starting the main experiment you will be given a practice session.

The main experiment contains 336 trials and takes approximately 20 minutes.

Thank you for agreeing to participate in this experiment.

Please note:

* You are free to withdraw from this experiment at any time.
* A full debriefing as to the purpose of the study will be given after the experiment.

Exp1:Mapping One

Instructions, Experiment One, Mapping Two

In this experiment you will be presented with a series of pictures on the computer screen. Shortly after each picture appears, an arrow will appear on the screen. This arrow will point to one of four objects in the picture. Using the hand device provided, you are required to make a decision as to whether the object being pointed at is 'naturally formed' or 'manufactured'.

The hand device has two switches. One of the switches is held between your thumb and index finger and the other in the palm of your hand.

* If you decide the object being pointed at is manufactured, please make a response by pressing the switch held between your thumb and index finger.

* If you decide the object being pointed at is naturally formed, please make a response by pressing the switch held in the palm of your hand.

When you make your decision the picture will disappear and you will see an instruction asking you to get ready for the next picture. PLEASE MAKE YOUR RESPONSE AS FAST AS YOU CAN WHILST MAINTAINING ACCURACY.

If you make an error you will hear an error signal.

Before starting the main experiment you will be given a practice session.

The main experiment contains 336 trials and takes approximately 20 minutes.

Thank you for agreeing to participate in this experiment.

Please note:

* You are free to withdraw from this experiment at any time.
* A full debriefing as to the purpose of the study will be given after the experiment.

Expl:Mapping Two

Appendix E

Table 1
Experiment One: Mean Response Times for Power and Precision Responses to Power and Precision Compatible Objects in Mapping Conditions One and Two

Mapping Condition One*

Response Condition	Object Compatibility	
	Power	Precision
Power	688.91 (85.00)	738.16 (93.99)
Precision	677.99 (98.47)	693.23 (95.26)

Mapping Condition Two**

Response Condition	Object Compatibility	
	Power	Precision
Power	733.47 (95.96)	793.17 (124.52)
Precision	815.74 (132.41)	791.97 (112.95)

* precision response-naturally formed: power response-manufactured
** precision response–manufactured: power response-naturally formed

Appendix F

Experiment One: Three-way Mixed ANOVA Tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
GRIP	Sphericity Assumed	24561.722	1	24561.722	74.550	.000
	Greenhouse-Geisser	24561.722	1.000	24561.722	74.550	.000
	Huynh-Feldt	24561.722	1.000	24561.722	74.550	.000
	Lower-bound	24561.722	1.000	24561.722	74.550	.000
GRIP * MAPPING	Sphericity Assumed	1986.543	1	1986.543	6.030	.019
	Greenhouse-Geisser	1986.543	1.000	1986.543	6.030	.019
	Huynh-Feldt	1986.543	1.000	1986.543	6.030	.019
	Lower-bound	1986.543	1.000	1986.543	6.030	.019
Error(GRIP)	Sphericity Assumed	12190.262	37	329.467		
	Greenhouse-Geisser	12190.262	37.000	329.467		
	Huynh-Feldt	12190.262	37.000	329.467		
	Lower-bound	12190.262	37.000	329.467		
RESPONSE	Sphericity Assumed	1550.688	1	1550.688	.658	.422
	Greenhouse-Geisser	1550.688	1.000	1550.688	.658	.422
	Huynh-Feldt	1550.688	1.000	1550.688	.658	.422
	Lower-bound	1550.688	1.000	1550.688	.658	.422
RESPONSE * MAPPING	Sphericity Assumed	45659.893	1	45659.893	19.386	.000
	Greenhouse-Geisser	45659.893	1.000	45659.893	19.386	.000
	Huynh-Feldt	45659.893	1.000	45659.893	19.386	.000
	Lower-bound	45659.893	1.000	45659.893	19.386	.000
Error(RESPONSE)	Sphericity Assumed	87147.834	37	2355.347		
	Greenhouse-Geisser	87147.834	37.000	2355.347		
	Huynh-Feldt	87147.834	37.000	2355.347		
	Lower-bound	87147.834	37.000	2355.347		
GRIP * RESPONSE	Sphericity Assumed	33627.021	1	33627.021	8.204	.007
	Greenhouse-Geisser	33627.021	1.000	33627.021	8.204	.007
	Huynh-Feldt	33627.021	1.000	33627.021	8.204	.007
	Lower-bound	33627.021	1.000	33627.021	8.204	.007
GRIP * RESPONSE * MAPPING	Sphericity Assumed	5960.332	1	5960.332	1.454	.236
	Greenhouse-Geisser	5960.332	1.000	5960.332	1.454	.236
	Huynh-Feldt	5960.332	1.000	5960.332	1.454	.236
	Lower-bound	5960.332	1.000	5960.332	1.454	.236
Error(GRIP*RESPONSE)	Sphericity Assumed	151666.204	37	4099.087		
	Greenhouse-Geisser	151666.204	37.000	4099.087		
	Huynh-Feldt	151666.204	37.000	4099.087		
	Lower-bound	151666.204	37.000	4099.087		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	85734512.3	1	85734512.32	2232.319	.000
MAPPING	275114.696	1	275114.696	7.163	.011
Error	1421023.188	37	38406.032		

Table 2
Experiment One: Mean Number of Errors for Power and Precision Responses to Power and Precision Compatible Objects in Mapping Conditions One and Two

Mapping Condition One*

Response Condition	Object Compatibility	
	Power	Precision
Power	1.89 (2.44)	3.53 (2.17)
Precision	6.16 (3.74)	3.13 (2.96)

Mapping Condition Two**

Response Condition	Object Compatibility	
	Power	Precision
Power	2.25 (2.05)	4.50 (2.68)
Precision	4.95 (4.09)	2.90 (2.17)

* precision response-naturally formed: power response-manufactured
** precision response–manufactured: power response-naturally formed

Appendix H

Experiment One: Three-way mixed ANOVA Tables for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RESPONSE	Sphericity Assumed	64.672	1	64.672	19.346	.000
	Greenhouse-Geisser	64.672	1.000	64.672	19.346	.000
	Huynh-Feldt	64.672	1.000	64.672	19.346	.000
	Lower-bound	64.672	1.000	64.672	19.346	.000
RESPONSE * MAPPING	Sphericity Assumed	21.236	1	21.236	6.353	.016
	Greenhouse-Geisser	21.236	1.000	21.236	6.353	.016
	Huynh-Feldt	21.236	1.000	21.236	6.353	.016
	Lower-bound	21.236	1.000	21.236	6.353	.016
Error(RESPONSE)	Sphericity Assumed	123.687	37	3.343		
	Greenhouse-Geisser	123.687	37.000	3.343		
	Huynh-Feldt	123.687	37.000	3.343		
	Lower-bound	123.687	37.000	3.343		
GRIP	Sphericity Assumed	2.487	1	2.487	.632	.432
	Greenhouse-Geisser	2.487	1.000	2.487	.632	.432
	Huynh-Feldt	2.487	1.000	2.487	.632	.432
	Lower-bound	2.487	1.000	2.487	.632	.432
GRIP * MAPPING	Sphericity Assumed	4.846	1	4.846	1.232	.274
	Greenhouse-Geisser	4.846	1.000	4.846	1.232	.274
	Huynh-Feldt	4.846	1.000	4.846	1.232	.274
	Lower-bound	4.846	1.000	4.846	1.232	.274
Error(GRIP)	Sphericity Assumed	145.589	37	3.935		
	Greenhouse-Geisser	145.589	37.000	3.935		
	Huynh-Feldt	145.589	37.000	3.935		
	Lower-bound	145.589	37.000	3.935		
RESPONSE * GRIP	Sphericity Assumed	187.509	1	187.509	53.272	.000
	Greenhouse-Geisser	187.509	1.000	187.509	53.272	.000
	Huynh-Feldt	187.509	1.000	187.509	53.272	.000
	Lower-bound	187.509	1.000	187.509	53.272	.000
RESPONSE * GRIP * MAPPING	Sphericity Assumed	7.348E-02	1	7.348E-02	.021	.886
	Greenhouse-Geisser	7.348E-02	1.000	7.348E-02	.021	.886
	Huynh-Feldt	7.348E-02	1.000	7.348E-02	.021	.886
	Lower-bound	7.348E-02	1.000	7.348E-02	.021	.886
Error(RESPONSE*GRIP)	Sphericity Assumed	130.234	37	3.520		
	Greenhouse-Geisser	130.234	37.000	3.520		
	Huynh-Feldt	130.234	37.000	3.520		
	Lower-bound	130.234	37.000	3.520		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	2119.083	1	2119.083	94.562	.000
MAPPING	.212	1	.212	.009	.923
Error	829.147	37	22.409		

Instructions, Experiment Two, Mapping One

This study comprises two tasks:

Task One

The experiment comprises 336 trials. On each trial you will be presented with a picture on the computer screen. Each picture contains four objects. These objects will be positioned to the top, bottom, left and right of the picture. The picture will remain on the screen for 1.5 seconds before disappearing. A blank screen will then appear. After a further half second, an arrow radiating from the middle of the screen will point to a position on the screen previously occupied by one of the objects in the previous picture (top/bottom/left/right of the screen).

Using the hand device provided, you are required to make a decision as to whether the object at that position was 'naturally formed' or 'manufactured'.

The hand device has two switches. One of the switches is held between your thumb and index finger and the other in the palm of your hand.

- If you decide that the object was naturally formed, please make a response by pressing the switch held between your thumb and index finger (Precision Switch).

- If you decide that the object was manufactured, please make a response by pressing the switch held in the palm of your hand (Power Switch).

When you make your decision the picture will disappear and you will see an instruction asking you to get ready for the next picture. Please make your response as fast as you can whilst maintaining accuracy.
If you make an error you will hear an error signal.

IMPORTANT: IN ORDER TO AID YOU WITH TASK TWO IT IS IMPORTANT THAT YOU TRY TO FORM A MENTAL IMAGE OF EACH PICTURE BEFORE IT DISAPPEARS FROM VIEW, I.E. FORM A MENTAL IMAGE OF EACH OBJECT AND ITS POSITION ON THE SCREEN.

Task Two

At random intervals during the above task you will be given a memory test. The test will appear after you have responded to the 'Manufactured/Natural' decision task. The task will require that you remember the objects from the previous picture and the positions of those objects.

When the test appears, you will be presented with the names of four objects positioned to the top bottom left and right of the screen.
Your task is to decide whether that configuration of objects is correct or incorrect.

- If you think the configuration is correct you must press the small 'precision' switch.
- However, if you think the configuration is incorrect you must press the large 'power' switch. You will be reminded of the correct responses to make when the test appears.

After the memory test the trials will continue in the manner described above.

Before starting the main experiment you will be given a practice session.

Thank you for agreeing to participate in this experiment.

Please note:

* You are free to withdraw from this experiment at any time.
* A full debriefing as to the purpose of the study will be given after the experiment.

Exp2: Mapping One

Instructions, Experiment Two, Mapping Two

This study comprises two tasks:

Task One

The experiment comprises 336 trials. On each trial you will be presented with a picture on the computer screen. Each picture contains four objects. These objects will be positioned to the top, bottom, left and right of the picture. The picture will remain on the screen for 1.5 seconds before disappearing. A blank screen will then appear. After a further half second, an arrow radiating from the middle of the screen will point to a position on the screen previously occupied by one of the objects in the previous picture (top/bottom/left/right of the screen).

Using the hand device provided, you are required to make a decision as to whether the object at that position was 'naturally formed' or 'manufactured'.

The hand device has two switches. One of the switches is held between your thumb and index finger and the other in the palm of your hand.

* If you decide that the object was manufactured, please make a response by pressing the switch held between your thumb and index finger (Precision Switch).

* If you decide that the object was naturally formed, please make a response by pressing the switch held in the palm of your hand (Power Switch).

When you make your decision the picture will disappear and you will see an instruction asking you to get ready for the next picture. Please make your response as fast as you can whilst maintaining accuracy.
If you make an error you will hear an error signal.

IMPORTANT: IN ORDER TO AID YOU WITH TASK TWO IT IS IMPORTANT THAT YOU TRY TO FORM A MENTAL IMAGE OF EACH PICTURE BEFORE IT DISAPPEARS FROM VIEW, I.E. FORM A MENTAL IMAGE OF EACH OBJECT AND ITS POSITION ON THE SCREEN.

Task Two

At random intervals during the above task you will be given a memory test. The test will appear after you have responded to the 'Manufactured/Natural' decision task. The task will require that you remember the objects from the previous picture and the positions of those objects.

When the test appears, you will be presented with the names of four objects positioned to the top bottom left and right of the screen.
Your task is to decide whether that configuration of objects is correct or incorrect.

- If you think the configuration is <u>correct</u> you must press the small 'precision' switch.

- However, if you think the configuration is <u>incorrect</u> you must press the large 'power' switch. You will be reminded of the correct responses to make when the test appears.

After the memory test the trials will continue in the manner described above.

Before starting the main experiment you will be given a practice session.

Thank you for agreeing to participate in this experiment.

Please note:

* You are free to withdraw from this experiment at any time.
* A full debriefing as to the purpose of the study will be given after the experiment.

Exp2: Mapping Two

Appendix J

Table 3
Experiment Two: Mean Response Times for Power and Precision Responses to Power and Precision Compatible Objects in Mapping Conditions One and Two

Mapping Condition One*

Response Condition	Object Compatibility	
	Power	Precision
Power	675.87 (138.33)	696.29 (136.89)
Precision	682.58 (139.44)	649.99 (122.16)

Mapping Condition Two**

Response Condition	Object Compatibility	
	Power	Precision
Power	743.74 (110.58)	781.53 (150.65)
Precision	808.09 (154.32)	793.38 (135.01)

* precision response-naturally formed: power response-manufactured
** precision response–manufactured: power response-naturally formed

Appendix K

Experiment Two: Three-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RESPONSE	Sphericity Assumed	2259.299	1	2259.299	1.155	.293
	Greenhouse-Geisser	2259.299	1.000	2259.299	1.155	.293
	Huynh-Feldt	2259.299	1.000	2259.299	1.155	.293
	Lower-bound	2259.299	1.000	2259.299	1.155	.293
RESPONSE * MAPPING	Sphericity Assumed	22588.391	1	22588.391	11.549	.002
	Greenhouse-Geisser	22588.391	1.000	22588.391	11.549	.002
	Huynh-Feldt	22588.391	1.000	22588.391	11.549	.002
	Lower-bound	22588.391	1.000	22588.391	11.549	.002
Error(RESPONSE)	Sphericity Assumed	48897.490	25	1955.900		
	Greenhouse-Geisser	48897.490	25.000	1955.900		
	Huynh-Feldt	48897.490	25.000	1955.900		
	Lower-bound	48897.490	25.000	1955.900		
COMPAT	Sphericity Assumed	201.085	1	201.085	.410	.528
	Greenhouse-Geisser	201.085	1.000	201.085	.410	.528
	Huynh-Feldt	201.085	1.000	201.085	.410	.528
	Lower-bound	201.085	1.000	201.085	.410	.528
COMPAT * MAPPING	Sphericity Assumed	2094.563	1	2094.563	4.273	.049
	Greenhouse-Geisser	2094.563	1.000	2094.563	4.273	.049
	Huynh-Feldt	2094.563	1.000	2094.563	4.273	.049
	Lower-bound	2094.563	1.000	2094.563	4.273	.049
Error(COMPAT)	Sphericity Assumed	12254.565	25	490.183		
	Greenhouse-Geisser	12254.565	25.000	490.183		
	Huynh-Feldt	12254.565	25.000	490.183		
	Lower-bound	12254.565	25.000	490.183		
RESPONSE * COMPAT	Sphericity Assumed	18761.709	1	18761.709	19.987	.000
	Greenhouse-Geisser	18761.709	1.000	18761.709	19.987	.000
	Huynh-Feldt	18761.709	1.000	18761.709	19.987	.000
	Lower-bound	18761.709	1.000	18761.709	19.987	.000
RESPONSE * COMPAT * MAPPING	Sphericity Assumed	.417	1	.417	.000	.983
	Greenhouse-Geisser	.417	1.000	.417	.000	.983
	Huynh-Feldt	.417	1.000	.417	.000	.983
	Lower-bound	.417	1.000	.417	.000	.983
Error(RESPONSE*COMPAT)	Sphericity Assumed	23467.549	25	938.702		
	Greenhouse-Geisser	23467.549	25.000	938.702		
	Huynh-Feldt	23467.549	25.000	938.702		
	Lower-bound	23467.549	25.000	938.702		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	5.7E+07	1	5.7E+07	803.581	.000
MAPPING	300133.0	1	300133.0	4.209	.051
Error	1782855	25	71314.220		

Table 4
Experiment Two: Mean Number of Errors for Power and Precision Responses to Power and Precision Compatible Objects in Mapping Conditions One and Two

Mapping Condition One*

Response Condition	Object Compatibility	
	Power	Precision
Power	2.71 (3.31)	5.71 (4.08)
Precision	5.00 (3.23)	4.00 (2.07)

Mapping Condition Two**

Response Condition	Object Compatibility	
	Power	Precision
Power	1.92 (1.75)	2.54 (2.47)
Precision	3.85 (2.97)	3.15 (2.30)

* precision response-naturally formed: power response-manufactured
** precision response–manufactured: power response-naturally formed

Appendix M

Experiment Two: Three-way mixed ANOVA tables for Error Data.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RESPONSE	Sphericity Assumed	16.298	1	16.298	5.180	.032
	Greenhouse-Geisser	16.298	1.000	16.298	5.180	.032
	Huynh-Feldt	16.298	1.000	16.298	5.180	.032
	Lower-bound	16.298	1.000	16.298	5.180	.032
RESPONSE * MAPPING	Sphericity Assumed	6.520	1	6.520	2.072	.162
	Greenhouse-Geisser	6.520	1.000	6.520	2.072	.162
	Huynh-Feldt	6.520	1.000	6.520	2.072	.162
	Lower-bound	6.520	1.000	6.520	2.072	.162
Error(RESPONSE)	Sphericity Assumed	78.665	25	3.147		
	Greenhouse-Geisser	78.665	25.000	3.147		
	Huynh-Feldt	78.665	25.000	3.147		
	Lower-bound	78.665	25.000	3.147		
COMPAT	Sphericity Assumed	6.232	1	6.232	2.057	.164
	Greenhouse-Geisser	6.232	1.000	6.232	2.057	.164
	Huynh-Feldt	6.232	1.000	6.232	2.057	.164
	Lower-bound	6.232	1.000	6.232	2.057	.164
COMPAT * MAPPING	Sphericity Assumed	7.269	1	7.269	2.400	.134
	Greenhouse-Geisser	7.269	1.000	7.269	2.400	.134
	Huynh-Feldt	7.269	1.000	7.269	2.400	.134
	Lower-bound	7.269	1.000	7.269	2.400	.134
Error(COMPAT)	Sphericity Assumed	75.731	25	3.029		
	Greenhouse-Geisser	75.731	25.000	3.029		
	Huynh-Feldt	75.731	25.000	3.029		
	Lower-bound	75.731	25.000	3.029		
RESPONSE * COMPAT	Sphericity Assumed	47.474	1	47.474	12.211	.002
	Greenhouse-Geisser	47.474	1.000	47.474	12.211	.002
	Huynh-Feldt	47.474	1.000	47.474	12.211	.002
	Lower-bound	47.474	1.000	47.474	12.211	.002
RESPONSE * COMPAT * MAPPING	Sphericity Assumed	12.215	1	12.215	3.142	.088
	Greenhouse-Geisser	12.215	1.000	12.215	3.142	.088
	Huynh-Feldt	12.215	1.000	12.215	3.142	.088
	Lower-bound	12.215	1.000	12.215	3.142	.088
Error(RESPONSE*COMPAT)	Sphericity Assumed	97.192	25	3.888		
	Greenhouse-Geisser	97.192	25.000	3.888		
	Huynh-Feldt	97.192	25.000	3.888		
	Lower-bound	97.192	25.000	3.888		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1406.520	1	1406.520	60.661	.000
MAPPING	60.002	1	60.002	2.588	.120
Error	579.665	25	23.187		

Appendix N

Regression Analyses for Experiments One and Two

Experiment One

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	638.391	23.020		27.733	.000
	EFFECT	2.995	.350	.560	8.557	.000

a. Dependent Variable: GRP_MEAN

Experiment Two

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	718.746	15.456		46.504	.000
	EFFECT_S	1.127	.129	.498	8.741	.000

a. Dependent Variable: GRP_MEAN

Appendix O

List of 40 Objects used in Experiment Three

Garage Tools

Hand Saw
Hacksaw
Shovel
Gardening Form
Hand Shears
Hammer
Trowel
Screwdriver
Mallet
Chisel
Torch
Spanner
Pliers
Adjustable Spanner
Socket Spanner
File
Crowbar
Paint Brush
Hand Drill
Stanley Knife

Kitchen Utensils

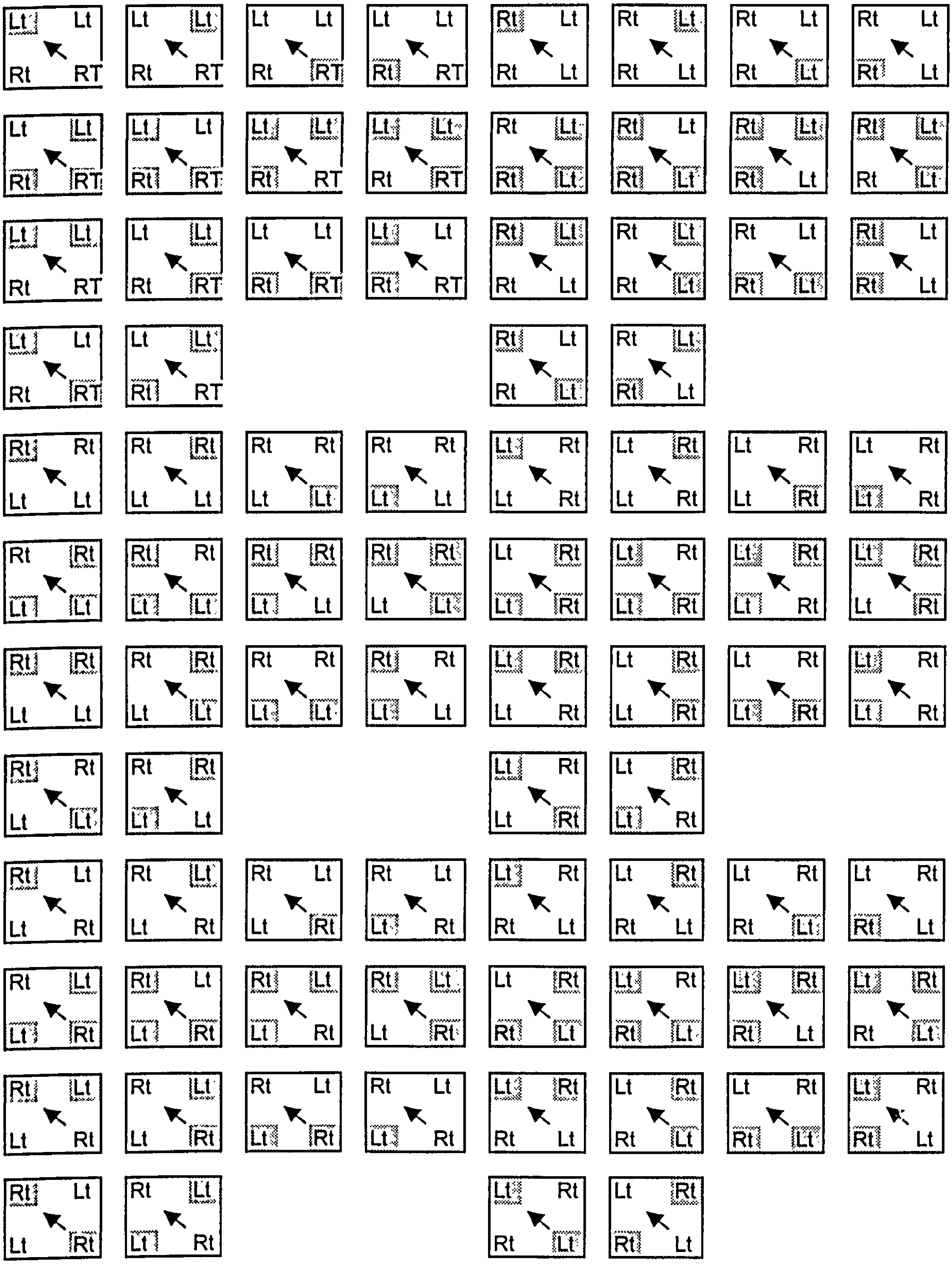
Roasting Fork
Carving Knife
Frying Pan
Ladle
Slotted Spoon
Sieve
Potato Masher
Egg Slice
Spatula
Whisk
Wooden Spoon
Rolling Pin
Saucepan
Ice Cream Scoop
Pizza Cutter
Cheese Knife
Washing-Up Brush
Potato Peeler
Pastry Brush

All Object Combinations for the Photographs used in Experiment Three

Note: each photograph would be shown four occasions with the arrow pointing to a different object on each occasion.

☐ = Manufactured Object **Lt** = Oriented for maximum compatibility with a left-hand grasp

▨ = Naturally Formed Object **Rt** = Oriented for maximum compatibility with a right-hand grasp



Appendix Q

Instructions: Experiment Three, Mapping One

This study comprises two tasks:

Task One

The experiment comprises 336 trials. On each trial you will be presented with a picture on the computer screen. Each picture contains four objects. These objects will be positioned to the top left, top right, bottom left and bottom right of the picture. The picture will remain on the screen for 1.5 seconds before disappearing. A blank screen will then appear. After a further half second, an arrow radiating from the middle of the screen will point to a position on the screen previously occupied by one of the objects in the previous picture (top left, top right, bottom left and bottom right of the screen).

Using the two hand devices provided, you are required to make a decision as to whether the object at that position would normally be found in a garage or in a kitchen.

* If you decide that the object is normally found in a garage, please make a response by pressing the switch held in your right hand.

* If you decide that the object is normally found in a kitchen, please make a response by pressing the switch held in your left hand.

When you make your decision the picture will disappear and you will see an instruction asking you to get ready for the next picture. Please make your response as fast as you can whilst maintaining accuracy.
If you make an error you will hear an error signal.

IMPORTANT: IN ORDER TO AID YOU WITH TASK TWO IT IS IMPORTANT THAT YOU TRY TO FORM A MENTAL IMAGE OF EACH PICTURE BEFORE IT DISAPPEARS FROM VIEW, I.E. FORM A MENTAL IMAGE OF EACH OBJECT AND ITS POSITION ON THE SCREEN.

Task Two

At random intervals during the above task you will be given a memory test. The test will appear after you have responded to the 'Garage/Kitchen decision task. The task will require that you remember the objects from the previous picture and the positions of those objects.

When the test appears, you will be presented with the names of four objects positioned to the top left, top right, bottom left and bottom right of the screen. YOUR TASK IS TO DECIDE WHETHER THAT CONFIGURATION OF OBJECTS IS CORRECT OR INCORRECT.

- If you think the configuration is correct you must press the switch in your left hand.
- However, if you think the configuration is incorrect you must press the switch in your right hand. You will be reminded of the correct responses to make when the test appears.

After the memory test the trials will continue in the manner described above.

Before starting the main experiment you will be given a practice session.

Thank you for agreeing to participate in this experiment.

Please note:

* You are free to withdraw from this experiment at any time.
* A full debriefing as to the purpose of the study will be given after the experiment.

Instructions: Experiment Three, Mapping Two

This study comprises two tasks:

Task One

The experiment comprises 336 trials. On each trial you will be presented with a picture on the computer screen. Each picture contains four objects. These objects will be positioned to the top left, top right, bottom left and bottom right of the picture. The picture will remain on the screen for 1.5 seconds before disappearing. A blank screen will then appear. After a further half second, an arrow radiating from the middle of the screen will point to a position on the screen previously occupied by one of the objects in the previous picture (top left, top right, bottom left and bottom right of the screen).

Using the two hand devices provided, you are required to make a decision as to whether the object at that position would normally be found in a garage or in a kitchen.

- If you decide that the object is normally found in a kitchen, please make a response by pressing the switch held in your right hand.
- If you decide that the object is normally found in a garage, please make a response by pressing the switch held in your left hand.

When you make your decision the picture will disappear and you will see an instruction asking you to get ready for the next picture. Please make your response as fast as you can whilst maintaining accuracy.
If you make an error you will hear an error signal.

IMPORTANT: IN ORDER TO AID YOU WITH TASK TWO IT IS IMPORTANT THAT YOU TRY TO FORM A MENTAL IMAGE OF EACH PICTURE BEFORE IT DISAPPEARS FROM VIEW, I.E. FORM A MENTAL IMAGE OF EACH OBJECT AND ITS POSITION ON THE SCREEN.

Task Two

At random intervals during the above task you will be given a memory test. The test will appear after you have responded to the 'Garage/Kitchen decision task. The task will require that you remember the objects from the previous picture and the positions of those objects.

When the test appears, you will be presented with the names of four objects positioned to the top left, top right, bottom left and bottom right of the screen. YOUR TASK IS TO DECIDE WHETHER THAT CONFIGURATION OF OBJECTS IS CORRECT OR INCORRECT.

- If you think the configuration is correct you must press the switch in your left hand.

- However, if you think the configuration is incorrect you must press the switch in your right hand. You will be reminded of the correct responses to make when the test appears.

After the memory test the trials will continue in the manner described above.

Before starting the main experiment you will be given a practice session.

Thank you for agreeing to participate in this experiment.

Please note:

* You are free to withdraw from this experiment at any time.
* A full debriefing as to the purpose of the study will be given after the experiment.

Exp3: Mapping Two

Table 6
Experiment Three: Mean Response Times for Left and Right-hand Responses to Left and Right-orientated Objects in Mapping Conditions One and Two

Mapping Condition One*		
Response Condition	Object Orientation	
	Left	Right
Left Hand	705.29 (138.78)	703.92 (142.45)
Right Hand	721.73 (122.73)	715.74 (135.20)

Mapping Condition Two**		
Response Condition	Object Orientation	
	Left	Right
Left Hand	865.60 (231.76)	869.71 (219.28)
Right Hand	842.88 (238.86)	844.19 (222.76)

* Right-hand responses to garage tools and left-hand responses to kitchen utensils
** Left-hand responses to garage tools and right-hand responses to kitchen utensils

Appendix S

Experiment Three: Three-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RESPONSE	Sphericity Assumed	698.074	1	698.074	.201	.657
	Greenhouse-Geisser	698.074	1.000	698.074	.201	.657
	Huynh-Feldt	698.074	1.000	698.074	.201	.657
	Lower-bound	698.074	1.000	698.074	.201	.657
RESPONSE * MAP	Sphericity Assumed	10240.682	1	10240.682	2.953	.098
	Greenhouse-Geisser	10240.682	1.000	10240.682	2.953	.098
	Huynh-Feldt	10240.682	1.000	10240.682	2.953	.098
	Lower-bound	10240.682	1.000	10240.682	2.953	.098
Error(RESPONSE)	Sphericity Assumed	90176.874	26	3468.341		
	Greenhouse-Geisser	90176.874	26.000	3468.341		
	Huynh-Feldt	90176.874	26.000	3468.341		
	Lower-bound	90176.874	26.000	3468.341		
ORIENTAT	Sphericity Assumed	6.618	1	6.618	.009	.926
	Greenhouse-Geisser	6.618	1.000	6.618	.009	.926
	Huynh-Feldt	6.618	1.000	6.618	.009	.926
	Lower-bound	6.618	1.000	6.618	.009	.926
ORIENTAT * MAP	Sphericity Assumed	285.649	1	285.649	.383	.541
	Greenhouse-Geisser	285.649	1.000	285.649	.383	.541
	Huynh-Feldt	285.649	1.000	285.649	.383	.541
	Lower-bound	285.649	1.000	285.649	.383	.541
Error(ORIENTAT)	Sphericity Assumed	19391.997	26	745.846		
	Greenhouse-Geisser	19391.997	26.000	745.846		
	Huynh-Feldt	19391.997	26.000	745.846		
	Lower-bound	19391.997	26.000	745.846		
RESPONSE * ORIENTAT	Sphericity Assumed	96.718	1	96.718	.091	.766
	Greenhouse-Geisser	96.718	1.000	96.718	.091	.766
	Huynh-Feldt	96.718	1.000	96.718	.091	.766
	Lower-bound	96.718	1.000	96.718	.091	.766
RESPONSE * ORIENTAT * MAP	Sphericity Assumed	5.833	1	5.833	.005	.942
	Greenhouse-Geisser	5.833	1.000	5.833	.005	.942
	Huynh-Feldt	5.833	1.000	5.833	.005	.942
	Lower-bound	5.833	1.000	5.833	.005	.942
Error(RESPONSE*ORIENTAT)	Sphericity Assumed	27698.961	26	1065.345		
	Greenhouse-Geisser	27698.961	26.000	1065.345		
	Huynh-Feldt	27698.961	26.000	1065.345		
	Lower-bound	27698.961	26.000	1065.345		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	6.9E+07	1	6.9E+07	508.269	.000
MAP	580011.4	1	580011.4	4.286	.048
Error	3518232	26	135316.6		

Table 7

Experiment Three: Mean Number of Errors for Left and Right-hand Responses to Left and Right-orientated Objects in Mapping Conditions One and Two

Mapping Condition One*

Response Condition	Object Orientation	
	Left	Right
Left Hand	9.07 (6.82)	8.36 (4.16)
Right Hand	6.93 (4.58)	9.36 (5.53)

Mapping Condition Two**

Response Condition	Object Orientation	
	Left	Right
Left Hand	8.36 (5.68)	8.64 (6.16)
Right Hand	8.93 (7.63)	9.14 (6.77)

* Right-hand responses to garage tools and left-hand responses to kitchen utensils
** Left-hand responses to garage tools and right-hand responses to kitchen utensils

Appendix U

Experiment Three: Three-way mixed ANOVA tables for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RESPONSE	Sphericity Assumed	8.929E-03	1	8.929E-03	.001	.978
	Greenhouse-Geisser	8.929E-03	1.000	8.929E-03	.001	.978
	Huynh-Feldt	8.929E-03	1.000	8.929E-03	.001	.978
	Lower-bound	8.929E-03	1.000	8.929E-03	.001	.978
RESPONSE * MAPPING	Sphericity Assumed	8.580	1	8.580	.712	.406
	Greenhouse-Geisser	8.580	1.000	8.580	.712	.406
	Huynh-Feldt	8.580	1.000	8.580	.712	.406
	Lower-bound	8.580	1.000	8.580	.712	.406
Error(RESPONSE)	Sphericity Assumed	313.161	26	12.045		
	Greenhouse-Geisser	313.161	26.000	12.045		
	Huynh-Feldt	313.161	26.000	12.045		
	Lower-bound	313.161	26.000	12.045		
ORIENTAT	Sphericity Assumed	8.580	1	8.580	1.209	.282
	Greenhouse-Geisser	8.580	1.000	8.580	1.209	.282
	Huynh-Feldt	8.580	1.000	8.580	1.209	.282
	Lower-bound	8.580	1.000	8.580	1.209	.282
ORIENTAT * MAPPING	Sphericity Assumed	2.580	1	2.580	.363	.552
	Greenhouse-Geisser	2.580	1.000	2.580	.363	.552
	Huynh-Feldt	2.580	1.000	2.580	.363	.552
	Lower-bound	2.580	1.000	2.580	.363	.552
Error(ORIENTAT)	Sphericity Assumed	184.589	26	7.100		
	Greenhouse-Geisser	184.589	26.000	7.100		
	Huynh-Feldt	184.589	26.000	7.100		
	Lower-bound	184.589	26.000	7.100		
RESPONSE * ORIENTAT	Sphericity Assumed	16.509	1	16.509	1.650	.210
	Greenhouse-Geisser	16.509	1.000	16.509	1.650	.210
	Huynh-Feldt	16.509	1.000	16.509	1.650	.210
	Lower-bound	16.509	1.000	16.509	1.650	.210
RESPONSE * ORIENTAT * MAPPING	Sphericity Assumed	18.080	1	18.080	1.807	.190
	Greenhouse-Geisser	18.080	1.000	18.080	1.807	.190
	Huynh-Feldt	18.080	1.000	18.080	1.807	.190
	Lower-bound	18.080	1.000	18.080	1.807	.190
Error(RESPONSE*ORIENTAT)	Sphericity Assumed	260.161	26	10.006		
	Greenhouse-Geisser	260.161	26.000	10.006		
	Huynh-Feldt	260.161	26.000	10.006		
	Lower-bound	260.161	26.000	10.006		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	8280.080	1	8280.080	71.583	.000
MAPPING	3.223	1	3.223	.028	.869
Error	3007.446	26	115.671		

Appendix V

Experiment Three: Three-way repeated measures ANOVA table for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	3163.093	3	1054.364	.308	.820
	Greenhouse-Geisser	3163.093	2.105	1502.527	.308	.747
	Huynh-Feldt	3163.093	2.287	1382.816	.308	.765
	Lower-bound	3163.093	1.000	3163.093	.308	.584
Error(POSITION)	Sphericity Assumed	277366.4	81	3424.277		
	Greenhouse-Geisser	277366.4	56.840	4879.781		
	Huynh-Feldt	277366.4	61.761	4490.995		
	Lower-bound	277366.4	27.000	10272.831		
RESPONSE	Sphericity Assumed	2569.322	1	2569.322	.173	.680
	Greenhouse-Geisser	2569.322	1.000	2569.322	.173	.680
	Huynh-Feldt	2569.322	1.000	2569.322	.173	.680
	Lower-bound	2569.322	1.000	2569.322	.173	.680
Error(RESPONSE)	Sphericity Assumed	400192.5	27	14821.945		
	Greenhouse-Geisser	400192.5	27.000	14821.945		
	Huynh-Feldt	400192.5	27.000	14821.945		
	Lower-bound	400192.5	27.000	14821.945		
ORIENTAT	Sphericity Assumed	15.498	1	15.498	.006	.941
	Greenhouse-Geisser	15.498	1.000	15.498	.006	.941
	Huynh-Feldt	15.498	1.000	15.498	.006	.941
	Lower-bound	15.498	1.000	15.498	.006	.941
Error(ORIENTAT)	Sphericity Assumed	75612.719	27	2800.471		
	Greenhouse-Geisser	75612.719	27.000	2800.471		
	Huynh-Feldt	75612.719	27.000	2800.471		
	Lower-bound	75612.719	27.000	2800.471		
POSITION * RESPONSE	Sphericity Assumed	95427.737	3	31809.246	9.807	.000
	Greenhouse-Geisser	95427.737	2.707	35248.332	9.807	.000
	Huynh-Feldt	95427.737	3.000	31809.246	9.807	.000
	Lower-bound	95427.737	1.000	95427.737	9.807	.004
Error(POSITION*RESPONSE)	Sphericity Assumed	262723.6	81	3243.501		
	Greenhouse-Geisser	262723.6	73.097	3594.175		
	Huynh-Feldt	262723.6	81.000	3243.501		
	Lower-bound	262723.6	27.000	9730.504		
POSITION * ORIENTAT	Sphericity Assumed	25702.265	3	8567.422	2.341	.079
	Greenhouse-Geisser	25702.265	2.566	10015.011	2.341	.090
	Huynh-Feldt	25702.265	2.859	8989.596	2.341	.083
	Lower-bound	25702.265	1.000	25702.265	2.341	.138
Error(POSITION*ORIENTAT)	Sphericity Assumed	296475.6	81	3660.193		
	Greenhouse-Geisser	296475.6	69.292	4278.635		
	Huynh-Feldt	296475.6	77.196	3840.555		
	Lower-bound	296475.6	27.000	10980.579		
RESPONSE * ORIENTAT	Sphericity Assumed	466.651	1	466.651	.110	.742
	Greenhouse-Geisser	466.651	1.000	466.651	.110	.742
	Huynh-Feldt	466.651	1.000	466.651	.110	.742
	Lower-bound	466.651	1.000	466.651	.110	.742
Error(RESPONSE*ORIENTAT)	Sphericity Assumed	114047.5	27	4223.981		
	Greenhouse-Geisser	114047.5	27.000	4223.981		
	Huynh-Feldt	114047.5	27.000	4223.981		
	Lower-bound	114047.5	27.000	4223.981		
POSITION * RESPONSE * ORIENTAT	Sphericity Assumed	8322.544	3	2774.181	1.183	.322
	Greenhouse-Geisser	8322.544	2.625	3170.145	1.183	.320
	Huynh-Feldt	8322.544	2.934	2836.877	1.183	.321
	Lower-bound	8322.544	1.000	8322.544	1.183	.286
Error(POSITION*RESPONSE*ORIENTAT)	Sphericity Assumed	189984.5	81	2345.488		
	Greenhouse-Geisser	189984.5	70.883	2680.263		
	Huynh-Feldt	189984.5	79.210	2398.495		
	Lower-bound	189984.5	27.000	7036.463		

Appendix W

Table 8
Experiment Three: Mean Response Times for Left and Right-hand Responses to Left and Right-orientated Objects at each Image Position

Picture Position	Top Left		Top Right		Bottom Left		Bottom Right	
Object Orientation	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
Left-hand Response	780.18 (210.13)	787.09 (211.80)	788.17 (207.75)	811.59 (197.56)	760.74 (205.75)	761.24 (195.25)	814.19 (217.11)	790.04 (216.40)
Right-hand Response	773.37 (183.07)	799.63 (204.97)	778.23 (223.18)	773.65 (185.21)	804.73 (187.60)	795.54 (193.53)	775.96 (204.96)	753.81 (209.82)

Appendix X

Experiment Three: Three-way repeated measures ANOVA table for the Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	10.650	3	3.550	2.180	.097
	Greenhouse-Geisser	10.650	2.910	3.660	2.180	.099
	Huynh-Feldt	10.650	3.000	3.550	2.180	.097
	Lower-bound	10.650	1.000	10.650	2.180	.151
Error(POSITION)	Sphericity Assumed	131.913	81	1.629		
	Greenhouse-Geisser	131.913	78.562	1.679		
	Huynh-Feldt	131.913	81.000	1.629		
	Lower-bound	131.913	27.000	4.886		
RESPONSE	Sphericity Assumed	2.232E-03	1	2.232E-03	.001	.978
	Greenhouse-Geisser	2.232E-03	1.000	2.232E-03	.001	.978
	Huynh-Feldt	2.232E-03	1.000	2.232E-03	.001	.978
	Lower-bound	2.232E-03	1.000	2.232E-03	.001	.978
Error(RESPONSE)	Sphericity Assumed	80.435	27	2.979		
	Greenhouse-Geisser	80.435	27.000	2.979		
	Huynh-Feldt	80.435	27.000	2.979		
	Lower-bound	80.435	27.000	2.979		
ORIENTAT	Sphericity Assumed	2.145	1	2.145	1.238	.276
	Greenhouse-Geisser	2.145	1.000	2.145	1.238	.276
	Huynh-Feldt	2.145	1.000	2.145	1.238	.276
	Lower-bound	2.145	1.000	2.145	1.238	.276
Error(ORIENTAT)	Sphericity Assumed	46.792	27	1.733		
	Greenhouse-Geisser	46.792	27.000	1.733		
	Huynh-Feldt	46.792	27.000	1.733		
	Lower-bound	46.792	27.000	1.733		
POSITION * RESPONSE	Sphericity Assumed	126.667	3	42.222	14.301	.000
	Greenhouse-Geisser	126.667	2.628	48.192	14.301	.000
	Huynh-Feldt	126.667	2.938	43.119	14.301	.000
	Lower-bound	126.667	1.000	126.667	14.301	.001
Error(POSITION*RESPONSE)	Sphericity Assumed	239.145	81	2.952		
	Greenhouse-Geisser	239.145	70.967	3.370		
	Huynh-Feldt	239.145	79.316	3.015		
	Lower-bound	239.145	27.000	8.857		
POSITION * ORIENTAT	Sphericity Assumed	8.025	3	2.675	1.481	.226
	Greenhouse-Geisser	8.025	2.226	3.605	1.481	.235
	Huynh-Feldt	8.025	2.435	3.295	1.481	.232
	Lower-bound	8.025	1.000	8.025	1.481	.234
Error(POSITION*ORIENTAT)	Sphericity Assumed	146.288	81	1.806		
	Greenhouse-Geisser	146.288	60.105	2.434		
	Huynh-Feldt	146.288	65.752	2.225		
	Lower-bound	146.288	27.000	5.418		
RESPONSE * ORIENTAT	Sphericity Assumed	4.127	1	4.127	1.602	.216
	Greenhouse-Geisser	4.127	1.000	4.127	1.602	.216
	Huynh-Feldt	4.127	1.000	4.127	1.602	.216
	Lower-bound	4.127	1.000	4.127	1.602	.216
Error(RESPONSE*ORIENTAT)	Sphericity Assumed	69.560	27	2.576		
	Greenhouse-Geisser	69.560	27.000	2.576		
	Huynh-Feldt	69.560	27.000	2.576		
	Lower-bound	69.560	27.000	2.576		
POSITION * RESPONSE * ORIENTAT	Sphericity Assumed	7.114	3	2.371	1.556	.206
	Greenhouse-Geisser	7.114	2.400	2.964	1.556	.215
	Huynh-Feldt	7.114	2.650	2.684	1.556	.212
	Lower-bound	7.114	1.000	7.114	1.556	.223
Error(POSITION*RESPONSE*ORIENTAT)	Sphericity Assumed	123.449	81	1.524		
	Greenhouse-Geisser	123.449	64.799	1.905		
	Huynh-Feldt	123.449	71.559	1.725		
	Lower-bound	123.449	27.000	4.572		

Table 9
Experiment Three: Mean Number of Errors for Left and Right-hand Responses to Left and Right-orientated Objects at each Image Position

Picture Position	Top Left		Top Right		Bottom Left		Bottom Right	
Object Orientation	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
Left-hand Response	1.75 (1.51)	1.89 (1.50)	1.89 (1.85)	2.21 (1.89)	1.89 (1.32)	1.46 (1.07)	3.18 (2.80)	2.93 (2.21)
Right-hand Response	2.11 (1.81)	3.11 (2.35)	1.79 (2.01)	1.64 (1.45)	2.75 (2.62)	2.86 (2.32)	1.29 (1.51)	1.64 (1.52)

Appendix Z

Experiment Three: Three-way repeated measures ANOVA table for the Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	427.386	1	427.386	.148	.704
	Greenhouse-Geisser	427.386	1.000	427.386	.148	.704
	Huynh-Feldt	427.386	1.000	427.386	.148	.704
	Lower-bound	427.386	1.000	427.386	.148	.704
Error(POSITION)	Sphericity Assumed	78088.190	27	2892.155		
	Greenhouse-Geisser	78088.190	27.000	2892.155		
	Huynh-Feldt	78088.190	27.000	2892.155		
	Lower-bound	78088.190	27.000	2892.155		
GRIP	Sphericity Assumed	2.258	1	2.258	.002	.968
	Greenhouse-Geisser	2.258	1.000	2.258	.002	.968
	Huynh-Feldt	2.258	1.000	2.258	.002	.968
	Lower-bound	2.258	1.000	2.258	.002	.968
Error(GRIP)	Sphericity Assumed	38163.421	27	1413.460		
	Greenhouse-Geisser	38163.421	27.000	1413.460		
	Huynh-Feldt	38163.421	27.000	1413.460		
	Lower-bound	38163.421	27.000	1413.460		
RESPONSE	Sphericity Assumed	1226.113	1	1226.113	.167	.686
	Greenhouse-Geisser	1226.113	1.000	1226.113	.167	.686
	Huynh-Feldt	1226.113	1.000	1226.113	.167	.686
	Lower-bound	1226.113	1.000	1226.113	.167	.686
Error(RESPONSE)	Sphericity Assumed	198627.998	27	7356.593		
	Greenhouse-Geisser	198627.998	27.000	7356.593		
	Huynh-Feldt	198627.998	27.000	7356.593		
	Lower-bound	198627.998	27.000	7356.593		
POSITION * GRIP	Sphericity Assumed	2227.620	1	2227.620	1.638	.212
	Greenhouse-Geisser	2227.620	1.000	2227.620	1.638	.212
	Huynh-Feldt	2227.620	1.000	2227.620	1.638	.212
	Lower-bound	2227.620	1.000	2227.620	1.638	.212
Error(POSITION*GRIP)	Sphericity Assumed	36724.442	27	1360.165		
	Greenhouse-Geisser	36724.442	27.000	1360.165		
	Huynh-Feldt	36724.442	27.000	1360.165		
	Lower-bound	36724.442	27.000	1360.165		
POSITION * RESPONSE	Sphericity Assumed	37097.775	1	37097.775	17.907	.000
	Greenhouse-Geisser	37097.775	1.000	37097.775	17.907	.000
	Huynh-Feldt	37097.775	1.000	37097.775	17.907	.000
	Lower-bound	37097.775	1.000	37097.775	17.907	.000
Error(POSITION*RESPONSE)	Sphericity Assumed	55935.921	27	2071.701		
	Greenhouse-Geisser	55935.921	27.000	2071.701		
	Huynh-Feldt	55935.921	27.000	2071.701		
	Lower-bound	55935.921	27.000	2071.701		
GRIP * RESPONSE	Sphericity Assumed	147.210	1	147.210	.070	.794
	Greenhouse-Geisser	147.210	1.000	147.210	.070	.794
	Huynh-Feldt	147.210	1.000	147.210	.070	.794
	Lower-bound	147.210	1.000	147.210	.070	.794
Error(GRIP*RESPONSE)	Sphericity Assumed	57156.264	27	2116.899		
	Greenhouse-Geisser	57156.264	27.000	2116.899		
	Huynh-Feldt	57156.264	27.000	2116.899		
	Lower-bound	57156.264	27.000	2116.899		
POSITION * GRIP * RESPONSE	Sphericity Assumed	1383.897	1	1383.897	.904	.350
	Greenhouse-Geisser	1383.897	1.000	1383.897	.904	.350
	Huynh-Feldt	1383.897	1.000	1383.897	.904	.350
	Lower-bound	1383.897	1.000	1383.897	.904	.350
Error(POSITION*GRIP*RESPONSE)	Sphericity Assumed	41317.862	27	1530.291		
	Greenhouse-Geisser	41317.862	27.000	1530.291		
	Huynh-Feldt	41317.862	27.000	1530.291		
	Lower-bound	41317.862	27.000	1530.291		

List of Object Pairs used in Experiment Four

OBJECT ONE	OBJECT TWO
Trowel	Gardening Fork
Wooden Spoon	Frying Pan
Screwdriver	Wire Brush
Mallet	Hammer

Instructions: Experiment Four

- In this experiment you will be presented with four blocks of 50 trials.

- At the start of each block of trials you will be shown a 'target' picture on the computer screen which contains two objects. You are asked to try and form a mental image of the two objects in the picture so that you can recall the images when responding to the preceding trials.

- You will see the target picture for a period of 20 seconds. You will then have a short break in which you are asked to try and conjure up a mental image of the picture, after which you will see the picture again for a period of 20 seconds.

- When the picture has disappeared from the screen for the second time you will be presented with a response rule to follow when responding to the preceding trials.

- On each of the following trials you will be presented with a picture of one of the two objects displayed in the target picture. According to the response rule given, you will respond to this image by pressing either the switch held in your left hand or the one in your right hand.

- IMPORTANTLY, before making your response you are asked to try and conjure up a mental image of that object as it was seen in the target picture.

- When you make your response, the image will disappear and the next trial will begin. If you make an error you will hear a 'beeping' sound.

- After 50 (fifty) trials the above process will be repeated with another picture containing two different objects. This process will continue until you have completed four blocks of 50 trials.

NOTE: Your ability to carry out the experiment is not dependent on your forming a mental image of the objects as instructed. However, you are asked to make your best efforts to do so.

- Before the main experiment begins you will be given a short practice session.

Table 10
Experiment Four: Mean Response Times for Left and Right-hand Responses to Left and Right-orientated Objects in Mapping Conditions One and Two

Mapping Condition One*		
Response Condition	Object Orientation	
	Left	Right
Left Hand	495.32 (195.16)	494.21 (196.68)
Right Hand	494.06 (209.32)	469.81 (143.54)

Mapping Condition Two**		
Response Condition	Object Orientation	
	Left	Right
Left Hand	525.99 (198.09)	497.82 (174.50)
Right Hand	498.31 (221.09)	483.59 (173.46)

* left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer – right-hand response paired with: Trowel Wooden Spoon; Screwdriver and Mallet.

** left-hand response paired with; Trowel, Wooden Spoon, Screwdriver and Mallet – left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer.

Experiment Three: Three-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RESPONSE	Sphericity Assumed	11119.970	1	11119.970	6.750	.013
	Greenhouse-Geisser	11119.970	1.000	11119.970	6.750	.013
	Huynh-Feldt	11119.970	1.000	11119.970	6.750	.013
	Lower-bound	11119.970	1.000	11119.970	6.750	.013
RESPONSE * MAP	Sphericity Assumed	644.397	1	644.397	.391	.536
	Greenhouse-Geisser	644.397	1.000	644.397	.391	.536
	Huynh-Feldt	644.397	1.000	644.397	.391	.536
	Lower-bound	644.397	1.000	644.397	.391	.536
Error(RESPONSE)	Sphericity Assumed	60953.850	37	1647.401		
	Greenhouse-Geisser	60953.850	37.000	1647.401		
	Huynh-Feldt	60953.850	37.000	1647.401		
	Lower-bound	60953.850	37.000	1647.401		
ORIENTAT	Sphericity Assumed	11347.947	1	11347.947	3.584	.066
	Greenhouse-Geisser	11347.947	1.000	11347.947	3.584	.066
	Huynh-Feldt	11347.947	1.000	11347.947	3.584	.066
	Lower-bound	11347.947	1.000	11347.947	3.584	.066
ORIENTAT * MAP	Sphericity Assumed	749.426	1	749.426	.237	.629
	Greenhouse-Geisser	749.426	1.000	749.426	.237	.629
	Huynh-Feldt	749.426	1.000	749.426	.237	.629
	Lower-bound	749.426	1.000	749.426	.237	.629
Error(ORIENTAT)	Sphericity Assumed	117162.8	37	3166.561		
	Greenhouse-Geisser	117162.8	37.000	3166.561		
	Huynh-Feldt	117162.8	37.000	3166.561		
	Lower-bound	117162.8	37.000	3166.561		
RESPONSE * ORIENTAT	Sphericity Assumed	228.258	1	228.258	.083	.775
	Greenhouse-Geisser	228.258	1.000	228.258	.083	.775
	Huynh-Feldt	228.258	1.000	228.258	.083	.775
	Lower-bound	228.258	1.000	228.258	.083	.775
RESPONSE * ORIENTAT * MAP	Sphericity Assumed	3261.934	1	3261.934	1.183	.284
	Greenhouse-Geisser	3261.934	1.000	3261.934	1.183	.284
	Huynh-Feldt	3261.934	1.000	3261.934	1.183	.284
	Lower-bound	3261.934	1.000	3261.934	1.183	.284
Error(RESPONSE*ORIENTAT)	Sphericity Assumed	102043.6	37	2757.935		
	Greenhouse-Geisser	102043.6	37.000	2757.935		
	Huynh-Feldt	102043.6	37.000	2757.935		
	Lower-bound	102043.6	37.000	2757.935		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	3.8E+07	1	3.8E+07	278.187	.000
MAP	6667.160	1	6667.160	.049	.827
Error	5078274	37	137250.7		

Table 11
Experiment Four: Mean Number of Errors for Left and Right-hand Responses to Left and Right-orientated Objects in Mapping Conditions One and Two

Mapping Condition One*		
Response Condition	Object Orientation	
	Left	Right
Left Hand	0.88 (1.11)	1.59 (1.46)
Right Hand	1.76 (2.41)	1.29 (1.05)

Mapping Condition Two**		
Response Condition	Object Orientation	
	Left	Right
Left Hand	1.33 (1.17)	1.00 (1.73)
Right Hand	1.00 (1.36)	1.33 (1.06)

* left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer – right-hand response paired with: Trowel Wooden Spoon; Screwdriver and Mallet.

** left-hand response paired with; Trowel, Wooden Spoon, Screwdriver and Mallet – left-hand response paired with; Gardening Fork, Frying Pan, Wire Brush and Hammer.

Experiment Four: Three-way mixed ANOVA tables for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RES_CON	Sphericity Assumed	.300	1	.300	.268	.609
	Greenhouse-Geisser	.300	1.000	.300	.268	.609
	Huynh-Feldt	.300	1.000	.300	.268	.609
	Lower-bound	.300	1.000	.300	.268	.609
RES_CON * MAPPING	Sphericity Assumed	1.238	1	1.238	1.104	.302
	Greenhouse-Geisser	1.238	1.000	1.238	1.104	.302
	Huynh-Feldt	1.238	1.000	1.238	1.104	.302
	Lower-bound	1.238	1.000	1.238	1.104	.302
Error(RES_CON)	Sphericity Assumed	33.629	30	1.121		
	Greenhouse-Geisser	33.629	30.000	1.121		
	Huynh-Feldt	33.629	30.000	1.121		
	Lower-bound	33.629	30.000	1.121		
ORIENTAT	Sphericity Assumed	2.482E-03	1	2.482E-03	.002	.964
	Greenhouse-Geisser	2.482E-03	1.000	2.482E-03	.002	.964
	Huynh-Feldt	2.482E-03	1.000	2.482E-03	.002	.964
	Lower-bound	2.482E-03	1.000	2.482E-03	.002	.964
ORIENTAT * MAPPING	Sphericity Assumed	.377	1	.377	.316	.578
	Greenhouse-Geisser	.377	1.000	.377	.316	.578
	Huynh-Feldt	.377	1.000	.377	.316	.578
	Lower-bound	.377	1.000	.377	.316	.578
Error(ORIENTAT)	Sphericity Assumed	35.865	30	1.195		
	Greenhouse-Geisser	35.865	30.000	1.195		
	Huynh-Feldt	35.865	30.000	1.195		
	Lower-bound	35.865	30.000	1.195		
RES_CON * ORIENTAT	Sphericity Assumed	1.004	1	1.004	.374	.546
	Greenhouse-Geisser	1.004	1.000	1.004	.374	.546
	Huynh-Feldt	1.004	1.000	1.004	.374	.546
	Lower-bound	1.004	1.000	1.004	.374	.546
RES_CON * ORIENTAT * MAPPING	Sphericity Assumed	5.379	1	5.379	2.003	.167
	Greenhouse-Geisser	5.379	1.000	5.379	2.003	.167
	Huynh-Feldt	5.379	1.000	5.379	2.003	.167
	Lower-bound	5.379	1.000	5.379	2.003	.167
Error(RES_CON*ORIENTAT)	Sphericity Assumed	80.551	30	2.685		
	Greenhouse-Geisser	80.551	30.000	2.685		
	Huynh-Feldt	80.551	30.000	2.685		
	Lower-bound	80.551	30.000	2.685		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	199.063	1	199.063	50.828	.000
MAPPING	2.250	1	2.250	.575	.454
Error	117.492	30	3.916		

Experiment Four: Two-way repeated measures ANOVA table for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RESPONSE	Sphericity Assumed	11491.549	1	11491.549	17.186	.000
	Greenhouse-Geisser	11491.549	1.000	11491.549	17.186	.000
	Huynh-Feldt	11491.549	1.000	11491.549	17.186	.000
	Lower-bound	11491.549	1.000	11491.549	17.186	.000
Error(RESPONSE)	Sphericity Assumed	25408.654	38	668.649		
	Greenhouse-Geisser	25408.654	38.000	668.649		
	Huynh-Feldt	25408.654	38.000	668.649		
	Lower-bound	25408.654	38.000	668.649		
POSITION	Sphericity Assumed	264.573	1	264.573	.437	.513
	Greenhouse-Geisser	264.573	1.000	264.573	.437	.513
	Huynh-Feldt	264.573	1.000	264.573	.437	.513
	Lower-bound	264.573	1.000	264.573	.437	.513
Error(POSITION)	Sphericity Assumed	23021.168	38	605.820		
	Greenhouse-Geisser	23021.168	38.000	605.820		
	Huynh-Feldt	23021.168	38.000	605.820		
	Lower-bound	23021.168	38.000	605.820		
RESPONSE * POSITION	Sphericity Assumed	12354.952	1	12354.952	4.685	.037
	Greenhouse-Geisser	12354.952	1.000	12354.952	4.685	.037
	Huynh-Feldt	12354.952	1.000	12354.952	4.685	.037
	Lower-bound	12354.952	1.000	12354.952	4.685	.037
Error(RESPONSE*POSITION)	Sphericity Assumed	100202.5	38	2636.908		
	Greenhouse-Geisser	100202.5	38.000	2636.908		
	Huynh-Feldt	100202.5	38.000	2636.908		
	Lower-bound	100202.5	38.000	2636.908		

Table 12
Experiment Four: Mean Response Times for Left and Right-hand Responses to Objects Positioned on the Left and Right-hand Side of the Computer Screen

	Object Position	
Response Condition	Left	Right
Left Hand	493.02 (184.08)	513.42 (199.66)
Right Hand	493.66 (179.00)	478.46 (188.64)

Experiment Four: Two-way repeated measures ANOVA for the Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RES_CON	Sphericity Assumed	.945	1	.945	.983	.329
	Greenhouse-Geisser	.945	1.000	.945	.983	.329
	Huynh-Feldt	.945	1.000	.945	.983	.329
	Lower-bound	.945	1.000	.945	.983	.329
Error(RES_CON)	Sphericity Assumed	29.805	31	.961		
	Greenhouse-Geisser	29.805	31.000	.961		
	Huynh-Feldt	29.805	31.000	.961		
	Lower-bound	29.805	31.000	.961		
POSITION	Sphericity Assumed	.383	1	.383	.450	.507
	Greenhouse-Geisser	.383	1.000	.383	.450	.507
	Huynh-Feldt	.383	1.000	.383	.450	.507
	Lower-bound	.383	1.000	.383	.450	.507
Error(POSITION)	Sphericity Assumed	26.367	31	.851		
	Greenhouse-Geisser	26.367	31.000	.851		
	Huynh-Feldt	26.367	31.000	.851		
	Lower-bound	26.367	31.000	.851		
RES_CON * POSITION	Sphericity Assumed	3.445	1	3.445	1.364	.252
	Greenhouse-Geisser	3.445	1.000	3.445	1.364	.252
	Huynh-Feldt	3.445	1.000	3.445	1.364	.252
	Lower-bound	3.445	1.000	3.445	1.364	.252
Error(RES_CON*POSITION)	Sphericity Assumed	78.305	31	2.526		
	Greenhouse-Geisser	78.305	31.000	2.526		
	Huynh-Feldt	78.305	31.000	2.526		
	Lower-bound	78.305	31.000	2.526		

Table 13
Experiment Four: Mean number of Errors for Left and Right-hand Responses to Objects Positioned on the Left and Right-hand Side of the Computer Screen

	Object Position	
Response Condition	Left	Right
Left Hand	1.59 (1.88)	1.16 (1.22)
Right Hand	1.09 (1.20)	1.31 (1.42)

Table 14

Mean Response Times to Left and Right-oriented Objects for the Four Left-handed Participants taking part in Experiment Four

Participant Number	Mean RT for Responses to Right-oriented Objects	Mean RT for Responses to Left-oriented Objects
5	310.17	328.90
12	416.10	398.60
13	434.00	412.96
33	374.35	363.97

List of Object Images used in Experiment Five

Object	Grasp Compatibility
Coin	Precision
Key	Precision
Torch	Power
Mallet	Power

Instructions: Experiment Five, Mapping One

- In this experiment you will be presented with four blocks of 50 trials
- At the start of each block of trials you will be shown a 'target' picture on the computer screen which contains one object. You are asked to try and form a mental image of the object in the picture so that you can recall it when responding to the following trials.
- You will see the target picture for a period of 15 seconds. You will then have a short break in which you are asked to try and conjure up a visual mental image of the picture, after which you will see the picture again for a period of 15 seconds.
- When the picture has disappeared from the screen for the second time you will be presented with a series of response trials.
- On each of the following trials you will either hear a high pitch tone or a low pitch tone. If you hear:

  A **High Pitch Tone** press the switch in your **Right Hand.**
  If you hear:
  A **Low Pitch Tone** press the switch in your **Left hand.**
- IMPORTANTLY, before hearing the tone you will be instructed to form a visual mental image of the object that appeared in the target picture. Try and retain the image until after you have responded to the tone.
- When you make your response, the next trial will begin. If you make an error you will see the word "Wrong!" appear on the computer screen.
- After 50 (fifty) trials the above process will be repeated with another picture containing another object. This process will continue until you have completed four blocks of 50 trials.

NOTE: Your ability to carry out the experiment is not dependent on your forming a mental image of the objects as instructed. However, you are asked to make your best efforts to do so.

- Before the main experiment begins you will be given a short practice session.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Exp5 Mappings One and Four

Instructions: Experiment Five, Mapping Two

- In this experiment you will be presented with four blocks of 50 trials
- At the start of each block of trials you will be shown a 'target' picture on the computer screen which contains one object. You are asked to try and form a mental image of the object in the picture so that you can recall it when responding to the following trials.
- You will see the target picture for a period of 15 seconds. You will then have a short break in which you are asked to try and conjure up a visual mental image of the picture, after which you will see the picture again for a period of 15 seconds.
- When the picture has disappeared from the screen for the second time you will be presented with a series of response trials.
- On each of the following trials you will either hear a high pitch tone or a low pitch tone. If you hear:

  A **High Pitch Tone** press the switch in your **Left Hand.**
  If you hear:
  A **Low Pitch Tone** press the switch in your **Right hand.**
- IMPORTANTLY, before hearing the tone you will be instructed to form a visual mental image of the object that appeared in the target picture. Try and retain the image until after you have responded to the tone.
- When you make your response, the next trial will begin. If you make an error you will see the word "Wrong!" appear on the computer screen.
- After 50 (fifty) trials the above process will be repeated with another picture containing another object. This process will continue until you have completed four blocks of 50 trials.

NOTE: Your ability to carry out the experiment is not dependent on your forming a mental image of the objects as instructed. However, you are asked to make your best efforts to do so.

- Before the main experiment begins you will be given a short practice session.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Exp5 Mappings Two and Three

Table 15
Experiment Five: Mean Response Times for Power and Precision Responses to Power and Precision Compatible Objects in Four Mapping Conditions

Mapping Condition One

Response Condition	Object Compatibility	
	Power	Precision
Power Response	596.41 (111.82)	614.95 (93.09)
Precision Response	608.55 (100.52)	611.97 (106.91)

Mapping Condition Two

Response Condition	Object Compatibility	
	Power	Precision
Power Response	577.38 (130.83)	583.67 (151.56)
Precision Response	604.92 (143.43)	606.02 (170.40)

Mapping Condition Three

Response Condition	Object Compatibility	
	Power	Precision
Power Response	611.77 (140.75)	611.51 (88.72)
Precision Response	644.56 (126.49)	638.23 (120.59)

Mapping Condition Four		
Response Condition	Object Compatibility	
	Power	Precision
Power Response	586.60 (215.50)	570.35 (181.87)
Precision Response	604.25 (210.34)	601.22 (218.67)

Key: Mapping One: Lt Hand Power Grasp & Low Tone/Rt Hand Precision Grasp & High Tone
Mapping Two: Lt Hand Power Grasp & High Tone/Rt Hand Precision Grasp & Low Tone
Mapping Three: Lt Hand Precision Grasp & High Tone/Rt Hand Power Grasp & Low Tone
Mapping Four: Lt Hand Precision Grasp & Low Tone/Rt Hand Power Grasp & High Tone

Appendix o

Experiment Five: Three-way mixed ANOVA Tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
R_GRASP	Sphericity Assumed	24216.587	1	24216.587	10.047	.003
	Greenhouse-Geisser	24216.587	1.000	24216.587	10.047	.003
	Huynh-Feldt	24216.587	1.000	24216.587	10.047	.003
	Lower-bound	24216.587	1.000	24216.587	10.047	.003
R_GRASP * MAP	Sphericity Assumed	4719.459	3	1573.153	.653	.585
	Greenhouse-Geisser	4719.459	3.000	1573.153	.653	.585
	Huynh-Feldt	4719.459	3.000	1573.153	.653	.585
	Lower-bound	4719.459	3.000	1573.153	.653	.585
Error(R_GRASP)	Sphericity Assumed	125340.5	52	2410.394		
	Greenhouse-Geisser	125340.5	52.000	2410.394		
	Huynh-Feldt	125340.5	52.000	2410.394		
	Lower-bound	125340.5	52.000	2410.394		
OBJ_COMP	Sphericity Assumed	10.958	1	10.958	.004	.951
	Greenhouse-Geisser	10.958	1.000	10.958	.004	.951
	Huynh-Feldt	10.958	1.000	10.958	.004	.951
	Lower-bound	10.958	1.000	10.958	.004	.951
OBJ_COMP * MAP	Sphericity Assumed	3188.443	3	1062.814	.372	.774
	Greenhouse-Geisser	3188.443	3.000	1062.814	.372	.774
	Huynh-Feldt	3188.443	3.000	1062.814	.372	.774
	Lower-bound	3188.443	3.000	1062.814	.372	.774
Error(OBJ_COMP)	Sphericity Assumed	148715.3	52	2859.910		
	Greenhouse-Geisser	148715.3	52.000	2859.910		
	Huynh-Feldt	148715.3	52.000	2859.910		
	Lower-bound	148715.3	52.000	2859.910		
R_GRASP * OBJ_COMP	Sphericity Assumed	146.099	1	146.099	.169	.683
	Greenhouse-Geisser	146.099	1.000	146.099	.169	.683
	Huynh-Feldt	146.099	1.000	146.099	.169	.683
	Lower-bound	146.099	1.000	146.099	.169	.683
R_GRASP * OBJ_COMP * MAP	Sphericity Assumed	1469.866	3	489.955	.566	.640
	Greenhouse-Geisser	1469.866	3.000	489.955	.566	.640
	Huynh-Feldt	1469.866	3.000	489.955	.566	.640
	Lower-bound	1469.866	3.000	489.955	.566	.640
Error(R_GRASP*OBJ_COMP)	Sphericity Assumed	45048.253	52	866.313		
	Greenhouse-Geisser	45048.253	52.000	866.313		
	Huynh-Feldt	45048.253	52.000	866.313		
	Lower-bound	45048.253	52.000	866.313		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	8.1E+07	1	8.1E+07	931.104	.000
MAP	48614.365	3	16204.788	.186	.906
Error	4533791	52	87188.294		

Table 16
Experiment Five: Mean Number of Errors for Power and Precision Responses to Power and Precision Compatible Objects in Four Mapping Conditions

Mapping Condition One

Response Condition	Object Compatibility	
	Power	Precision
Power Response	1.10 (1.85)	0.80 (2.20)
Precision Response	1.60 (1.58)	1.60 (3.37)

Mapping Condition Two

Response Condition	Object Compatibility	
	Power	Precision
Power Response	1.70 (2.36)	1.60 (2.37)
Precision Response	2.00 (2.26)	1.80 (1.55)

Mapping Condition Three

Response Condition	Object Compatibility	
	Power	Precision
Power Response	0.80 (0.92)	1.30 (1.06)
Precision Response	0.90 (0.99)	0.90 (1.45)

Mapping Condition Four		
Response Condition	Object Compatibility	
	Power	Precision
Power Response	1.30 (1.25)	0.90 (1.20)
Precision Response	1.20 (1.55)	0.80 (0.42)

Key:
Mapping One: Lt Hand Power Grasp & Low Tone/Rt Hand Precision Grasp & High Tone
Mapping Two: Lt Hand Power Grasp & High Tone/Rt Hand Precision Grasp & Low Tone
Mapping Three: Lt Hand Precision Grasp & High Tone/Rt Hand Power Grasp & Low Tone
Mapping Four: Lt Hand Precision Grasp & Low Tone/Rt Hand Power Grasp & High Tone

Experiment Five: Three-way mixed ANOVA tables for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RES_CON	Sphericity Assumed	1.056	1	1.056	.767	.387
	Greenhouse-Geisser	1.056	1.000	1.056	.767	.387
	Huynh-Feldt	1.056	1.000	1.056	.767	.387
	Lower-bound	1.056	1.000	1.056	.767	.387
RES_CON * MAP	Sphericity Assumed	4.119	3	1.373	.997	.405
	Greenhouse-Geisser	4.119	3.000	1.373	.997	.405
	Huynh-Feldt	4.119	3.000	1.373	.997	.405
	Lower-bound	4.119	3.000	1.373	.997	.405
Error(RES_CON)	Sphericity Assumed	49.575	36	1.377		
	Greenhouse-Geisser	49.575	36.000	1.377		
	Huynh-Feldt	49.575	36.000	1.377		
	Lower-bound	49.575	36.000	1.377		
OBJ_COMP	Sphericity Assumed	.506	1	.506	.314	.579
	Greenhouse-Geisser	.506	1.000	.506	.314	.579
	Huynh-Feldt	.506	1.000	.506	.314	.579
	Lower-bound	.506	1.000	.506	.314	.579
OBJ_COMP * MAP	Sphericity Assumed	2.169	3	.723	.448	.720
	Greenhouse-Geisser	2.169	3.000	.723	.448	.720
	Huynh-Feldt	2.169	3.000	.723	.448	.720
	Lower-bound	2.169	3.000	.723	.448	.720
Error(OBJ_COMP)	Sphericity Assumed	58.075	36	1.613		
	Greenhouse-Geisser	58.075	36.000	1.613		
	Huynh-Feldt	58.075	36.000	1.613		
	Lower-bound	58.075	36.000	1.613		
RES_CON * OBJ_COMP	Sphericity Assumed	5.625E-02	1	5.625E-02	.068	.796
	Greenhouse-Geisser	5.625E-02	1.000	5.625E-02	.068	.796
	Huynh-Feldt	5.625E-02	1.000	5.625E-02	.068	.796
	Lower-bound	5.625E-02	1.000	5.625E-02	.068	.796
RES_CON * OBJ_COMP * MAP	Sphericity Assumed	.819	3	.273	.329	.804
	Greenhouse-Geisser	.819	3.000	.273	.329	.804
	Huynh-Feldt	.819	3.000	.273	.329	.804
	Lower-bound	.819	3.000	.273	.329	.804
Error(RES_CON*OBJ_COMP)	Sphericity Assumed	29.875	36	.830		
	Greenhouse-Geisser	29.875	36.000	.830		
	Huynh-Feldt	29.875	36.000	.830		
	Lower-bound	29.875	36.000	.830		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	257.556	1	257.556	28.479	.000
MAP	15.619	3	5.206	.576	.635
Error	325.575	36	9.044		

Experiment Five: Two-way repeated measures ANOVA table for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_POS	Sphericity Assumed	928.813	1	928.813	.401	.529
	Greenhouse-Geisser	928.813	1.000	928.813	.401	.529
	Huynh-Feldt	928.813	1.000	928.813	.401	.529
	Lower-bound	928.813	1.000	928.813	.401	.529
Error(OBJ_POS)	Sphericity Assumed	127510.0	55	2318.364		
	Greenhouse-Geisser	127510.0	55.000	2318.364		
	Huynh-Feldt	127510.0	55.000	2318.364		
	Lower-bound	127510.0	55.000	2318.364		
RESPONSE	Sphericity Assumed	541.129	1	541.129	.304	.583
	Greenhouse-Geisser	541.129	1.000	541.129	.304	.583
	Huynh-Feldt	541.129	1.000	541.129	.304	.583
	Lower-bound	541.129	1.000	541.129	.304	.583
Error(RESPONSE)	Sphericity Assumed	97796.650	55	1778.121		
	Greenhouse-Geisser	97796.650	55.000	1778.121		
	Huynh-Feldt	97796.650	55.000	1778.121		
	Lower-bound	97796.650	55.000	1778.121		
OBJ_POS * RESPONSE	Sphericity Assumed	4717.314	1	4717.314	6.839	.011
	Greenhouse-Geisser	4717.314	1.000	4717.314	6.839	.011
	Huynh-Feldt	4717.314	1.000	4717.314	6.839	.011
	Lower-bound	4717.314	1.000	4717.314	6.839	.011
Error(OBJ_POS*RESPONSE)	Sphericity Assumed	37939.468	55	689.809		
	Greenhouse-Geisser	37939.468	55.000	689.809		
	Huynh-Feldt	37939.468	55.000	689.809		
	Lower-bound	37939.468	55.000	689.809		

Table 17
Experiment Five: Mean Response Times for Left and Right Responses to Objects Positioned on the Left and Right-hand Side of the Computer Screen

Response Condition	Object Position	
	Left	Right
Left Hand	601.55 (147.27)	614.80 (155.94)
Right Hand	607.62 (145.90)	602.51 (149.78)

Experiment Five: Two-way repeated measures ANOVA table for Response Time Data from Precision Compatible Objects Only

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	5852.892	1	5852.892	.966	.330
	Greenhouse-Geisser	5852.892	1.000	5852.892	.966	.330
	Huynh-Feldt	5852.892	1.000	5852.892	.966	.330
	Lower-bound	5852.892	1.000	5852.892	.966	.330
Error(POSITION)	Sphericity Assumed	333353.167	55	6060.967		
	Greenhouse-Geisser	333353.167	55.000	6060.967		
	Huynh-Feldt	333353.167	55.000	6060.967		
	Lower-bound	333353.167	55.000	6060.967		
RESPONSE	Sphericity Assumed	1825.658	1	1825.658	.632	.430
	Greenhouse-Geisser	1825.658	1.000	1825.658	.632	.430
	Huynh-Feldt	1825.658	1.000	1825.658	.632	.430
	Lower-bound	1825.658	1.000	1825.658	.632	.430
Error(RESPONSE)	Sphericity Assumed	158951.700	55	2890.031		
	Greenhouse-Geisser	158951.700	55.000	2890.031		
	Huynh-Feldt	158951.700	55.000	2890.031		
	Lower-bound	158951.700	55.000	2890.031		
POSITION * RESPONSE	Sphericity Assumed	2641.584	1	2641.584	2.961	.091
	Greenhouse-Geisser	2641.584	1.000	2641.584	2.961	.091
	Huynh-Feldt	2641.584	1.000	2641.584	2.961	.091
	Lower-bound	2641.584	1.000	2641.584	2.961	.091
Error(POSITION*RESPONSE)	Sphericity Assumed	49064.527	55	892.082		
	Greenhouse-Geisser	49064.527	55.000	892.082		
	Huynh-Feldt	49064.527	55.000	892.082		
	Lower-bound	49064.527	55.000	892.082		

Table 18
Experiment Five: Mean Response Times for Left and Right-hand Responses to Precision Compatible Objects Positioned on the Left and Right-hand Side of the Computer Screen

Response Condition	Object Position	
	Left	Right
Left Hand	601.72 (151.24)	618.81 (167.44)
Right Hand	602.87 (147.36)	606.23 (148.94)

Table 19
Experiment Five: Mean Number of Errors for Left and Right-hand Responses to Objects Positioned on the Left and Right-hand Side of the Computer Screen.

Response Condition	Object Position	
	Left	Right
Left Hand	1.17 (1.63)	1.20 (1.84)
Right Hand	1.45 (2.06)	1.35 (1.54)

Appendix w

Experiment Five: Two-way repeated measures ANOVA table for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	5.625E-02	1	5.625E-02	.031	.861
	Greenhouse-Geisser	5.625E-02	1.000	5.625E-02	.031	.861
	Huynh-Feldt	5.625E-02	1.000	5.625E-02	.031	.861
	Lower-bound	5.625E-02	1.000	5.625E-02	.031	.861
Error(POSITION)	Sphericity Assumed	70.194	39	1.800		
	Greenhouse-Geisser	70.194	39.000	1.800		
	Huynh-Feldt	70.194	39.000	1.800		
	Lower-bound	70.194	39.000	1.800		
RESPONSE	Sphericity Assumed	1.806	1	1.806	1.550	.221
	Greenhouse-Geisser	1.806	1.000	1.806	1.550	.221
	Huynh-Feldt	1.806	1.000	1.806	1.550	.221
	Lower-bound	1.806	1.000	1.806	1.550	.221
Error(RESPONSE)	Sphericity Assumed	45.444	39	1.165		
	Greenhouse-Geisser	45.444	39.000	1.165		
	Huynh-Feldt	45.444	39.000	1.165		
	Lower-bound	45.444	39.000	1.165		
POSITION * RESPONSE	Sphericity Assumed	.156	1	.156	.184	.670
	Greenhouse-Geisser	.156	1.000	.156	.184	.670
	Huynh-Feldt	.156	1.000	.156	.184	.670
	Lower-bound	.156	1.000	.156	.184	.670
Error(POSITION*RESPONSE)	Sphericity Assumed	33.094	39	.849		
	Greenhouse-Geisser	33.094	39.000	.849		
	Huynh-Feldt	33.094	39.000	.849		
	Lower-bound	33.094	39.000	.849		

Appendix x

List of 50 Object Images used in Experiments Six, Seven and Eight

Target Objects		Non Target Objects	
1.	Teapot	1.	Vase
2.	Mug	2.	Calculator
3.	Screwdriver	3.	Pine Cone
4.	Saucepan	4.	Bottle
5.	Frying pan	5.	Coffee Jar
6.	Hammer	6.	Book
7.	Coffee Pot	7.	Disk Box
8.	Mallet	8.	Cake
9.	Torch	9.	Drinks Can
10.	Saw	10.	Light bulb
11.	Kettle	11.	Apple
12.	Iron	12.	Orange
13.	Hairbrush	13.	Cigarette Box
14.	Sieve	14.	Pepper mill
15.	Wire brush	15.	Bowl
16.	Jug	16.	Flowerpot
17.	Gardening Fork	17.	Sunglasses
18.	Knife	18.	Toilet Roll
19.	Spoon	19.	Desk Tidy
20.	Paintbrush	20.	Shoe
21.	Trowel	21.	Coat Hanger
22.	Shovel*	22.	Photo Frame
23.	Dustpan	23.	Headphones
24.	Electric Whisk	24.	Mobile Phone
25.	Blender	25.	Dumbbell

Instructions, Experiment Six, Mapping One

- In this experiment you will be presented with 240 trials.
- At the start of each trial you will be shown a "Get Ready" message to inform you that the trial is about to begin. When the message has been removed from view you will see a series of four pictures, each depicting an object. Each picture will remain on the screen for 100 mecs.
- After the fourth picture has been removed from the screen, the name of an object will appear on the screen. When you see the object name you are asked to decide whether or not you remember seeing the named object in the previous four pictures.
- If you DO remember seeing the object named, please press the switch in your LEFT HAND. At the same time try and visualise the object – this will help with the memory test at the end of the experiment.
- If you DO NOT remember seeing the object named, please press the switch in your RIGHT HAND.
- When you make your response, the next trial will begin. If you make an error you will hear a short "bleep".
- Before the main experiment begins you will be given a short practice session.
- Please make your response as quickly as possible whilst maintaining accuracy.
- At the end of the experiment you will be given a short memory test.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Instructions, Experiment Six, Mapping Two

- In this experiment you will be presented with 240 trials.
- At the start of each trial you will be shown a "Get Ready" message to inform you that the trial is about to begin. When the message has been removed from view you will see a series of four pictures, each depicting an object. Each picture will remain on the screen for 100 mecs.
- After the fourth picture has been removed from the screen, the name of an object will appear on the screen. When you see the object name you are asked to decide whether or not you remember seeing the named object in the previous four pictures.
- If you DO remember seeing the object named, please press the switch in your RIGHT HAND. At the same time try and visualise the object – this will help with the memory test at the end of the experiment.
- If you DO NOT remember seeing the object named, please press the switch in your LEFT HAND.
- When you make your response, the next trial will begin. If you make an error you will hear a short "bleep".
- Before the main experiment begins you will be given a short practice session.
- Please make your response as quickly as possible whilst maintaining accuracy.
- At the end of the experiment you will be given a short memory test.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Exp6 Mapping Two

Experiment Six: Three-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	516936.5	3	172312.2	17.342	.000
	Greenhouse-Geisser	516936.5	2.637	196064.7	17.342	.000
	Huynh-Feldt	516936.5	2.934	176182.1	17.342	.000
	Lower-bound	516936.5	1.000	516936.5	17.342	.000
POSITION * RES	Sphericity Assumed	43330.595	3	14443.532	1.454	.231
	Greenhouse-Geisser	43330.595	2.637	16434.509	1.454	.235
	Huynh-Feldt	43330.595	2.934	14767.914	1.454	.232
	Lower-bound	43330.595	1.000	43330.595	1.454	.236
Error(POSITION)	Sphericity Assumed	1102923	111	9936.242		
	Greenhouse-Geisser	1102923	97.553	11305.909		
	Huynh-Feldt	1102923	108.562	10159.397		
	Lower-bound	1102923	37.000	29808.726		
OBJ_ORI	Sphericity Assumed	18825.255	1	18825.255	1.905	.176
	Greenhouse-Geisser	18825.255	1.000	18825.255	1.905	.176
	Huynh-Feldt	18825.255	1.000	18825.255	1.905	.176
	Lower-bound	18825.255	1.000	18825.255	1.905	.176
OBJ_ORI * RES	Sphericity Assumed	41827.528	1	41827.528	4.232	.047
	Greenhouse-Geisser	41827.528	1.000	41827.528	4.232	.047
	Huynh-Feldt	41827.528	1.000	41827.528	4.232	.047
	Lower-bound	41827.528	1.000	41827.528	4.232	.047
Error(OBJ_ORI)	Sphericity Assumed	365711.5	37	9884.095		
	Greenhouse-Geisser	365711.5	37.000	9884.095		
	Huynh-Feldt	365711.5	37.000	9884.095		
	Lower-bound	365711.5	37.000	9884.095		
POSITION * OBJ_ORI	Sphericity Assumed	27029.426	3	9009.809	1.193	.316
	Greenhouse-Geisser	27029.426	2.858	9457.869	1.193	.315
	Huynh-Feldt	27029.426	3.000	9009.809	1.193	.316
	Lower-bound	27029.426	1.000	27029.426	1.193	.282
POSITION * OBJ_ORI * RES	Sphericity Assumed	3243.758	3	1081.253	.143	.934
	Greenhouse-Geisser	3243.758	2.858	1135.024	.143	.927
	Huynh-Feldt	3243.758	3.000	1081.253	.143	.934
	Lower-bound	3243.758	1.000	3243.758	.143	.707
Error(POSITION*OBJ_ORI)	Sphericity Assumed	837995.8	111	7549.511		
	Greenhouse-Geisser	837995.8	105.741	7924.951		
	Huynh-Feldt	837995.8	111.000	7549.511		
	Lower-bound	837995.8	37.000	22648.534		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1.8E+08	1	1.8E+08	707.749	.000
RES	226060.7	1	226060.7	.889	.352
Error	9407690	37	254261.9		

Table 20
Experiment Six: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects at each stimulus Position within Trials

	Photograph 1		Photograph 2		Photograph 3		Photograph 4	
	Left Oriented	Right Oriented	Left Oriented	Right Oriented	Left Oriented	Right Oriented	Left Oriented	Right Oriented
Left Hand	721.92 (190.33)	770.08 (214.04)	790.66 (247.86)	779.06 (204.49)	716.78 (198.27)	720.67 (206.18)	686.51 (162.80)	676.57 (180.77)
Right Hand	843.42 (175.50)	824.23 (236.69)	840.47 (218.05)	794.41 (174.50)	799.27 (181.88)	765.95 (188.14)	740.78 (199.74)	684.53 (185.02)

Appendix BB

LSD Follow-up Analysis on Stimulus Position Factor in Experiment Six

$n = 39$
s^2 = Error MS = 9936.242
Error df = 111

$$SED = \frac{\sqrt{2\,s^2}}{\sqrt{n}}$$

$$SED = \frac{\sqrt{2 \times 9936.242}}{\sqrt{39}}$$

SED = 22.57

LSD = (t @ 111 df) x SED

LSD = 1.96 x 22.57

LSD = 44.24

Primacy Effect

Difference in means between position one and position two = 11.24
LSD = 44.24 > 11.24 (t crit)$\therefore$ non-significant difference.

Recency Effect

Difference in means between image position three and image position four = 59.82
LSD = 44.24 < 59.82 (t crit) significant difference.

Appendix CC

Table 21
Experiment Six: Mean Number of Errors for Left and Right-hand Responses to Left and Right-oriented Objects

Response Condition	Object Orientation	
	Left	Right
Left Hand	3.50 (2.21)	2.65 (1.39)
Right Hand	2.88 (1.87)	1.94 (1.60)

Appendix DD

Experiment Six: Two-way mixed ANOVA tables for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	14.741	1	14.741	7.092	.012
	Greenhouse-Geisser	14.741	1.000	14.741	7.092	.012
	Huynh-Feldt	14.741	1.000	14.741	7.092	.012
	Lower-bound	14.741	1.000	14.741	7.092	.012
OBJ_ORI * RES_MADE	Sphericity Assumed	3.820E-02	1	3.820E-02	.018	.893
	Greenhouse-Geisser	3.820E-02	1.000	3.820E-02	.018	.893
	Huynh-Feldt	3.820E-02	1.000	3.820E-02	.018	.893
	Lower-bound	3.820E-02	1.000	3.820E-02	.018	.893
Error(OBJ_ORI)	Sphericity Assumed	72.746	35	2.078		
	Greenhouse-Geisser	72.746	35.000	2.078		
	Huynh-Feldt	72.746	35.000	2.078		
	Lower-bound	72.746	35.000	2.078		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	553.273	1	553.273	126.145	.000
RES_MADE	8.084	1	8.084	1.843	.183
Error	153.510	35	4.386		

Appendix EE

Experiment Six: Three-way mixed ANOVA table for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
RES_POS	Sphericity Assumed	415538.4	1	415538.4	33.984	.000
	Greenhouse-Geisser	415538.4	1.000	415538.4	33.984	.000
	Huynh-Feldt	415538.4	1.000	415538.4	33.984	.000
	Lower-bound	415538.4	1.000	415538.4	33.984	.000
RES_POS * RES	Sphericity Assumed	3018.940	1	3018.940	.247	.622
	Greenhouse-Geisser	3018.940	1.000	3018.940	.247	.622
	Huynh-Feldt	3018.940	1.000	3018.940	.247	.622
	Lower-bound	3018.940	1.000	3018.940	.247	.622
Error(RES_POS)	Sphericity Assumed	452414.5	37	12227.419		
	Greenhouse-Geisser	452414.5	37.000	12227.419		
	Huynh-Feldt	452414.5	37.000	12227.419		
	Lower-bound	452414.5	37.000	12227.419		
OBJ_ORI	Sphericity Assumed	55.480	1	55.480	.009	.923
	Greenhouse-Geisser	55.480	1.000	55.480	.009	.923
	Huynh-Feldt	55.480	1.000	55.480	.009	.923
	Lower-bound	55.480	1.000	55.480	.009	.923
OBJ_ORI * RES	Sphericity Assumed	15621.003	1	15621.003	2.671	.111
	Greenhouse-Geisser	15621.003	1.000	15621.003	2.671	.111
	Huynh-Feldt	15621.003	1.000	15621.003	2.671	.111
	Lower-bound	15621.003	1.000	15621.003	2.671	.111
Error(OBJ_ORI)	Sphericity Assumed	216407.2	37	5848.842		
	Greenhouse-Geisser	216407.2	37.000	5848.842		
	Huynh-Feldt	216407.2	37.000	5848.842		
	Lower-bound	216407.2	37.000	5848.842		
RES_POS * OBJ_ORI	Sphericity Assumed	2989.469	1	2989.469	1.148	.291
	Greenhouse-Geisser	2989.469	1.000	2989.469	1.148	.291
	Huynh-Feldt	2989.469	1.000	2989.469	1.148	.291
	Lower-bound	2989.469	1.000	2989.469	1.148	.291
RES_POS * OBJ_ORI * RES	Sphericity Assumed	5253.648	1	5253.648	2.017	.164
	Greenhouse-Geisser	5253.648	1.000	5253.648	2.017	.164
	Huynh-Feldt	5253.648	1.000	5253.648	2.017	.164
	Lower-bound	5253.648	1.000	5253.648	2.017	.164
Error(RES_POS*OBJ_ORI)	Sphericity Assumed	96376.821	37	2604.779		
	Greenhouse-Geisser	96376.821	37.000	2604.779		
	Huynh-Feldt	96376.821	37.000	2604.779		
	Lower-bound	96376.821	37.000	2604.779		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	9.1E+07	1	9.1E+07	701.596	.000
RES	118194.2	1	118194.2	.915	.345
Error	4777672	37	129126.3		

Table 22
Experiment Six: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects during the First and Second Halves of the Experiment

Response Condition	Object Orientation			
	First Half of Experiment		Second Half of Experiment	
	Left	Right	Left	Right
Left Hand	781.58 (213.88)	782.42 (235.64)	666.76 (167.29)	708.34 (173.31)
Right Hand	853.86 (198.02)	837.88 (222.24)	744.65 (165.32)	722.97 (157.77)

Instructions, Experiments Seven and Eight, Mapping One

- In this experiment you will be presented with two blocks of 200 trials.
- At the start of each trial you will be shown a "Get Ready" message to inform you that the trial is about to begin. When the message has been removed from view you will see a series of pictures, each depicting an object. Each picture will remain on the screen for 200 msecs. In block one you will see a series of four pictures on each trial, and in block two you will see a series of eight pictures on each trial.
- After the last picture in a trial has been removed from the screen, the name of an object will appear on the screen. When you see the object name you are asked to decide whether or not you remember seeing the named object in the series of pictures just seen.
- If you DO remember seeing the object named, please press the switch in your LEFT HAND. At the same time try and visualise the object – this will help with the memory test at the end of the experiment.
- If you DO NOT remember seeing the object named, please press the switch in your RIGHT HAND.
- When you make your response, the next trial will begin. If you make an error you will hear a short "bleep".
- Before the main experiment begins you will be given a short practice session for both the 'four picture' block, and the 'eight picture' block.
- Please make your response as quickly as possible whilst maintaining accuracy.
- At the end of the experiment you will be given a short memory test.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Exp 7 & 8 Mapping One

Instructions, Experiments Seven and Eight, Mapping Two

- In this experiment you will be presented with two blocks of 200 trials.
- At the start of each trial you will be shown a "Get Ready" message to inform you that the trial is about to begin. When the message has been removed from view you will see a series of pictures, each depicting an object. Each picture will remain on the screen for 200 msecs. In block one you will see a series of eight pictures on each trials, and in block two you will see a series of four pictures on each trial.
- After the last picture in a trial has been removed from the screen, the name of an object will appear on the screen. When you see the object name you are asked to decide whether or not you remember seeing the named object in the series of pictures just seen.
- If you DO remember seeing the object named, please press the switch in your RIGHT HAND. At the same time try and visualise the object – this will help with the memory test at the end of the experiment.
- If you DO NOT remember seeing the object named, please press the switch in your LEFT HAND.
- When you make your response, the next trial will begin. If you make an error you will hear a short "bleep".
- Before the main experiment begins you will be given a short practice session for both the 'eight picture' block, and the 'four picture' block.
- Please make your response as quickly as possible whilst maintaining accuracy.
- At the end of the experiment you will be given a short memory test.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Instructions, Experiments Seven and Eight, Mapping Three

- In this experiment you will be presented with two blocks of 200 trials.
- At the start of each trial you will be shown a "Get Ready" message to inform you that the trial is about to begin. When the message has been removed from view you will see a series of pictures, each depicting an object. Each picture will remain on the screen for 200 msecs. In block one you will see a series of four pictures on each trial, and in block two you will see a series of eight pictures on each trial.
- After the last picture in a trial has been removed from the screen, the name of an object will appear on the screen. When you see the object name you are asked to decide whether or not you remember seeing the named object in the series of pictures just seen.
- If you DO remember seeing the object named, please press the switch in your RIGHT HAND. At the same time try and visualise the object – this will help with the memory test at the end of the experiment.
- If you DO NOT remember seeing the object named, please press the switch in your LEFT HAND.
- When you make your response, the next trial will begin. If you make an error you will hear a short "bleep".
- Before the main experiment begins you will be given a short practice session for both the 'four picture' block, and the 'eight picture' block.
- Please make your response as quickly as possible whilst maintaining accuracy.
- At the end of the experiment you will be given a short memory test.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Exp 7 & 8 Mapping Three

Instructions, Experiments Seven and Eight, Mapping Four

- In this experiment you will be presented with two blocks of 200 trials.
- At the start of each trial you will be shown a "Get Ready" message to inform you that the trial is about to begin. When the message has been removed from view you will see a series of pictures, each depicting an object. Each picture will remain on the screen for 200 msecs. In block one you will see a series of eight pictures on each trials, and in block two you will see a series of four pictures on each trial.
- After the last picture in a trial has been removed from the screen, the name of an object will appear on the screen. When you see the object name you are asked to decide whether or not you remember seeing the named object in the series of pictures just seen.
- If you DO remember seeing the object named, please press the switch in your LEFT HAND. At the same time try and visualise the object – this will help with the memory test at the end of the experiment.
- If you DO NOT remember seeing the object named, please press the switch in your RIGHT HAND.
- When you make your response, the next trial will begin. If you make an error you will hear a short "bleep".
- Before the main experiment begins you will be given a short practice session for both the 'eight picture' block, and the 'four picture' block.
- Please make your response as quickly as possible whilst maintaining accuracy.
- At the end of the experiment you will be given a short memory test.

THANK YOU FOR PARTICIPATING

Note: You have the right to withdraw from the experiment at any time.
Every effort is made to maintain the anonymity of all response data.

Exp 7 & 8 Mapping four

Appendix HH

Experiment Seven: Four-way mixed ANOVA table for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	610805.112	3	203601.704	9.706	.000
	Greenhouse-Geisser	610805.112	2.338	261242.752	9.706	.000
	Huynh-Feldt	610805.112	2.596	235269.076	9.706	.000
	Lower-bound	610805.112	1.000	610805.112	9.706	.003
POSITION * RES	Sphericity Assumed	98994.064	3	32998.021	1.573	.198
	Greenhouse-Geisser	98994.064	2.338	42339.989	1.573	.208
	Huynh-Feldt	98994.064	2.596	38130.398	1.573	.204
	Lower-bound	98994.064	1.000	98994.064	1.573	.215
POSITION * ORDER	Sphericity Assumed	42985.180	3	14328.393	.683	.564
	Greenhouse-Geisser	42985.180	2.338	18384.860	.683	.529
	Huynh-Feldt	42985.180	2.596	16556.973	.683	.543
	Lower-bound	42985.180	1.000	42985.180	.683	.412
POSITION * RES * ORDER	Sphericity Assumed	28946.056	3	9648.685	.460	.711
	Greenhouse-Geisser	28946.056	2.338	12380.295	.460	.663
	Huynh-Feldt	28946.056	2.596	11149.402	.460	.683
	Lower-bound	28946.056	1.000	28946.056	.460	.501
Error(POSITION)	Sphericity Assumed	3272332.105	156	20976.488		
	Greenhouse-Geisser	3272332.105	121.580	26915.076		
	Huynh-Feldt	3272332.105	135.002	24239.085		
	Lower-bound	3272332.105	52.000	62929.464		
ORI	Sphericity Assumed	4.000	1	4.000	.000	.986
	Greenhouse-Geisser	4.000	1.000	4.000	.000	.986
	Huynh-Feldt	4.000	1.000	4.000	.000	.986
	Lower-bound	4.000	1.000	4.000	.000	.986
ORI * RES	Sphericity Assumed	6056.576	1	6056.576	.483	.490
	Greenhouse-Geisser	6056.576	1.000	6056.576	.483	.490
	Huynh-Feldt	6056.576	1.000	6056.576	.483	.490
	Lower-bound	6056.576	1.000	6056.576	.483	.490
ORI * ORDER	Sphericity Assumed	53003.120	1	53003.120	4.226	.045
	Greenhouse-Geisser	53003.120	1.000	53003.120	4.226	.045
	Huynh-Feldt	53003.120	1.000	53003.120	4.226	.045
	Lower-bound	53003.120	1.000	53003.120	4.226	.045
ORI * RES * ORDER	Sphericity Assumed	4699.147	1	4699.147	.375	.543
	Greenhouse-Geisser	4699.147	1.000	4699.147	.375	.543
	Huynh-Feldt	4699.147	1.000	4699.147	.375	.543
	Lower-bound	4699.147	1.000	4699.147	.375	.543
Error(ORI)	Sphericity Assumed	652218.883	52	12542.671		
	Greenhouse-Geisser	652218.883	52.000	12542.671		
	Huynh-Feldt	652218.883	52.000	12542.671		
	Lower-bound	652218.883	52.000	12542.671		
POSITION * ORI	Sphericity Assumed	16948.913	3	5649.638	.342	.795
	Greenhouse-Geisser	16948.913	2.198	7711.031	.342	.731
	Huynh-Feldt	16948.913	2.431	6970.849	.342	.752
	Lower-bound	16948.913	1.000	16948.913	.342	.561
POSITION * ORI * RES	Sphericity Assumed	5538.138	3	1846.046	.112	.953
	Greenhouse-Geisser	5538.138	2.198	2519.616	.112	.911
	Huynh-Feldt	5538.138	2.431	2277.758	.112	.926
	Lower-bound	5538.138	1.000	5538.138	.112	.740
POSITION * ORI * ORDER	Sphericity Assumed	30121.784	3	10040.595	.607	.611
	Greenhouse-Geisser	30121.784	2.198	13704.124	.607	.562
	Huynh-Feldt	30121.784	2.431	12388.666	.607	.578
	Lower-bound	30121.784	1.000	30121.784	.607	.439
POSITION * ORI * RES * ORDER	Sphericity Assumed	25947.701	3	8649.234	.523	.667
	Greenhouse-Geisser	25947.701	2.198	11805.095	.523	.611
	Huynh-Feldt	25947.701	2.431	10671.924	.523	.629
	Lower-bound	25947.701	1.000	25947.701	.523	.473
Error(POSITION*ORI)	Sphericity Assumed	2578957.323	156	16531.778		
	Greenhouse-Geisser	2578957.323	114.296	22563.756		
	Huynh-Feldt	2578957.323	126.433	20397.863		
	Lower-bound	2578957.323	52.000	49595.333		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	274716248	1	274716248.5	1006.559	.000
RES	97391.326	1	97391.326	.357	.553
ORDER	27751.857	1	27751.857	.102	.751
RES * ORDER	42485.589	1	42485.589	.156	.695
Error	14192165.1	52	272926.251		

Table 23
Experiment Seven: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects at each Stimulus Position, when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7 – Exp8)

	Photograph 1		Photograph 2		Photograph 3		Photograph 4	
	Left Oriented	Right Oriented	Left Oriented	Right Oriented	Left Oriented	Right Oriented	Left Oriented	Right Oriented
Left Hand	794.21 (201.38)	757.88 (223.02)	830.47 (199.32)	793.18 (219.17	752.64 (252.34)	755.88 (138.68)	772.36 (395.96)	700.57 (186.32)
Right Hand	868.51 (292.36)	871.21 (274.36)	892.10 (220.33)	842.89 (256.91)	789.10 (278.34)	812.18 (223.28)	741.09 (203.81)	733.46 (236.34)

Experiment Presentation Order Two (Exp8 – Exp7)

	Photograph 1		Photograph 2		Photograph 3		Photograph 4	
	Left Oriented	Right Oriented	Left Oriented	Right Oriented	Left Oriented	Right Oriented	Left Oriented	Right Oriented
Left Hand	795.26 (288.39)	794.33 (275.80)	785.94 (210.10)	766.88 (262.28)	767.11 (182.32)	806.65 (276.28)	702.97 (188.77)	768.06 (241.60)
Right Hand	796.42 (172.29)	805.26 (182.54)	813.44 (157.75)	855.68 (165.80)	802.15 (145.24)	802.10 (122.42)	675.97 (126.48)	715.70 (116.23)

Appendix JJ

LSD Follow-up Analysis on Stimulus Position Factor in Experiment Seven

$n = 56$
s^2 = Error MS = 20976.49
Error df = 156

$$SED = \frac{\sqrt{2s^2}}{\sqrt{n}}$$

$$SED = \frac{\sqrt{2 \times 20976.49}}{\sqrt{56}}$$

$SED = 27.37$

LSD = (t @ 156 df) x SED

LSD = 1.96 x 27.37

LSD = 53.64

Primacy Effect

Difference in means between position one and position two = 12.19
LSD = 53.64 > 12.19 (t-crit) ∴ non-significant difference.

Recency Effect

Difference in means between image position three and image position four = 59.81
LSD = 53.64 < 59.81(t-crit)∴ significant difference.

Appendix KK

Experiment Seven: Four-way mixed ANOVA on Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
HALF	Sphericity Assumed	123327.612	1	123327.612	10.765	.002
	Greenhouse-Geisser	123327.612	1.000	123327.612	10.765	.002
	Huynh-Feldt	123327.612	1.000	123327.612	10.765	.002
	Lower-bound	123327.612	1.000	123327.612	10.765	.002
HALF * RES	Sphericity Assumed	5464.546	1	5464.546	.477	.493
	Greenhouse-Geisser	5464.546	1.000	5464.546	.477	.493
	Huynh-Feldt	5464.546	1.000	5464.546	.477	.493
	Lower-bound	5464.546	1.000	5464.546	.477	.493
HALF * ORDER	Sphericity Assumed	74596.385	1	74596.385	6.512	.014
	Greenhouse-Geisser	74596.385	1.000	74596.385	6.512	.014
	Huynh-Feldt	74596.385	1.000	74596.385	6.512	.014
	Lower-bound	74596.385	1.000	74596.385	6.512	.014
HALF * RES * ORDER	Sphericity Assumed	981.406	1	981.406	.086	.771
	Greenhouse-Geisser	981.406	1.000	981.406	.086	.771
	Huynh-Feldt	981.406	1.000	981.406	.086	.771
	Lower-bound	981.406	1.000	981.406	.086	.771
Error(HALF)	Sphericity Assumed	595710.033	52	11455.962		
	Greenhouse-Geisser	595710.033	52.000	11455.962		
	Huynh-Feldt	595710.033	52.000	11455.962		
	Lower-bound	595710.033	52.000	11455.962		
OBJ_ORI	Sphericity Assumed	667.673	1	667.673	.161	.690
	Greenhouse-Geisser	667.673	1.000	667.673	.161	.690
	Huynh-Feldt	667.673	1.000	667.673	.161	.690
	Lower-bound	667.673	1.000	667.673	.161	.690
OBJ_ORI * RES	Sphericity Assumed	3898.715	1	3898.715	.938	.337
	Greenhouse-Geisser	3898.715	1.000	3898.715	.938	.337
	Huynh-Feldt	3898.715	1.000	3898.715	.938	.337
	Lower-bound	3898.715	1.000	3898.715	.938	.337
OBJ_ORI * ORDER	Sphericity Assumed	22801.652	1	22801.652	5.489	.023
	Greenhouse-Geisser	22801.652	1.000	22801.652	5.489	.023
	Huynh-Feldt	22801.652	1.000	22801.652	5.489	.023
	Lower-bound	22801.652	1.000	22801.652	5.489	.023
OBJ_ORI * RES * ORDER	Sphericity Assumed	5368.135	1	5368.135	1.292	.261
	Greenhouse-Geisser	5368.135	1.000	5368.135	1.292	.261
	Huynh-Feldt	5368.135	1.000	5368.135	1.292	.261
	Lower-bound	5368.135	1.000	5368.135	1.292	.261
Error(OBJ_ORI)	Sphericity Assumed	216023.266	52	4154.294		
	Greenhouse-Geisser	216023.266	52.000	4154.294		
	Huynh-Feldt	216023.266	52.000	4154.294		
	Lower-bound	216023.266	52.000	4154.294		
HALF * OBJ_ORI	Sphericity Assumed	2242.852	1	2242.852	.491	.487
	Greenhouse-Geisser	2242.852	1.000	2242.852	.491	.487
	Huynh-Feldt	2242.852	1.000	2242.852	.491	.487
	Lower-bound	2242.852	1.000	2242.852	.491	.487
HALF * OBJ_ORI * RES	Sphericity Assumed	2680.528	1	2680.528	.587	.447
	Greenhouse-Geisser	2680.528	1.000	2680.528	.587	.447
	Huynh-Feldt	2680.528	1.000	2680.528	.587	.447
	Lower-bound	2680.528	1.000	2680.528	.587	.447
HALF * OBJ_ORI * ORDER	Sphericity Assumed	9768.588	1	9768.588	2.138	.150
	Greenhouse-Geisser	9768.588	1.000	9768.588	2.138	.150
	Huynh-Feldt	9768.588	1.000	9768.588	2.138	.150
	Lower-bound	9768.588	1.000	9768.588	2.138	.150
HALF * OBJ_ORI * RES * ORDER	Sphericity Assumed	2284.595	1	2284.595	.500	.483
	Greenhouse-Geisser	2284.595	1.000	2284.595	.500	.483
	Huynh-Feldt	2284.595	1.000	2284.595	.500	.483
	Lower-bound	2284.595	1.000	2284.595	.500	.483
Error(HALF*OBJ_ORI)	Sphericity Assumed	237632.358	52	4569.853		
	Greenhouse-Geisser	237632.358	52.000	4569.853		
	Huynh-Feldt	237632.358	52.000	4569.853		
	Lower-bound	237632.358	52.000	4569.853		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	136635472	1	136635471.6	930.218	.000
RES	21133.635	1	21133.635	.144	.706
ORDER	30485.028	1	30485.028	.208	.651
RES * ORDER	8434.176	1	8434.176	.057	.812
Error	7638046.193	52	146885.504		

Table 24

Experiment Seven: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects in the First and Second Halves of the Experiment, when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7 – Exp8)				
	Object Orientation			
Response Condition	First Half of Experiment		Second Half of Experiment	
	Left	Right	Left	Right
Left Hand	846.66 (291.58)	791.51 (208.08)	757.76 (201.63)	776.49 (211.91)
Right Hand	865.47 (239.88)	847.80 (260.14)	767.16 (126.87)	809.71 (147.54)

Experiment Presentation Order Two (Exp8 – Exp7)				
	Object Orientation			
Response Condition	First Half of Experiment		Second Half of Experiment	
	Left	Right	Left	Right
Left Hand	748.46 (145.54)	733.60 (172.41)	754.96 (223.32)	786.59 (284.05)
Right Hand	756.89 (205.25)	777.39 (196.95)	762.83 (154.93)	764.84 (105.03)

Appendix MM

Experiment Seven: Four-way mixed ANOVA table for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
HALF	Sphericity Assumed	4.842	1	4.842	1.120	.295
	Greenhouse-Geisser	4.842	1.000	4.842	1.120	.295
	Huynh-Feldt	4.842	1.000	4.842	1.120	.295
	Lower-bound	4.842	1.000	4.842	1.120	.295
HALF * RES	Sphericity Assumed	20.854	1	20.854	4.824	.033
	Greenhouse-Geisser	20.854	1.000	20.854	4.824	.033
	Huynh-Feldt	20.854	1.000	20.854	4.824	.033
	Lower-bound	20.854	1.000	20.854	4.824	.033
HALF * ORDER	Sphericity Assumed	3.016	1	3.016	.698	.407
	Greenhouse-Geisser	3.016	1.000	3.016	.698	.407
	Huynh-Feldt	3.016	1.000	3.016	.698	.407
	Lower-bound	3.016	1.000	3.016	.698	.407
HALF * RES * ORDER	Sphericity Assumed	3.354	1	3.354	.776	.383
	Greenhouse-Geisser	3.354	1.000	3.354	.776	.383
	Huynh-Feldt	3.354	1.000	3.354	.776	.383
	Lower-bound	3.354	1.000	3.354	.776	.383
Error(HALF)	Sphericity Assumed	220.469	51	4.323		
	Greenhouse-Geisser	220.469	51.000	4.323		
	Huynh-Feldt	220.469	51.000	4.323		
	Lower-bound	220.469	51.000	4.323		
OBJ_ORI	Sphericity Assumed	.296	1	.296	.103	.750
	Greenhouse-Geisser	.296	1.000	.296	.103	.750
	Huynh-Feldt	.296	1.000	.296	.103	.750
	Lower-bound	.296	1.000	.296	.103	.750
OBJ_ORI * RES	Sphericity Assumed	6.410	1	6.410	2.220	.142
	Greenhouse-Geisser	6.410	1.000	6.410	2.220	.142
	Huynh-Feldt	6.410	1.000	6.410	2.220	.142
	Lower-bound	6.410	1.000	6.410	2.220	.142
OBJ_ORI * ORDER	Sphericity Assumed	7.611	1	7.611	2.636	.111
	Greenhouse-Geisser	7.611	1.000	7.611	2.636	.111
	Huynh-Feldt	7.611	1.000	7.611	2.636	.111
	Lower-bound	7.611	1.000	7.611	2.636	.111
OBJ_ORI * RES * ORDER	Sphericity Assumed	6.948	1	6.948	2.406	.127
	Greenhouse-Geisser	6.948	1.000	6.948	2.406	.127
	Huynh-Feldt	6.948	1.000	6.948	2.406	.127
	Lower-bound	6.948	1.000	6.948	2.406	.127
Error(OBJ_ORI)	Sphericity Assumed	147.264	51	2.888		
	Greenhouse-Geisser	147.264	51.000	2.888		
	Huynh-Feldt	147.264	51.000	2.888		
	Lower-bound	147.264	51.000	2.888		
HALF * OBJ_ORI	Sphericity Assumed	6.530E-02	1	6.530E-02	.018	.893
	Greenhouse-Geisser	6.530E-02	1.000	6.530E-02	.018	.893
	Huynh-Feldt	6.530E-02	1.000	6.530E-02	.018	.893
	Lower-bound	6.530E-02	1.000	6.530E-02	.018	.893
HALF * OBJ_ORI * RES	Sphericity Assumed	6.627	1	6.627	1.840	.181
	Greenhouse-Geisser	6.627	1.000	6.627	1.840	.181
	Huynh-Feldt	6.627	1.000	6.627	1.840	.181
	Lower-bound	6.627	1.000	6.627	1.840	.181
HALF * OBJ_ORI * ORDER	Sphericity Assumed	1.756E-02	1	1.756E-02	.005	.945
	Greenhouse-Geisser	1.756E-02	1.000	1.756E-02	.005	.945
	Huynh-Feldt	1.756E-02	1.000	1.756E-02	.005	.945
	Lower-bound	1.756E-02	1.000	1.756E-02	.005	.945
HALF * OBJ_ORI * RES * ORDER	Sphericity Assumed	1.491	1	1.491	.414	.523
	Greenhouse-Geisser	1.491	1.000	1.491	.414	.523
	Huynh-Feldt	1.491	1.000	1.491	.414	.523
	Lower-bound	1.491	1.000	1.491	.414	.523
Error(HALF*OBJ_ORI)	Sphericity Assumed	183.731	51	3.603		
	Greenhouse-Geisser	183.731	51.000	3.603		
	Huynh-Feldt	183.731	51.000	3.603		
	Lower-bound	183.731	51.000	3.603		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	2232.231	1	2232.231	131.495	.000
RES	6.676	1	6.676	.393	.533
ORDER	25.447	1	25.447	1.499	.226
RES * ORDER	.242	1	.242	.014	.905
Error	865.767	51	16.976		

Table 25
Experiment Seven: Mean Number of Errors for Left and Right-hand Responses to Left and Right-oriented Objects in the First and Second Halves of the Experiment, when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7 – Exp8)				
	Object Orientation			
Response Condition	First Half of Experiment		Second Half of Experiment	
	Left	Right	Left	Right
Left Hand	4.50 (3.12)	3.33 (3.05)	4.13 (2.47)	3.16 (3.16)
Right Hand	2.33 (1.40)	2.93 (2.22)	3.93 (2.84)	4.13 (2.47)

Experiment Presentation Order Two (Exp8 – Exp7)				
	Object Orientation			
Response Condition	First Half of Experiment		Second Half of Experiment	
	Left	Right	Left	Right
Left Hand	3.15 (2.19)	3.15 (2.97)	2.38 (1.66)	3.31 (4.31)
Right Hand	2.00 (1.81)	3.00 (1.73)	3.00 (2.42)	2.87 (1.92)

Appendix OO

Experiment Seven: Three-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	1233.560	1	1233.560	.721	.400
	Greenhouse-Geisser	1233.560	1.000	1233.560	.721	.400
	Huynh-Feldt	1233.560	1.000	1233.560	.721	.400
	Lower-bound	1233.560	1.000	1233.560	.721	.400
OBJ_ORI * RES	Sphericity Assumed	1896.654	1	1896.654	1.109	.297
	Greenhouse-Geisser	1896.654	1.000	1896.654	1.109	.297
	Huynh-Feldt	1896.654	1.000	1896.654	1.109	.297
	Lower-bound	1896.654	1.000	1896.654	1.109	.297
OBJ_ORI * ORDER	Sphericity Assumed	2328.489	1	2328.489	1.361	.249
	Greenhouse-Geisser	2328.489	1.000	2328.489	1.361	.249
	Huynh-Feldt	2328.489	1.000	2328.489	1.361	.249
	Lower-bound	2328.489	1.000	2328.489	1.361	.249
OBJ_ORI * RES * ORDER	Sphericity Assumed	409.879	1	409.879	.240	.627
	Greenhouse-Geisser	409.879	1.000	409.879	.240	.627
	Huynh-Feldt	409.879	1.000	409.879	.240	.627
	Lower-bound	409.879	1.000	409.879	.240	.627
Error(OBJ_ORI)	Sphericity Assumed	88963.135	52	1710.830		
	Greenhouse-Geisser	88963.135	52.000	1710.830		
	Huynh-Feldt	88963.135	52.000	1710.830		
	Lower-bound	88963.135	52.000	1710.830		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	73967114.8	1	73967114.76	1123.639	.000
RES	19578.369	1	19578.369	.297	.588
ORDER	199.414	1	199.414	.003	.956
RES * ORDER	6506.903	1	6506.903	.099	.754
Error	3423066.256	52	65828.197		

Table 26

Experiment Seven: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects when responses are made to Non-Oriented Objects and when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	797.42 (188.95)	795.49 (191.46)
Right Hand	834.85 (203.85)	841.77 (210.76)

Experiment Presentation Order Two (Exp8-Exp7)

Response Condition	Object Orientation	
	Left	Right
Left Hand	823.04 (197.87)	795.11 (204.10)
Right Hand	822.18 (118.48)	818.47 (138.85)

Appendix QQ

Experiment Seven: Three-way mixed ANOVA tables for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	5.072	1	5.072	.838	.364
	Greenhouse-Geisser	5.072	1.000	5.072	.838	.364
	Huynh-Feldt	5.072	1.000	5.072	.838	.364
	Lower-bound	5.072	1.000	5.072	.838	.364
OBJ_ORI * RES	Sphericity Assumed	5.359	1	5.359	.885	.351
	Greenhouse-Geisser	5.359	1.000	5.359	.885	.351
	Huynh-Feldt	5.359	1.000	5.359	.885	.351
	Lower-bound	5.359	1.000	5.359	.885	.351
OBJ_ORI * ORDER	Sphericity Assumed	1.654	1	1.654	.273	.603
	Greenhouse-Geisser	1.654	1.000	1.654	.273	.603
	Huynh-Feldt	1.654	1.000	1.654	.273	.603
	Lower-bound	1.654	1.000	1.654	.273	.603
OBJ_ORI * RES * ORDER	Sphericity Assumed	.221	1	.221	.037	.849
	Greenhouse-Geisser	.221	1.000	.221	.037	.849
	Huynh-Feldt	.221	1.000	.221	.037	.849
	Lower-bound	.221	1.000	.221	.037	.849
Error(OBJ_ORI)	Sphericity Assumed	314.757	52	6.053		
	Greenhouse-Geisser	314.757	52.000	6.053		
	Huynh-Feldt	314.757	52.000	6.053		
	Lower-bound	314.757	52.000	6.053		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	2027.693	1	2027.693	222.090	.000
RES	.982	1	.982	.108	.744
ORDER	4.932	1	4.932	.540	.466
RES * ORDER	1.362	1	1.362	.149	.701
Error	474.762	52	9.130		

Table 27
Mean Number of Inaccurate Responses for Left and Right-hand Responses to Left and Right-oriented Objects when responses are made to Non-Oriented Objects and when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	4.73 (2.09)	4.20 (2.04)
Right Hand	4.42 (3.42)	4.58 (2.31)

Experiment Presentation Order Two (Exp8-Exp7)

Response Condition	Object Orientation	
	Left	Right
Left Hand	4.87 (3.11)	3.67 (3.33)
Right Hand	3.93 (3.17)	3.78 (2.15)

Appendix SS

Experiment Seven: Three-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	192.555	1	192.555	.210	.648
	Greenhouse-Geisser	192.555	1.000	192.555	.210	.648
	Huynh-Feldt	192.555	1.000	192.555	.210	.648
	Lower-bound	192.555	1.000	192.555	.210	.648
OBJ_ORI * RES	Sphericity Assumed	63.735	1	63.735	.070	.793
	Greenhouse-Geisser	63.735	1.000	63.735	.070	.793
	Huynh-Feldt	63.735	1.000	63.735	.070	.793
	Lower-bound	63.735	1.000	63.735	.070	.793
OBJ_ORI * ORDER	Sphericity Assumed	9.242	1	9.242	.010	.920
	Greenhouse-Geisser	9.242	1.000	9.242	.010	.920
	Huynh-Feldt	9.242	1.000	9.242	.010	.920
	Lower-bound	9.242	1.000	9.242	.010	.920
OBJ_ORI * RES * ORDER	Sphericity Assumed	1750.089	1	1750.089	1.912	.173
	Greenhouse-Geisser	1750.089	1.000	1750.089	1.912	.173
	Huynh-Feldt	1750.089	1.000	1750.089	1.912	.173
	Lower-bound	1750.089	1.000	1750.089	1.912	.173
Error(OBJ_ORI)	Sphericity Assumed	47596.914	52	915.325		
	Greenhouse-Geisser	47596.914	52.000	915.325		
	Huynh-Feldt	47596.914	52.000	915.325		
	Lower-bound	47596.914	52.000	915.325		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	82228393.2	1	82228393.21	1032.027	.000
RES	55238.324	1	55238.324	.693	.409
ORDER	22353.120	1	22353.120	.281	.599
RES * ORDER	11078.564	1	11078.564	.139	.711
Error	4143183.125	52	79676.599		

Table 28

Experiment Seven: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects for "No" Responses, when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7-Exp8)		
Response Condition	Object Orientation	
	Left	Right
Left Hand	911.70 (244.44)	902.06 (248.25)
Right Hand	840.70 (188.01)	843.91 (216.67)

Experiment Presentation Order Two (Exp8-Exp7)		
Response Condition	Object Orientation	
	Left	Right
Left Hand	854.83 (112.24)	862.23 (114.25)
Right Hand	839.66 (223.13)	828.15 (211.19)

Appendix UU

Experiment Seven: Three-way mixed ANOVA table for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	.822	1	.822	.092	.763
	Greenhouse-Geisser	.822	1.000	.822	.092	.763
	Huynh-Feldt	.822	1.000	.822	.092	.763
	Lower-bound	.822	1.000	.822	.092	.763
OBJ_ORI * RES_C	Sphericity Assumed	1.896	1	1.896	.213	.647
	Greenhouse-Geisser	1.896	1.000	1.896	.213	.647
	Huynh-Feldt	1.896	1.000	1.896	.213	.647
	Lower-bound	1.896	1.000	1.896	.213	.647
OBJ_ORI * ORDER	Sphericity Assumed	6.567	1	6.567	.737	.395
	Greenhouse-Geisser	6.567	1.000	6.567	.737	.395
	Huynh-Feldt	6.567	1.000	6.567	.737	.395
	Lower-bound	6.567	1.000	6.567	.737	.395
OBJ_ORI * RES_C * ORDER	Sphericity Assumed	.600	1	.600	.067	.796
	Greenhouse-Geisser	.600	1.000	.600	.067	.796
	Huynh-Feldt	.600	1.000	.600	.067	.796
	Lower-bound	.600	1.000	.600	.067	.796
Error(OBJ_ORI)	Sphericity Assumed	463.506	52	8.914		
	Greenhouse-Geisser	463.506	52.000	8.914		
	Huynh-Feldt	463.506	52.000	8.914		
	Lower-bound	463.506	52.000	8.914		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	8171.338	1	8171.338	259.663	.000
RES_C	8.147E-02	1	8.147E-02	.003	.960
ORDER	28.938	1	28.938	.920	.342
RES_C * ORDER	18.332	1	18.332	.583	.449
Error	1636.392	52	31.469		

Table 29

Experiment Seven: Mean Number of Errors for Left and Right-hand Responses to Left and Right-oriented Objects for "No" Responses, when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	8.83 (4.15)	8.58 (3.53)
Right Hand	10.00 (4.47)	8.93 (3.81)

Experiment Presentation Order Two (Exp8-Exp7)

Response Condition	Object Orientation	
	Left	Right
Left Hand	8.28 (4.83)	8.71 (4.10)
Right Hand	7.53 (5.46)	7.73 (4.18)

Appendix WW

Experiment Eight: Four-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
POSITION	Sphericity Assumed	1793671.080	7	256238.726	10.691	.000
	Greenhouse-Geisser	1793671.080	5.659	316971.053	10.691	.000
	Huynh-Feldt	1793671.080	6.902	259861.210	10.691	.000
	Lower-bound	1793671.080	1.000	1793671.080	10.691	.002
POSITION * ORDER	Sphericity Assumed	170820.937	7	24402.991	1.018	.418
	Greenhouse-Geisser	170820.937	5.659	30186.857	1.018	.412
	Huynh-Feldt	170820.937	6.902	24747.980	1.018	.418
	Lower-bound	170820.937	1.000	170820.937	1.018	.318
POSITION * RES	Sphericity Assumed	124992.047	7	17856.007	.745	.634
	Greenhouse-Geisser	124992.047	5.659	22088.142	.745	.606
	Huynh-Feldt	124992.047	6.902	18108.440	.745	.632
	Lower-bound	124992.047	1.000	124992.047	.745	.392
POSITION * ORDER * RES	Sphericity Assumed	121101.174	7	17300.168	.722	.654
	Greenhouse-Geisser	121101.174	5.659	21400.561	.722	.624
	Huynh-Feldt	121101.174	6.902	17544.743	.722	.652
	Lower-bound	121101.174	1.000	121101.174	.722	.400
Error(POSITION)	Sphericity Assumed	8053081.811	336	23967.505		
	Greenhouse-Geisser	8053081.811	271.622	29648.155		
	Huynh-Feldt	8053081.811	331.316	24306.338		
	Lower-bound	8053081.811	48.000	167772.538		
OBJ_ORI	Sphericity Assumed	584.179	1	584.179	.053	.818
	Greenhouse-Geisser	584.179	1.000	584.179	.053	.818
	Huynh-Feldt	584.179	1.000	584.179	.053	.818
	Lower-bound	584.179	1.000	584.179	.053	.818
OBJ_ORI * ORDER	Sphericity Assumed	6394.775	1	6394.775	.585	.448
	Greenhouse-Geisser	6394.775	1.000	6394.775	.585	.448
	Huynh-Feldt	6394.775	1.000	6394.775	.585	.448
	Lower-bound	6394.775	1.000	6394.775	.585	.448
OBJ_ORI * RES	Sphericity Assumed	248.667	1	248.667	.023	.881
	Greenhouse-Geisser	248.667	1.000	248.667	.023	.881
	Huynh-Feldt	248.667	1.000	248.667	.023	.881
	Lower-bound	248.667	1.000	248.667	.023	.881
OBJ_ORI * ORDER * RES	Sphericity Assumed	19836.308	1	19836.308	1.815	.184
	Greenhouse-Geisser	19836.308	1.000	19836.308	1.815	.184
	Huynh-Feldt	19836.308	1.000	19836.308	1.815	.184
	Lower-bound	19836.308	1.000	19836.308	1.815	.184
Error(OBJ_ORI)	Sphericity Assumed	524693.507	48	10931.115		
	Greenhouse-Geisser	524693.507	48.000	10931.115		
	Huynh-Feldt	524693.507	48.000	10931.115		
	Lower-bound	524693.507	48.000	10931.115		
POSITION * OBJ_ORI	Sphericity Assumed	382638.377	7	54662.625	2.776	.008
	Greenhouse-Geisser	382638.377	5.556	68867.883	2.776	.015
	Huynh-Feldt	382638.377	6.760	56603.755	2.776	.009
	Lower-bound	382638.377	1.000	382638.377	2.776	.102
POSITION * OBJ_ORI * ORDER	Sphericity Assumed	137205.779	7	19600.826	.995	.434
	Greenhouse-Geisser	137205.779	5.556	24694.521	.995	.426
	Huynh-Feldt	137205.779	6.760	20296.872	.995	.433
	Lower-bound	137205.779	1.000	137205.779	.995	.323
POSITION * OBJ_ORI * RES	Sphericity Assumed	158783.493	7	22683.356	1.152	.330
	Greenhouse-Geisser	158783.493	5.556	28578.113	1.152	.333
	Huynh-Feldt	158783.493	6.760	23488.867	1.152	.331
	Lower-bound	158783.493	1.000	158783.493	1.152	.289
POSITION * OBJ_ORI * ORDER * RES	Sphericity Assumed	217675.274	7	31096.468	1.579	.141
	Greenhouse-Geisser	217675.274	5.556	39177.553	1.579	.159
	Huynh-Feldt	217675.274	6.760	32200.737	1.579	.143
	Lower-bound	217675.274	1.000	217675.274	1.579	.215
Error(POSITION*OBJ_ORI)	Sphericity Assumed	6616758.013	336	19692.732		
	Greenhouse-Geisser	6616758.013	266.694	24810.312		
	Huynh-Feldt	6616758.013	324.477	20392.043		
	Lower-bound	6616758.013	48.000	137849.125		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	632559754	1	632559753.7	1489.434	.000
ORDER	706249.589	1	706249.589	1.663	.203
RES	352733.662	1	352733.662	.831	.367
ORDER * RES	963476.549	1	963476.549	2.269	.139
Error	20385509.3	48	424698.109		

Appendix XX

Table 30

Experiment Eight: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects at each Stimulus Position, when Experiment Seven was run both before and after Experiment Eight

		Object Orientation			
		Order One*		Order Two**	
Stimulus Position	Response Condition	Left	Right	Left	Right
1	Left Hand	781.29	826.70	956.54	923.24
		(208.47)	(162.28)	(249.83)	(231.53)
	Right Hand	1015.88	882.79	912.04	853.70
		(275.85)	(203.67)	(204.00)	(244.41)
2	Left Hand	794.78	831.64	999.92	979.78
		(238.78)	(183.43)	(223.17)	(179.60)
	Right Hand	871.74	963.44	934.39	907.05
		(254.56)	(181.32)	(265.38)	(238.72)
3	Left Hand	786.14	841.37	931.36	914.52
		(143.02	(237.14)	(146.37)	(221.98)
	Right Hand	910.12	994.76	843.88	950.08
		(228.88)	(231.42)	(209.06)	(290.21)
4	Left Hand	803.94	829.42	820.48	970.52
		(141.28)	(138.31)	(182.17)	(190.62)
	Right Hand	913.27	945.00	957.77	992.28
		(254.91)	(212.38)	(233.70)	(233.15)
5	Left Hand	842.39	813.46	994.56	860.83
		(230.97)	(213.50)	(254.70)	(225.30)
	Right Hand	954.53	887.68	933.66	899.91
		(249.43)	(209.94)	(230.41)	(200.03)
6	Left Hand	720.96	826.44	978.19	900.09
		(182.32)	(187.66)	(211.96)	(164.96)
	Right Hand	897.86	845.53	919.71	908.41
		(224.31)	(199.21)	(315.14)	(329.37)
7	Left Hand	843.43	731.44	873.46	895.65
		(201.42)	(195.99)	(249.23)	(156.09)
	Right Hand	882.81	888.94	839.21	823.68
		(233.56)	(222.83)	(181.77)	(222.98)
8	Left Hand	669.53	686.84	822.76	832.17
		(175.39)	(136.47)	(169.35)	(215.97)
	Right Hand	758.47	767.37	751.76	795.80
		(156.61)	(183.70)	(161.35)	(176.55)

* = Experiment Seven followed by Experiment Eight

** = Experiment Eight followed by Experiment Seven

Appendix YY

LSD Follow-up Analysis on Stimulus Position Factor in Experiment Eight

n= 52
s^2 = Error MS = 23967.505
Error df = 336

SED = $\surd 2\, S^2$
$\surd$ n

SED = $\surd 2 \times 23967.505$
$\surd$ 52

SED = 30.36

LSD = (t @ 336 df) x SED

LSD = 1.96 x 30.36

LSD= 59.51

Primacy Effect

Difference in means between position one and position two = 910.344 - 894.024 = 16.32.
LSD = 59.51 > 16.32 (t-crit) ∴ **non-significant difference.**

Recency Effect

Difference in means between image position seven and image position eight = 847.329 – 760.589 = 86.74.
LSD = 59.51 < 86.74 (t-crit) ∴ **significant difference.**

Appendix ZZ

Experiment Eight: Three-way mixed ANOVA tables for Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	6.546	1	6.546	1.225	.274
	Greenhouse-Geisser	6.546	1.000	6.546	1.225	.274
	Huynh-Feldt	6.546	1.000	6.546	1.225	.274
	Lower-bound	6.546	1.000	6.546	1.225	.274
OBJ_ORI * AC_RES	Sphericity Assumed	.829	1	.829	.155	.695
	Greenhouse-Geisser	.829	1.000	.829	.155	.695
	Huynh-Feldt	.829	1.000	.829	.155	.695
	Lower-bound	.829	1.000	.829	.155	.695
OBJ_ORI * ORDER	Sphericity Assumed	14.805	1	14.805	2.771	.103
	Greenhouse-Geisser	14.805	1.000	14.805	2.771	.103
	Huynh-Feldt	14.805	1.000	14.805	2.771	.103
	Lower-bound	14.805	1.000	14.805	2.771	.103
OBJ_ORI * AC_RES * ORDER	Sphericity Assumed	.594	1	.594	.111	.740
	Greenhouse-Geisser	.594	1.000	.594	.111	.740
	Huynh-Feldt	.594	1.000	.594	.111	.740
	Lower-bound	.594	1.000	.594	.111	.740
Error(OBJ_ORI)	Sphericity Assumed	256.502	48	5.344		
	Greenhouse-Geisser	256.502	48.000	5.344		
	Huynh-Feldt	256.502	48.000	5.344		
	Lower-bound	256.502	48.000	5.344		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	7626.488	1	7626.488	338.691	.000
AC_RES	3.135	1	3.135	.139	.711
ORDER	188.126	1	188.126	8.355	.006
AC_RES * ORDER	84.559	1	84.559	3.755	.059
Error	1080.843	48	22.518		

Table 31
Experiment Eight: Mean Number of Errors for Left and Right-hand Responses to Left and Right-oriented Objects when Experiment Seven was run both before and after Experiment Eight

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	8.23 (4.28)	9.46 (3.78)
Right Hand	10.36 (4.07)	11.64 (4.20)

Experiment Presentation Order Two (Exp8-Exp7)

Response Condition	Object Orientation	
	Left	Right
Left Hand	8.25 (2.96)	7.67 (3.89)
Right Hand	6.46 (2.79)	6.54 (3.48)

Appendix bb

Experiment Eight: Three-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	206.032	1	206.032	.093	.761
	Greenhouse-Geisser	206.032	1.000	206.032	.093	.761
	Huynh-Feldt	206.032	1.000	206.032	.093	.761
	Lower-bound	206.032	1.000	206.032	.093	.761
OBJ_ORI * RES	Sphericity Assumed	.445	1	.445	.000	.989
	Greenhouse-Geisser	.445	1.000	.445	.000	.989
	Huynh-Feldt	.445	1.000	.445	.000	.989
	Lower-bound	.445	1.000	.445	.000	.989
OBJ_ORI * ORDER	Sphericity Assumed	2167.700	1	2167.700	.982	.327
	Greenhouse-Geisser	2167.700	1.000	2167.700	.982	.327
	Huynh-Feldt	2167.700	1.000	2167.700	.982	.327
	Lower-bound	2167.700	1.000	2167.700	.982	.327
OBJ_ORI * RES * ORDER	Sphericity Assumed	8621.150	1	8621.150	3.905	.054
	Greenhouse-Geisser	8621.150	1.000	8621.150	3.905	.054
	Huynh-Feldt	8621.150	1.000	8621.150	3.905	.054
	Lower-bound	8621.150	1.000	8621.150	3.905	.054
Error(OBJ_ORI)	Sphericity Assumed	105966.497	48	2207.635		
	Greenhouse-Geisser	105966.497	48.000	2207.635		
	Huynh-Feldt	105966.497	48.000	2207.635		
	Lower-bound	105966.497	48.000	2207.635		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	79011837.0	1	79011836.99	1417.893	.000
RES	38890.278	1	38890.278	.698	.408
ORDER	110243.325	1	110243.325	1.978	.166
RES * ORDER	105021.213	1	105021.213	1.885	.176
Error	2674791.364	48	55724.820		

Table 32
Experiment Eight: Mean Response Times for Left and Right-hand Responses to Left and Right-Oriented Objects, when Experiment Seven is run both before and after Experiment Eight

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	776.91 (161.47)	801.34 (148.80)
Right Hand	897.39 (192.19)	885.61 (166.39)

Experiment Presentation Order Two (Exp8-Exp7)

Response Hand	Object Orientation	
	Left	Right
Left Hand	933.15 (167.11)	902.82 (169.34)
Right Hand	889.87 (168.38)	896.27 (182.40)

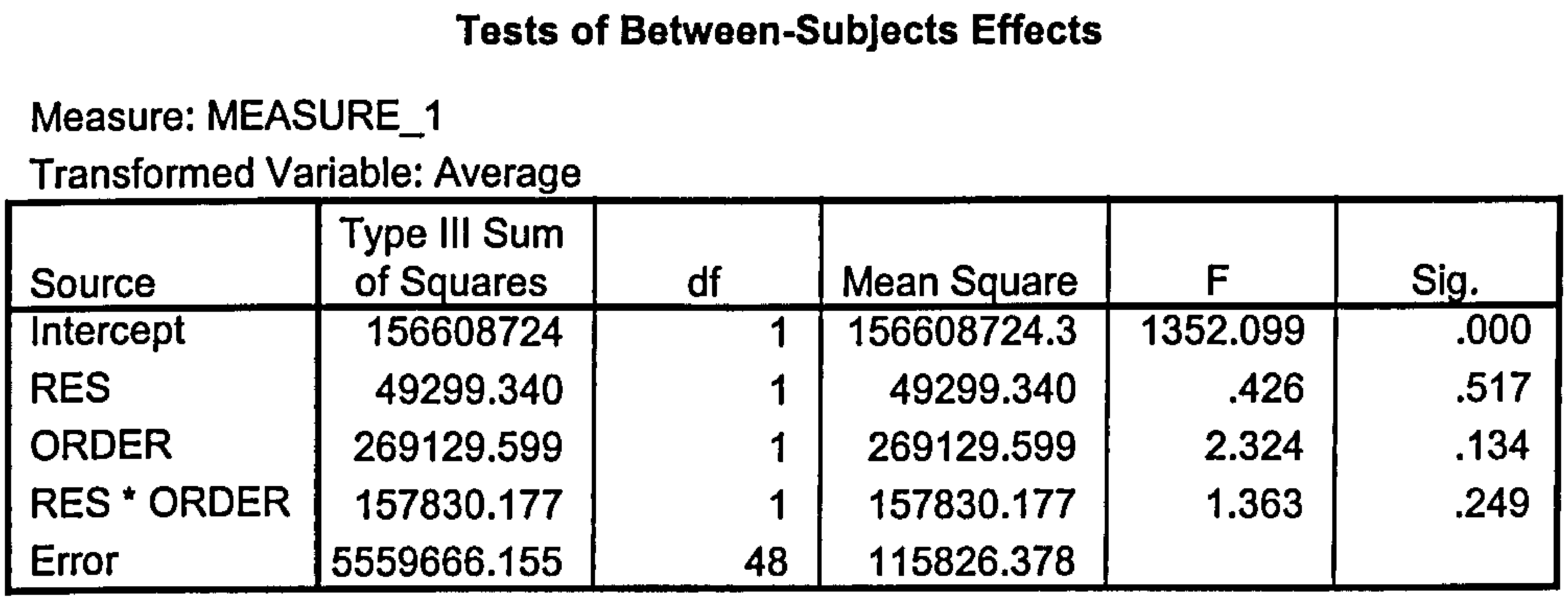
Appendix dd

Experiment Eight: Four-way mixed ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
HALF	Sphericity Assumed	246646.381	1	246646.381	17.651	.000
	Greenhouse-Geisser	246646.381	1.000	246646.381	17.651	.000
	Huynh-Feldt	246646.381	1.000	246646.381	17.651	.000
	Lower-bound	246646.381	1.000	246646.381	17.651	.000
HALF * RES	Sphericity Assumed	6439.892	1	6439.892	.461	.500
	Greenhouse-Geisser	6439.892	1.000	6439.892	.461	.500
	Huynh-Feldt	6439.892	1.000	6439.892	.461	.500
	Lower-bound	6439.892	1.000	6439.892	.461	.500
HALF * ORDER	Sphericity Assumed	2.460	1	2.460	.000	.989
	Greenhouse-Geisser	2.460	1.000	2.460	.000	.989
	Huynh-Feldt	2.460	1.000	2.460	.000	.989
	Lower-bound	2.460	1.000	2.460	.000	.989
HALF * RES * ORDER	Sphericity Assumed	933.979	1	933.979	.067	.797
	Greenhouse-Geisser	933.979	1.000	933.979	.067	.797
	Huynh-Feldt	933.979	1.000	933.979	.067	.797
	Lower-bound	933.979	1.000	933.979	.067	.797
Error(HALF)	Sphericity Assumed	670733.663	48	13973.618		
	Greenhouse-Geisser	670733.663	48.000	13973.618		
	Huynh-Feldt	670733.663	48.000	13973.618		
	Lower-bound	670733.663	48.000	13973.618		
OBJ_ORI	Sphericity Assumed	2386.935	1	2386.935	.323	.572
	Greenhouse-Geisser	2386.935	1.000	2386.935	.323	.572
	Huynh-Feldt	2386.935	1.000	2386.935	.323	.572
	Lower-bound	2386.935	1.000	2386.935	.323	.572
OBJ_ORI * RES	Sphericity Assumed	821.447	1	821.447	.111	.740
	Greenhouse-Geisser	821.447	1.000	821.447	.111	.740
	Huynh-Feldt	821.447	1.000	821.447	.111	.740
	Lower-bound	821.447	1.000	821.447	.111	.740
OBJ_ORI * ORDER	Sphericity Assumed	4483.697	1	4483.697	.607	.440
	Greenhouse-Geisser	4483.697	1.000	4483.697	.607	.440
	Huynh-Feldt	4483.697	1.000	4483.697	.607	.440
	Lower-bound	4483.697	1.000	4483.697	.607	.440
OBJ_ORI * RES * ORDER	Sphericity Assumed	1644.048	1	1644.048	.223	.639
	Greenhouse-Geisser	1644.048	1.000	1644.048	.223	.639
	Huynh-Feldt	1644.048	1.000	1644.048	.223	.639
	Lower-bound	1644.048	1.000	1644.048	.223	.639
Error(OBJ_ORI)	Sphericity Assumed	354391.067	48	7383.147		
	Greenhouse-Geisser	354391.067	48.000	7383.147		
	Huynh-Feldt	354391.067	48.000	7383.147		
	Lower-bound	354391.067	48.000	7383.147		
HALF * OBJ_ORI	Sphericity Assumed	4755.567	1	4755.567	.994	.324
	Greenhouse-Geisser	4755.567	1.000	4755.567	.994	.324
	Huynh-Feldt	4755.567	1.000	4755.567	.994	.324
	Lower-bound	4755.567	1.000	4755.567	.994	.324
HALF * OBJ_ORI * RES	Sphericity Assumed	1384.952	1	1384.952	.290	.593
	Greenhouse-Geisser	1384.952	1.000	1384.952	.290	.593
	Huynh-Feldt	1384.952	1.000	1384.952	.290	.593
	Lower-bound	1384.952	1.000	1384.952	.290	.593
HALF * OBJ_ORI * ORDER	Sphericity Assumed	3305.158	1	3305.158	.691	.410
	Greenhouse-Geisser	3305.158	1.000	3305.158	.691	.410
	Huynh-Feldt	3305.158	1.000	3305.158	.691	.410
	Lower-bound	3305.158	1.000	3305.158	.691	.410
HALF * OBJ_ORI * RES * ORDER	Sphericity Assumed	7205.221	1	7205.221	1.506	.226
	Greenhouse-Geisser	7205.221	1.000	7205.221	1.506	.226
	Huynh-Feldt	7205.221	1.000	7205.221	1.506	.226
	Lower-bound	7205.221	1.000	7205.221	1.506	.226
Error(HALF*OBJ_ORI)	Sphericity Assumed	229613.949	48	4783.624		
	Greenhouse-Geisser	229613.949	48.000	4783.624		
	Huynh-Feldt	229613.949	48.000	4783.624		
	Lower-bound	229613.949	48.000	4783.624		



Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	156608724	1	156608724.3	1352.099	.000
RES	49299.340	1	49299.340	.426	.517
ORDER	269129.599	1	269129.599	2.324	.134
RES * ORDER	157830.177	1	157830.177	1.363	.249
Error	5559666.155	48	115826.378		

Table 33
Experiment Eight: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects in the First and Second Halves of the Experiment, when Experiment Eight was run both after and before Experiment Seven

Experiment Presentation Order One (Exp7 – Exp8)

Response Condition	Object Orientation			
	First Half of Experiment		Second Half of Experiment	
	Left	Right	Left	Right
Left Hand	808.09 (162.83)	825.22 (163.26)	754.12 (161.96)	772.46 (142.50)
Right Hand	928.10 (216.23)	908.01 (178.70)	809.44 (279.78)	858.39 (165.85)

Experiment Presentation Order Two (Exp8 – Exp7)

Response Condition	Object Orientation			
	First Half of Experiment		Second Half of Experiment	
	Left	Right	Left	Right
Left Hand	958.51 (182.40)	938.17 (219.05)	888.01 (182.75)	884.09 (157.91)
Right Hand	924.84 (207.84)	936.97 (214.14)	853.78 (144.12)	855.85 (175.29)

Appendix ff

Experiment Eight: Three-way ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	4871.470	1	4871.470	1.694	.199
	Greenhouse-Geisser	4871.470	1.000	4871.470	1.694	.199
	Huynh-Feldt	4871.470	1.000	4871.470	1.694	.199
	Lower-bound	4871.470	1.000	4871.470	1.694	.199
OBJ_ORI * RES	Sphericity Assumed	47.790	1	47.790	.017	.898
	Greenhouse-Geisser	47.790	1.000	47.790	.017	.898
	Huynh-Feldt	47.790	1.000	47.790	.017	.898
	Lower-bound	47.790	1.000	47.790	.017	.898
OBJ_ORI * ORDER	Sphericity Assumed	3996.357	1	3996.357	1.390	.244
	Greenhouse-Geisser	3996.357	1.000	3996.357	1.390	.244
	Huynh-Feldt	3996.357	1.000	3996.357	1.390	.244
	Lower-bound	3996.357	1.000	3996.357	1.390	.244
OBJ_ORI * RES * ORDER	Sphericity Assumed	56.742	1	56.742	.020	.889
	Greenhouse-Geisser	56.742	1.000	56.742	.020	.889
	Huynh-Feldt	56.742	1.000	56.742	.020	.889
	Lower-bound	56.742	1.000	56.742	.020	.889
Error(OBJ_ORI)	Sphericity Assumed	138040.136	48	2875.836		
	Greenhouse-Geisser	138040.136	48.000	2875.836		
	Huynh-Feldt	138040.136	48.000	2875.836		
	Lower-bound	138040.136	48.000	2875.836		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	92578826.5	1	92578826.49	1379.252	.000
RES	166500.462	1	166500.462	2.481	.122
ORDER	216515.013	1	216515.013	3.226	.079
RES * ORDER	29706.186	1	29706.186	.443	.509
Error	3221880.289	48	67122.506		

Table 34
Experiment Eight: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects, when Experiment Eight was run both after and before Experiment Seven

Experiment Presentation Order One (Exp7-Exp8)		
Response Condition	Object Orientation	
	Left	Right
Left Hand	829.20 (172.56)	855.20 (195.40)
Right Hand	943.07 (202.94)	969.32 (216.26)

Experiment Presentation Order Two (Exp8-Exp7)		
Response Hand	Object Orientation	
	Left	Right
Left Hand	965.38 (154.88)	969.51 (153.86)
Right Hand	1014.51 (194.62)	1012.96 (187.57)

Appendix hh

Experiment Eight: Three-way mixed ANOVA tables for the Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	9.477	1	9.477	2.084	.155
	Greenhouse-Geisser	9.477	1.000	9.477	2.084	.155
	Huynh-Feldt	9.477	1.000	9.477	2.084	.155
	Lower-bound	9.477	1.000	9.477	2.084	.155
OBJ_ORI * RES	Sphericity Assumed	15.550	1	15.550	3.419	.071
	Greenhouse-Geisser	15.550	1.000	15.550	3.419	.071
	Huynh-Feldt	15.550	1.000	15.550	3.419	.071
	Lower-bound	15.550	1.000	15.550	3.419	.071
OBJ_ORI * ORDER	Sphericity Assumed	6.618	1	6.618	1.455	.234
	Greenhouse-Geisser	6.618	1.000	6.618	1.455	.234
	Huynh-Feldt	6.618	1.000	6.618	1.455	.234
	Lower-bound	6.618	1.000	6.618	1.455	.234
OBJ_ORI * RES * ORDER	Sphericity Assumed	14.254	1	14.254	3.134	.083
	Greenhouse-Geisser	14.254	1.000	14.254	3.134	.083
	Huynh-Feldt	14.254	1.000	14.254	3.134	.083
	Lower-bound	14.254	1.000	14.254	3.134	.083
Error(OBJ_ORI)	Sphericity Assumed	218.315	48	4.548		
	Greenhouse-Geisser	218.315	48.000	4.548		
	Huynh-Feldt	218.315	48.000	4.548		
	Lower-bound	218.315	48.000	4.548		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	3600.903	1	3600.903	343.807	.000
RES	6.630	1	6.630	.633	.430
ORDER	.131	1	.131	.013	.911
RES * ORDER	3.413	1	3.413	.326	.571
Error	502.733	48	10.474		

Table 35
Experiment Eight: Mean Number of Errors for Right and Left-hand Responses to Left and Right-oriented Objects, when Experiment Eight was run both after and before Experiment Seven

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	6.54 (3.66)	5.46 (2.87)
Right Hand	6.43 (2.98)	5.28 (3.07)

Experiment Presentation Order Two (Exp8-Exp7)

Response Condition	Object Orientation	
	Left	Right
Left Hand	5.58 (2.27)	7.00 (2.45)
Right Hand	6.23 (2.01)	4.61 (2.06)

Appendix jj

Experiment Eight: Three-way ANOVA tables for Response Time Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	982.893	1	982.893	.852	.361
	Greenhouse-Geisser	982.893	1.000	982.893	.852	.361
	Huynh-Feldt	982.893	1.000	982.893	.852	.361
	Lower-bound	982.893	1.000	982.893	.852	.361
OBJ_ORI * RES	Sphericity Assumed	313.519	1	313.519	.272	.605
	Greenhouse-Geisser	313.519	1.000	313.519	.272	.605
	Huynh-Feldt	313.519	1.000	313.519	.272	.605
	Lower-bound	313.519	1.000	313.519	.272	.605
OBJ_ORI * ORDER	Sphericity Assumed	3414.776	1	3414.776	2.959	.092
	Greenhouse-Geisser	3414.776	1.000	3414.776	2.959	.092
	Huynh-Feldt	3414.776	1.000	3414.776	2.959	.092
	Lower-bound	3414.776	1.000	3414.776	2.959	.092
OBJ_ORI * RES * ORDER	Sphericity Assumed	716.920	1	716.920	.621	.434
	Greenhouse-Geisser	716.920	1.000	716.920	.621	.434
	Huynh-Feldt	716.920	1.000	716.920	.621	.434
	Lower-bound	716.920	1.000	716.920	.621	.434
Error(OBJ_ORI)	Sphericity Assumed	55391.655	48	1153.993		
	Greenhouse-Geisser	55391.655	48.000	1153.993		
	Huynh-Feldt	55391.655	48.000	1153.993		
	Lower-bound	55391.655	48.000	1153.993		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	93461519.2	1	93461519.17	1148.599	.000
RES	26421.894	1	26421.894	.325	.571
ORDER	263285.579	1	263285.579	3.236	.078
RES * ORDER	13553.585	1	13553.585	.167	.685
Error	3905761.308	48	81370.027		

Table 36
Experiment Eight: Mean Response Times for Left and Right-hand Responses to Left and Right-oriented Objects, when Experiment Eight was run both after and before Experiment Seven

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	928.10 (211.96)	924.69 (201.05)
Right Hand	864.58 (225.19)	878.63 (239.12)

Experiment Presentation Order Two (Exp8-Exp7)

Response Condition	Object Orientation	
	Left	Right
Left Hand	1012.24 (181.48)	996.38 (195.12)
Right Hand	1004.96 (184.08)	985.54 (173.75)

Experiment Eight: Three-way mixed ANOVA tables for the Error Data

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
OBJ_ORI	Sphericity Assumed	28.963	1	28.963	3.085	.085
	Greenhouse-Geisser	28.963	1.000	28.963	3.085	.085
	Huynh-Feldt	28.963	1.000	28.963	3.085	.085
	Lower-bound	28.963	1.000	28.963	3.085	.085
OBJ_ORI * RES_C	Sphericity Assumed	11.434	1	11.434	1.218	.275
	Greenhouse-Geisser	11.434	1.000	11.434	1.218	.275
	Huynh-Feldt	11.434	1.000	11.434	1.218	.275
	Lower-bound	11.434	1.000	11.434	1.218	.275
OBJ_ORI * ORDER	Sphericity Assumed	17.345	1	17.345	1.847	.180
	Greenhouse-Geisser	17.345	1.000	17.345	1.847	.180
	Huynh-Feldt	17.345	1.000	17.345	1.847	.180
	Lower-bound	17.345	1.000	17.345	1.847	.180
OBJ_ORI * RES_C * ORDER	Sphericity Assumed	38.007	1	38.007	4.048	.050
	Greenhouse-Geisser	38.007	1.000	38.007	4.048	.050
	Huynh-Feldt	38.007	1.000	38.007	4.048	.050
	Lower-bound	38.007	1.000	38.007	4.048	.050
Error(OBJ_ORI)	Sphericity Assumed	450.688	48	9.389		
	Greenhouse-Geisser	450.688	48.000	9.389		
	Huynh-Feldt	450.688	48.000	9.389		
	Lower-bound	450.688	48.000	9.389		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	17821.670	1	17821.670	396.533	.000
RES_C	56.437	1	56.437	1.256	.268
ORDER	40.164	1	40.164	.894	.349
RES_C * ORDER	89.385	1	89.385	1.989	.165
Error	2157.296	48	44.944		

Table 37
Experiment Eight: Mean Number of Errors for Left and Right-hand Responses to Left and Right-oriented Objects, when Experiment Eight was run both before and after Experiment Seven

Experiment Presentation Order One (Exp7-Exp8)

Response Condition	Object Orientation	
	Left	Right
Left Hand	11.21 (4.32)	10.43 (3.76)
Right Hand	14.00 (6.53)	14.31 (6.83)

Experiment Presentation Order Two (Exp8-Exp7)

Response Condition	Object Orientation	
	Left	Right
Left Hand	13.92 (5.65)	13.92 (4.72)
Right Hand	15.42 (5.09)	11.67 (4.16)