AFFORDANCE, ATTENTION AND LATERALITY

by

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ABSTRACT

This thesis examines object-guided actions. Recently, micro-affordance effects have shown that a visual object affords actions automatically. These effects are observed when the grasp type (precision and power grasp) is facilitated by size (small and large) of the categorized object (the object-size effect), or when right or left hand responses are facilitated by object orientation (the object-orientation effect). It has been shown elsewhere that attentional mechanisms have a vital role in visually guided movements. In addition, visually guided movements have associated with hemispheric lateralization. Thus, the central focus of the thesis was the role of different components of attention (location-based-, object-based-, endogenous-, exogenous-, focused attention) in micro-affordance effects, and the hemispheric lateralisation of these effects. Using the stimulus-response compatibility (SRC) paradigm, a set of nine experiments (six that employed the object-orientation effect and three that employed the object-size effect) investigated aspects of attention and lateralization in visuomotor integration. A participant performed bi-manual keypresses or precision/power grip responses according to the identity of a target that was displayed over the task-irrelevant prime. Size or orientation properties of the prime object were manipulated, and outcome of interest was how those object properties effected corresponding or non-corresponding responses. The data showed that both micro-affordance effects could be observed when the allocation of endogenous attention to the prime is minimal or absent. However, the generation of both effects were observed to need resources of focused attention. In addition, the data supported the view that the object-orientation effect is generated by the orientation of the entire object and not by a shift of attention to the object's handle location. Finally, manual asymmetries in these effects suggested that visually guided precision grips are computed predominantly in the left hemisphere whereas power grips are computed in the right hemisphere.

AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award.

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To Maria

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CHAPTER 1: INTRODUCTION

1.1 Function of visual system: Background and thesis overview

Vision has two primary functions. One is involved in processes of recognition and the other is involved in action control. This thesis is concerned with exploring an idea about the integrated nature of vision and action involved in action control. However, in everyday life, people are more aware of the function of vision, which makes them 'perceive' the external world. People use perception, for example, in order to recognize faces and objects. Presumably, because people are biased to emphasize the perceptual function of vision, vision research has traditionally focused strongly on object recognition and the visual processes that are associated with the perceptual experience. However, evolution has simply no use for an organ that just wants to sit and watch the world go by. Today, a majority of researchers would agree that vision has evolved mainly to control actions that an organism uses to move its eye, head, limb, and body appropriately in an environment. The obvious role of vision in movement guidance has led to an action-oriented view of vision. This view assumes that visual and motor systems cannot be considered as functionally separate systems in which motor and visual representations for the object would be constructed independently in separate stages (e.g. Gibson, 1979; Milner and Goodale, 1995). Lately vision research has increased greatly in the field of action-oriented perception due to neuropsychological, neuro-imaging, neurosphysiological and behavioural evidence from integration of vision and action (e.g. Milner and Goodale, 1995; Tucker & Ellis, 1998; 2001; Rizzolatti, Luppino & Matelli, 1998; Craighero, Fadiga, Umiltá, Rizzolatti, 1996). This action-oriented perception is a central focus of this thesis.

One of the first scientists who recognized the importance of vision in action control was J.J. Gibson (1977). Gibson emphasised that the ultimate function of vision is to ensure an effective and adaptive behavioural output. Gibson introduced the noun 'affordance' to explicate this ultimate function of vision. Affordances specify action related aspects of the visual environment (e.g. an object or a surface), taking into account an animals or humans action capabilities at the current moment. According to this view, when the organism is motivated and capable of acting, the details of upcoming actions are directly specified by these affordances. For example, a solid, opaque surface tells a perceiver that one can walk forward. In this example, the affordance is walkability and the information that specifies walkability is a perceived combination of a solid, opaque surface. Gibson claims that the whole evolution of vision has been geared toward perceiving possibilities (i.e., handles for pulling and tools for manipulating) for action.

Although Gibson's theory of affordance has attracted little mainstream support, it has inspired many researchers to study the direct guidance of actions by visual inputs (e.g. Michaels, 1988). More recently, Tucker and Ellis (e.g. Tucker & Ellis, 1998, 2001; Ellis & Tucker, 2000) adapted the theory of affordance to develop a novel set of empirical questions. They asked whether action-relevant object properties such as orientation and size could influence choice reaction times (RT). This question was asked to explore whether actions that an object affords are represented automatically when the object is viewed. Based on their empirical findings, Tucker and Ellis developed a hypothesis, which states that a viewed object prepares actions regardless of intentions to act upon it. In other words, the hypothesis assumes that *'the representation of a visual object includes not only a description of its visual properties, but also encodings of actions relevant to that object'* (Ellis & Tucker, 2000, pp. 451). These properties of object that prepare actions are termed 'micro-affordances'. The account of micro-affordance is a central focus of the current thesis. It is important to clarify that the account of micro-affordance and the Gibsonian theory of affordance are emphasizing different action-relevant aspects of environment. While Gibsonian affordances are more associated with coherent global actions, such as walking, micro-affordances are restricted to cover only those affordances that are related to action relevant *object* characteristics, excluding rest of the action relevant aspects of the environment (i.e., surface that tells perceiver that one can walk forward). Furthermore, the account of micro-affordance focuses on object affordances that are related to reach-to-grasp actions. Therefore, when Gibson's view emphasizes that the mailbox affords mailing of letter (Gibson, 1979), the hypothesis of micro-affordance proposes that such mailing action is constructed by lower level actions, such as grasping the letter (i.e., the letter affords particularly a precision grip). These particular components (e.g. precision grip) in, for example, prehension, are micro-affordances that are encoded as part of visual representation. Taken together, the theoretical ground on which the thesis is standing assumes that when an object is looked at, the motor codes that are related to components of the actions associated with the object are coded as a part of the overall visual representation of that object.

These issues related to micro-affordances are considered in this thesis. 1) Previous research has shown that attention plays a fundamental role in visuomotor integration (e.g., Nicoletti and Umiltá, 1994; Roelfsema, Engel, König & Singer, 1997). In addition, it has been shown that attention can be controlled by exogenous and endogenous processes (e.g. Posner, Cohen, & Rafal, 1982) and can operate at the object-based (e.g. Duncan, 1984) and location-based (e.g. Nicoletti & Umiltá, 1994) levels. Furthermore, focused attention has been shown to have a fundamental role in enhancing perceptual processing of the object in order to create coherent perception of the object (e.g. Butler & McKelvie, 1985). Therefore, it is relevant to ask what kinds of attentional resources are essential for the occurrence of micro-affordance effects. 2) It has been found that left and right hemispheres have differential roles in motor control and planning (see Boulinguenz, Nougier & Velay, 2001 for a review), and in the recognition of object affordances (Handy, Grafton, Shroff, Ketay, & Gazzaniga, 2003). Therefore, the thesis also aims to investigate whether object affordances might be lateralized. 3) The division of the visual system of humans and primates into two major processing pathways (the ventral and dorsal stream) has been the most influential account of higher visual organization in the research of visuomotor integration. Thus, the thesis aims to discuss the contribution of the two different visual streams to the generation of affordance effects.

This chapter introduces the behavioural evidence for integration of vision and action and discusses the possible role of attention in visuomotor integration. The basic neurophysiology of the visuomotor system is introduced in Chapter 2. Chapter 3 discusses micro-affordance effects in relation to attention and the neurophysiological evidence for visuomotor integration. Chapter 4 describes six experiments examining the effect of object on the hand responses. Chapter 5 describes three experiments examining the effect of objects on grip. Finally, Chapter 6 summarises findings and attempts to construct a coherent conclusion from the results of the nine separate experiments.

1.2 Behavioural evidence for the integration of vision and action

This section introduces behavioural evidence for the tight relation between visual and motor representations. The stimulus-Response (S-R) compatibility paradigm is one of the most common methodologies in collecting behavioural evidence for visuomotor integration. So called symbolic S-R compatibility effects are observed in choice reaction time (RT), for example, when one is to respond with a red key to a red light and with a green key to a green light (e.g., Hedge & Marsh, 1975). When colour and the stimulus correspond, the response is facilitated. However, similar compatibility effects can also be observed when responses correspond with the spatial arrangements of the stimuli (Fitts & Seeger, 1953). Michaels (1988) was one of the first researchers who recognized that a theory of affordances could be used as a conceptual framework for understanding spatial S-R compatibility effects. In addition, she showed that the spatial S-R compatibility paradigm provides a useful methodological tool for the investigation of affordances. The Simon effect is particularly important for the purposes of the current thesis for two reasons. Firstly, it shows clear behavioural evidence for visuomotor integration, and secondly it has implications for the role of attention in the integration of vision and action. In a Simon task subjects respond faster when the location of the response is compatible with the right/left location of the stimulus. Typically, in the Simon task, the hand of response is selected by discriminating non-spatial stimulus features (e.g. two colours or two shapes). Therefore, it shows that even task-irrelevant stimulus property facilitates compatible actions (Simon & Rudell, 1967). Three information-processing stages are supposedly involved in the generation of the Simon effect. These stages are stimulus identification, response selection, and response programming. It is agreed by most researchers that the Simon effect occurs at the response selection stage in which match between cognitive spatial stimulus and response code results in the effect (Kornblum, Hasbroucq & Osman, 1990). A dual-route model is commonly considered to be the most adequate way of explaining the processing of the stimulus location and its influence on response selection. The most cited dual-route model, the dimensional overlap model (Kornblum et al., 1990), assumes that location-information about the stimuli primes automatically response selection, and if the visual stimuli that are processed in the response-identification route matches with the primed response dimension, the primed response can be executed without delay. In other words, Zhang, Riehle, Requin and Kornblum (1997, pp. 1709) stated that '*If the dimensions or attributes of a stimulus set are perceptually, structurally, or conceptually similar to those* *of the response set, then the presentation of a stimulus element automatically activates its corresponding response elements'.*

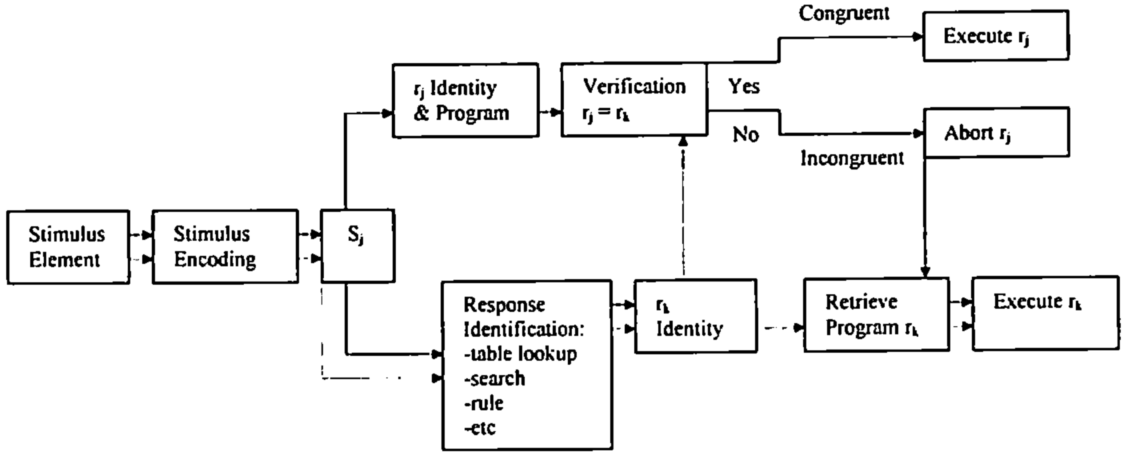


Figure 1.1. The dimensional overlap model proposed by Kornblub et al. 1190; p.257. Block diagram of the major information-processing operations in stimulus-response (S-R) compatibility tasks with (solid lines) and with no (dotted lines) dimensional overlap. The top branch illustrates the operations involved in the automatic activation of the congruent responses. The bottom branch illustrates the operations involved in the identification of the correct responses.

1.2.1 The role of attention in the Simon effect

The dimensional overlap model succeeds in explaining S-R compatibility effects in terms of basic cognitive mechanisms. However, it does not make any clear statement on *how* the spatial response code is formed for irrelevant stimulus location. The referential-coding account (e.g. Hommel, 1993; Umiltá & Nicoletti, 1985) makes an initial contribution in explaining how a spatial code develops. In this account, the reference frame such as a fixation point plays a fundamental role. It was reasoned that, for example, a stimulus that is presented at the left of a fixation cross is automatically related to the position of the cross and in turn evokes a spatial code 'left'. Interestingly, Nicoletti and Umiltá (1994) found that orienting of attention to a stimulus appears to produce a spatial response code, which in turn causes a Simon effect. This demonstration suggests *how* the spatial response code is formed for the irrelevant stimulus location. Nicoletti and Umiltá (1994) tested whether the Simon effect could be eliminated by keeping participants attention at fixation during the simultaneous imperative stimulus, as their account predicted. Consistent with the prediction of the attention-shift hypothesis, when the letter that signalled a catch trial was presented at fixation simultaneously with the imperative stimulus, no Simon effect was found. In addition, Stoffer and Yakin (1994) demonstrated that if the stimulus appeared at the attended location, no Simon effect occurred. Additionally, Rubichi, Iani, Nicoletti and Umiltá (1997) found evidence for this attention shift account of the Simon effect when they tested their prediction that the direction of attention-shift could explain the Simon effect. They found that if the response was selected when attention was in the process of being shifted back from the stimulus position to fixation, a reverse Simon effect was observed. These experiments demonstrate that orienting of attention to a stimulus produces the spatial response code, which in turn results in the Simon effects. Most importantly for purposes of the current thesis, these demonstrations suggest that attention may have a fundamental role in visually guided movements.

1.2.2 The premotor account of attention in visuomotor integration

The traditional view of spatial selective attention is that selective attention is controlled by a system that is anatomically separate from the sensory and motor systems (Posner & Petersen, 1990). Using patients with brain damage and the cued spatial orienting paradigm, Posner has developed the model of attentional orienting (see Posner & Petersen, 1990 for a review) in which mechanisms of spatial orienting are divided into three stages: the engagement of visual attention at a particular stimulus/locus, the disengagement of visual attention from a stimulus/locus, and the shifting of visual attention from one stimulus/locus to another. In this model there is a right frontal system that maintains vigilance, a posterior parietal system that is involved in orienting of attention, and an anterior cingulate system that is active in target detection. Patients with damage to specific areas of the brain experience deficits in these specific stages of attentional orienting. Damage to the posterior parietal cortex appears to impair the disengagement of attention; damage to the superior colliculus impairs the shifting function; and damage to the lateral pulvinar nucleus of the thalamus impairs the engage operation.

However, like the attention shift account of the Simon effect suggests, the orienting of spatial attention can be tightly linked to the computing of manual movements. Additionally, a wide variety of different findings suggests that covert orienting of spatial attention (orienting of attention that does not require overt eye movements) is tightly linked to programming of saccades. Although covert attention can shift without any eye movement an overt shift of spatial attention, which involves saccadic eye movement, requires a covert attentional shift (see Corbetta & Shulman, 1998 for a review). For instance, Hoffman and Subramamiam (1995) demonstrated that subjects could not move their eyes to one location and orient covert attention to a different location. Additionally, a PET experiment carried out by Beauchamp, Petit, Ellmore, Ingeholm, and Haxby (2001) demonstrated that the overt and covert orienting of attention is subserved by the same cortical network of visuospatial and oculomotor control areas. This evidence suggests that the relation between the attention system and the visuomotor system may be tighter than the traditional view of selective attention assumes.

Rizzolatti, Riggio, Dascola and Umiltá (1987) developed another view of selective attention. The view, termed the premotor theory of attention, suggests that attention derives from mechanisms that are intrinsic to the circuits underlying perception and action. The premotor account is based on neurophysiological findings on how space is coded in a series of parieto-frontal circuits working in parallel and how this code is then transformed into action. Three functional aspects of these parieto-frontal circuits form the basis of the premotor account of attention. Firstly, no spatial multipurpose map can be found within these circuits. Secondly, in each of these circuits spatial information is transformed for specific motor purposes. Thirdly, the coordinate frame in which space in coded depends on the motor requirements of the effectors that a given circuit controls (see Rizzolatti, Riggio,

& Sheliga, 1994 for a review). The premotor account suggests that when a stimulus is presented, the attention shift to the stimulus prepares the corresponding saccade to the stimulus, even in the absence of the execution of saccades. It was suggested that the Simon effect is depended on the direction of the attention shift toward the stimulus. Similarly, in the premotor account of attention, the directional feature of attention becomes the spatial response code of the stimulus that in turn programs the saccade. Importantly for the purpose of the current thesis, the premotor account suggests that when a stimulus is presented, all effectors that are involved in achieving current behavioural goals, such as manual reaches and saccadic eye movement, are automatically prepared for the location of the stimulus (Tipper, Howard & Paul, 2000). Therefore, not only the eye movements can be prepared by a directional attention shift but also the hand responses may be prepared by the same directional orienting of attention. In fact, Rubichi et al.'s (1997) result clearly supports the version of the attention-shift hypothesis of the Simon effects that is based on the premotor theory of attention.

Craighero, Fadiga, Rizzolatti and Umiltá (1999) suggested that the premotor account of attention could be extended from orienting of attention to spatial locations to orienting of attention to graspable objects. In their experiments, participants were required to grasp, as fast as possible, a bar that was oriented clockwise or anticlockwise. Before participants initiated their response, they were required to fixate to a central fixation cross until the go signal was displayed around the fixation cross. The go signal consisted of one of three pictures: a rectangle rotated 45^0 clockwise, a rectangle rotated 45^0 anticlockwise, or a circle. Craighero et al (1999) observed that when the orientation of the go signal matched the orientation of the bar to be grasped, participants' responses were facilitated. This result suggested that the detection of a visual object is facilitated by the preparation of a grasping movement congruent with the object's action-relevant properties. In turn, this was assumed to support the premotor account of attention. Furthermore, it was suggested that the premotor theory of attention *"is not limited to orienting to a spatial location but can be* *generalized to the orienting of attention to any object that can be acted on"* (Craighero et al., 1999, pp.1676). Taken together, the premotor view of attention assumes that attention can be involved in visually triggered motor guidance in two different ways. Firstly, orienting of attention to a stimulus location may prepare oculomotor and manual responses to that location, and secondly orienting of attention to an object may facilitate the hand shaping that is most appropriate to the action-relevant characteristics of the object, such as size, shape, and orientation.

Roelfsema et al. (1996) proposed a model of synchronized connections between visual and motor systems that may give some insight into the mechanisms that operate in attentional orienting to graspable objects. Firstly, they recognized that the distributed activity patterns representing the object and motor responses need to be integrated into a coherent representational state when a person is, for example, reaching to grasp a visual object. It was assumed that the synchronized connections between neurons in both the visual cortex and motor cortex may serve to integrate motor responses to different features of a visual object. In fact, Roelfsema et al. (1996) found that transformation of sensory information into pre-movement activity, when an animal is simply viewing the graspable object without intending to execute the action, is associated with synchronization between visual object representation and response preparation. Most importantly for our present purposes, Roelfsema, Engel, König and Singer (1997) demonstrated that when item in the visual field is attended, interactions between cortical areas of visual and parietal cortex and parietal and motor cortex that are related to processing of this item are characterized by tight synchronization, in the awake cat. This suggests that attention plays an important role in synchronizing connections between the visual and motor representation. Because of the convincing behavioural and neurophysiological evidence of the important role of attention in the integration of visual and motor representations, the next section discusses attention in more detail.

1.3 Exogenous and endogenous attention

Mechanisms for selecting the sensory inputs that warrant a response and the action most appropriate at that moment were as essential early in evolution as they are for human. As mentioned above, neurophysiological (e.g. Rizzolatti et al., 1987; Roelfsema, 1997) and behavioural evidence (e.g. Nicoletti & Umiltá, 1994; Craigher et al., 1999) suggest that attention is basis of such selection. Traditional views of attention assume that visual attention acts like a spotlight (Posner, 1980) or zoom lens (Eriken & James, 1986). This spotlight or zoom lens is directed to a region in the visual field in which the behaviourally most relevant stimuli is presented or where stimuli pops out from the background. This suggests that attention control arise from two mechanisms, one by bottom-up (exogenous attention) signals from the occurrence of unexpected and strong inputs (such as a brief flash of light), the other by top-down (endogenous attention) control from some required goal (such as by the face of a friend being searched for in a crowd). Systems that are controlling these two attentional mechanisms are proposed to be different because they have, for example, distinct temporal sequences (Nakayama & Mackeben, 1989).

Posner and Snyder (1975) and Jonides (1981) were among the first researchers who explored the distinction between endogenous and exogenous control of attention. These authors studied exogenous attention, for example, by a peripheral cueing paradigm. In this paradigm, an unpredictable cue appears shortly before the actual target. This cue appears to left or right of the central fixation point in the location of the upcoming target or on the opposite side. In contrast, endogenous attention has been traditionally studied by presenting a central directional cue (central arrow) which predicts the likely location of the target with an 80% probability. At least five fundamental differences between the results of experiments examining exogenous and endogenous attention can be identified (see Posner, Cohen, & Rafal, 1982 for a review). Firstly, although both types of cues produce facilitation at the cued location and inhibition at the contra lateral location, only peripheral (exogenous) cueing results in an inhibition at the cued location approximately 300 – 1000 ms after cue offset. No such inhibition is seen when attention is cued by the central (endogenous) cue. Secondly, endogenous attention is vulnerable to the effects of a concomitant memory load, whereas exogenous orienting is not affected by such cognitive demands. Thirdly, exogenous attention appears to be associated with stronger orienting effects that occur more quickly. Fourthly, endogenous orienting can be suppressed voluntarily, whereas exogenous attention cannot be suppressed voluntarily. Finally, exogenous orienting is not dependent on the likelihood of a peripheral cue. In contrast, endogenous attention is strongly influenced by the subjects' expectations.

In addition to the behavioural evidence, the distinction between exogenous and endogenous attention control has been also demonstrated by some neuro-imaging studies. For instance, Corbetta and Shulman (1998) demonstrated that when participants were required to carry out an endogenous task, significant blood flow changes were observed in the parietal and frontal cortex. In contrast, when participants were required to carry out an exogenous task, only the parietal region was active. It was suggested that the fronto-parietal spatial network is related to endogenous shifts of attention. Rosen, Rao, Caffarra, Scaglioni, Bobholz, Woodley, Hammeke, Cunningham, Prieto and Binder (1999) conducted a fMRI study to examine whether separable neural systems could be associated with the endogenous and exogenous orienting of attention. It was found that both exogenous and endogenous orienting activated bilateral parietal and dorsal premotor regions. This suggested that both types of orienting to the periphery are associated with similar premotor activation. Additionally, it was proposed that both the endogenous and exogenous covert orienting are mediated by a single attention system. However, again endogenous orienting was more associated with the right dorsolateral prefrontal cortex. This was said to indicate that voluntary shifts of attention engage working memory systems. There thus appears to be reasonable evidence that attention consists of two distinctive levels that appear to have separate functions in the processing of the visual stimuli. Endogenous attention is deeply rooted in slower cognitive processes, whereas exogenous attention operates for rapid and automatic processing of visual input. However, for our present purposes the tradition in research of two levels of attention has not been focused on whether endogenous and exogenous level of attention might have differential roles in the integration of visual and motor representations.

1.3.1 Qualities of focused attention

Wide varieties of studies have shown that salient unique features can attract resources of exogenous attention, leading to attentional capture (e.g. Yantis & Jonides, 1984). The attention capture is said to occur when an irrelevant item that is unique in some dimension affects the time to detect a target. For instance, Yantis and Jonides (1984) showed that target detection in a visual search task was significantly enhanced when the target (a letter) appeared as an abrupt visual onset. This capture is depending on factors such as saliency (i.e., a degree to which a stimulus differs from its immediate surround in some dimension) (e.g. Theeuwes, 1994) and novelty (e.g. Folk & Remington, 1999) of the irrelevant stimuli. This kind of stimulus that differs from its surround is called a feature singleton (e.g. Theeuwes, 1994). The idea of attentional capture of feature singleton assumes that the singleton exogenously orients attention to its spatial location, and simultaneously improves the processing of stimuli at that location. Although this exogenous attentional capture appears to be automatic, it seems clear that it can be endogenously modulated. That is, because attentional capture can be suppressed when attention is previously focused on a particular spatial location (Yantis & Jonides, 1990; Theeuwes, 1991). However, when the attentional state becomes less focused, it is more likely that the peripherally presented visual information will affect ongoing processing. Thus, attentional capture may be automatic, but can be either suppressed or enhanced by endogenous attention processes.

However, although resources of exogenous attention are easily captured by abrupt onset of peripheral stimuli, perceptual processes that are related to this peripheral object, such as feature integration (i.e., operation for accurate conjunction of object features), are highly limited in the absence of focused attention to the object (e.g. Rock, Linnett, Grant, & Mack, 1992). We are, for example, able to attend to one of the two overlapping objects while filtering out most of the information about the other object (e.g., Butler & McKelvie, 1985). In the overlapping figures task, observers do not appear to process the shape of unattended figure in enough detail to recognize it later. Modigliani, Wright and Loverock (1996) also demonstrated that merely noticing the presence of a novel object is not sufficient for the accurate integration of its features. In addition, a number of studies have demonstrated that when attention is covertly focused on a visual field location, detection and discrimination of the target, which is presented in the same location is significantly improved (e.g., Hawkins, Hillyard, Luck, Mouloua, Downing, & Woodward, 1990; Nakayama & Mackeben, 1989). In other words, if attention is already focused to the location at which the target is displayed the quality of target representation is enhanced. Therefore, it may be suggested that one of the main functions of the focused attention (which is normally inseparable from endogenous attention) is to enhance perceptual processing of the object in order to create a coherent perception of the object.

It is important to emphasize that even though in normal conditions focused attention is inseparable from endogenous attention (e.g., when one finds the intentionally searched object on the computer screen), in experimental conditions, focused attention could be distinguished from endogenous attention. For instance, when the prime object is displayed at the location to which attention is focused, the image enhancement is not necessarily related to endogenous processes (i.e., the participant is not endogenously trying to detect the prime). Rather, the enhancement is associated with the influence of resources of focused attention to image processing. Therefore, both endogenous and exogenous attention could be divided into focused and un-focused levels, which could be examined experimentally. The role of endogenous, exogenous and focused attention in perceptual processes is widely researched. However, importantly for the present purposes the importance of these levels of attention on visual guidance of actions is not studied to the same extent. In fact, one of the aims of this thesis is to provide new evidence for roles of endogenous, exogenous and focused attention in visuomotor integration.

However, Handy, Grafton, Shroff, Ketay and Gazzaniga (2003) showed that ignored manipulable objects (e.g. tools) that were presented peripherally capture attention more than non-manipulable objects (e.g. animals) even while participants maintain fixation. Their results suggested that objects' potential for action (affordance) is automatically recognized at the exogenous level of attention, and consequently after this recognition, the attentional resources are drawn to the location of the graspable object. Importantly for the present purposes, their experiment does not show whether the manipulable object that is presented in periphery actually affords actions or whether action-relevant attributes of this object only attract exogenous attention. In fact, Symes, Ellis and Tucker (in press) demonstrated that orientation of the object, which is presented in periphery, facilitates the orientation compatible responses if the object needs to be recognized (attentional demands relatively high). However, when only the colour of peripherally presented objects had to be categorized (attentional demands relatively low), the orientation effect was not observed. It may be assumed that the colour could be recognized in periphery in the absence of allocating focused attention fully to the object, whereas the recognition of the object type (e.g., kitchen or garage) may require more resources of focused attention. Therefore, their study may suggest that the resources of focused attention are needed for the generation of the orientation effect. Finally, it may be summed that the peripheral stimuli is highly capable of capturing attention particularly if the stimulus is a manipulable object. However, the perceptual processes that are related to this peripheral object are very limited in the absence of focused attention to the object. Hence, it is particularly important to examine the degree to which endogenous, exogenous and focused attention are needed in the generation of object affordance effects. In particular, the experimental work of the thesis aims to investigate whether the peripheral graspable object is capable of affording action.

1.4 Object-based attention

It was shown earlier that, in the Simon effect, orienting of attention to the stimulus location generates the response code. Therefore, in this example, the stimulus is encoded or selected at the location-based level. However, Craighero et al. (1999) demonstrated that the premotor account of attention could be extended from orienting of attention to spatial locations to orienting of attention to actual objects, suggesting that attentional selection for actions can operate also at the object-based level. In fact, many behavioural and neuropsychological studies have shown that attention can indeed also operate at the object-based level (Duncan, 1984; Baylis & Driver, 1993; Tipper, Driver, & Weaver, 1991). For instance, it has been found that selective attention can also be directed to one of two overlapping objects (Duncan, 1993). This single-object advantage holds even when the features of a single object are further apart in space than the features of two different objects. Therefore, attention cannot be based entirely on the spatial position of a spotlight but can also operate at the object-based level. Perhaps the most dramatic evidence for object-based selection is seen in patients with bilateral lesions of the parietal lobes. These patients can see only one object at a time (e.g. Holmes & Horax, 1919). This occurs even if the objects spatially overlap (e.g. Luria, 1965). These patients are also unable to disengage from one object to shift attention to another, even when both objects are in the same location. Purely space-based model of attention cannot be used to explain these phenomena. Furthermore, Egly, Driver and Rafal (1994) showed that both levels of attention –location-based and object-based- can apply in the same situation. Therefore, it may be assumed that both levels of attention may operate simultaneously.

1.4.1 The biased competition model of selective attention

The biased competition model of selective attention (Desimone & Duncan, 1995) emphasises the role of attention in the control of behaviour towards selected objects in the environment. The model suggests that object construction begins pre-attentively in early visual areas such as V1. The object representation is finally assumed to occur when this object information begins to compete for visual resources in higher visual areas such as the inferior temporal cortex (IT) (visual area that operates for constructing perception from the surrounding environment) or the posterior parietal cortex (PPC) (visual area that operates for integrating visual information with action planning). Because the model assumes that the selective attention operates between objects, the processes for the biased competition take place mainly in these higher areas of visual system. Therefore, for instance, receptive fields of IT and PPC are processing resources for which viewed objects must compete. Simply the object that wins the competition in receptive field of IT and/or PPC will get most resources for perceptual processes.

According to the model, attention does not originate in any single place in the cortex. Attention is emergent property of the competition and cooperation among multiple brain regions that has limited capacity for processing information. The capacity has to be limited because only a relatively small amount of retinal information can be processed at a given time. Because the capacity is limited, attentional resources that are used for one object in the visual field leave less available for others. This competition between objects for representation, analysis, or control is biased towards object or component of object that is currently most relevant for behaviour (endogenous attention) or 'pops out' in the visual field (exogenous attention). Furthermore, it has been suggested that responses in an early visual area can be suppressed for irrelevant objects (Schneider, 1995). Therefore, top-down effects may suppress bottom-up processes allocated for irrelevant objects. These irrelevant objects receive suppressed processing in all systems (e.g. visual and motor systems). Although the competition is thought to take place in multiple brain systems, the competition is integrated between these systems. Consequently, when one object has won the competition in any of these systems, the same object tends to become dominant in all other systems. The visuomotor system could operate optimally for processing visually- and behaviourally relevant properties of the object only when visual and motor systems are working on the same object.

1.5 Summary

Behavioural evidence, for instance, from the Simon effect was shown to demonstrate the integrated nature of vision and action. Importantly, attentional orienting was proposed to underlie the Simon effect, suggesting the important role of attention in visuomotor integration. Furthermore, the premotor account of attention suggested that attention derives from mechanisms that are intrinsic to the circuits underlying perception and action. This account was proposed to offer a neat neurophysiological explanation for generation of response code in the Simon effect. In addition, it was emphasized that, in the Simon effect, attention operates at the location-based level. However, a wide variety of behavioural and neuropsychological evidence was shown to support also an object-based view of attention. Interestingly, the premotor account of attention was offered as theoretical basis for location-based selection of stimulus for action control as well as object-based selection. Additionally, it was shown that attention could be controlled endogenously and exogenously. Although this exogenous attentional capture appears to be automatic, it seems clear that it can be endogenously modulated. Furthermore, this capture depends on factors such as saliency and novelty of the stimuli. Most importantly, the irrelevant object seems to capture attention if this object has attributes that are related to manipulatory actions (e.g. grasping the tool). Additionally, focused attention has been shown to have an important role in constructing coherent perception of the object. Because this thesis aims to study the role of attention in object affordances, one of the main objectives is to examine whether these levels of attention could be differentially involved in movement guidance. Particularly, the degree to which the endogenous and exogenous attention is required in the generation of object affordance effects will be investigated. Finally, the fact that the visual object can be selected for action control at the location-based and object-based levels offers the current thesis a further empirical basis for studying attention in affordance effects. Before introducing aspects of attention in object affordances in more detail some basic neurophysiology of the visuomotor system is introduced.

CHAPTER 2: NEUROPHYSIOLOGY OF VISUOMOTOR SYSTEM

2.1 Transformation of visual codes to motor codes

Chapter One introduced converging behavioural evidence for the integration of vision and action. However, it is necessary to introduce the neural substrates involved in visuomotor integration in order that the central hypothesis of the thesis (the motor involvement in visual representation) can be fully understood. This section focuses on discussing the basic neurophysiology of the visuomotor system. Circuits in motor and parietal areas form the system, which transforms sensory information into action. It has to be emphasized that most of the reviewed data concerns non-human primates. However, the available data on human cortical organization confirm the general validity of the picture presented in this section. Firstly, the motor system is not entirely devoted to executing a muscle movement. In the premotor cortex, for instance, less than a tenth of the cells are classic motor neurons. About half the neurons are sensory cells that react to, for example, action-related visual information (Murata, Fadica, Fogassi, Gallese, Raos & Rizzolatti, 1997). In addition to the premotor cortex, several other motor areas such as the supplementary motor area and the primary motor area contribute to the integration of visual and motor representation. Only a proportion of the cells in these areas have purely motor related activation functions (Georgopoulos, 1991; 1992). Furthermore, each motor area in the frontal lobe has different functional properties, and therefore has a specific role in movement programming. Electrophysiological research with macaque monkeys has shown that, for instance, motor area F5ab represents distal arm movements such as grasping, holding, tearing and manipulating (Rizzolatti, Camarda, Fogassi, Gentilucci, Luppino & Matelli, 1988). Area F5ab corresponds to the inferior area 6 in human (Grafton, Fadiga, Arbib & Rizzolatti, 1997). These neurons fire during execution of specific types of grasping, such as a precision grip and a whole-hand grip. Interestingly for the present purposes, these neurons discharge also to the presentation of 3D objects, even when no action upon the object is required (e.g. Grafton et al., 1997). However, it is obvious that this activation does not necessarily result in the execution of an action. Other factors such as motivation to act and physical possibility to act are required to start the movement. In short, this evidence suggests that the motor system has a special role in representing objects in the environment.

Similarly, the visual system does not only consist of cells that respond to sensory stimulation. There are some cells, for example, in the posterior parietal cortex (PPC) that have visuomotor functions. These cells are active during the execution of hand and finger movements (e.g. Sakata, Taira, Murata & Mine, 1995). Like areas in the premotor cortex, the posterior parietal lobe is constituted by areas that have different functional properties. The posterior parietal lobe includes areas that represent effectors such as arm and mouth (see Rizzolatti et al., 1998). Anatomically, the PPC is formed by two lobules, the superior parietal lobule (SPL) and the inferior parietal lobule (IPL) that both receive somatosensory and visual inputs. Each motor area receives inputs from specific set of parietal areas. Although each parietal area is reciprocally connected with several areas in the motor cortex and therefore receive 'additional' inputs from more than one motor area, 'predominant' inputs are received from one area. These predominant connections that form parieto-frontal functional circuits are involved in a specific sensory-motor transformation of visual codes to action codes (Rizzolatti et al., 1998).

One good example of a parieto-frontal circuit is the connection between area AIP in PPC and area F5ab in the premotor cortex. This circuit is a transformation pathway for grasping (Rizzolatti et al., 1998). In fact, it has been suggested that the connections between these areas play the principal role in generation of object affordances (e.g. Fagg & Arbib, 1998). It has been demonstrated that AIP discharges to the presentation of graspable objects like F5ab neurons (e.g. Murata et al., 1997). In particular, visual object properties of size and orientation make these cells fire (Sakata et al., 1995). Furthermore, Gallese, Murata, Kaseda, Niki and Sakata (1994) showed the important role of AIP in object-directed grasping. They trained monkeys to grasp objects of different shapes, sizes and orientations. After training, an agonist of an inhibitory transmitter GABA was injected to area AIP. During the inactivation of the AIP, monkeys were unable to shape their hands properly to grasp the objects. However, their reaching movements were coordinated appropriately. Therefore, these circuits are specifically involved in grasp planning.

In contrast, the position of target objects seems to be represented in the ventral intraparietal area (VIP). This area receives visual projections from the dorsal stream (Colby, Duhamel, & Goldberg, 1993). VIP neurons fall into two main categories: purely visual neurons and bimodal, visual and tactile, neurons (Bremmer, Duhamel, Ben Hamed, & Graf, 1997). The represented target position is passed from the VIP to F4 in the premotor cortex. VIP neurons together with F4 neurons set up the initial reach program. There thus appears to be reasonable evidence that connections between F4 and VIP form circuits are responsible for object-directed reach planning. Therefore, it appears that separate circuits between the PPC and the premotor cortex are responsible for planning reach and grasp movements. Interestingly, Jeannerod (1984) separated human prehension into two independent motor programs, reaching and grasping, that involve separate brain regions. Additionally, Jeannerod (1988) reported that in human infants, the development of reaching and grasping has rather different developmental profiles. Furthermore, object-directed reaching appears to be coded mainly in the location coordinates of the target object. In contrast, the object-directed grasp planning requires more coding of intrinsic object properties, such as shape and size. This separation of reach and grasp planning is of special importance for the empirical work of the present thesis. It was shown in Chapter One that attention can operate at the object-based and location-based levels, and that both levels of attention derive from mechanisms that are intrinsic to the circuits underlying perception and action. Therefore, it seems logical to assume that (visually guided) reaching is planned at the location-based level of attention, whereas grasping is planned at the object-based level of attention.

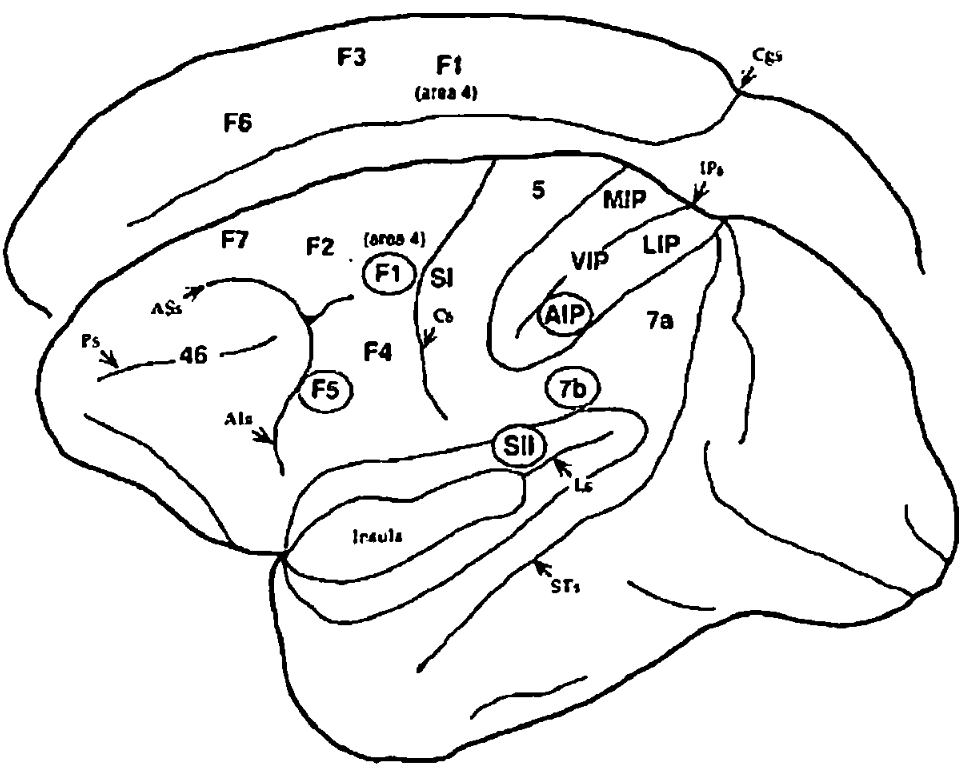


Figure 2.1 Cortical regions in the macaque (figure adapted from Jeannrod et al., 1995). The ventral intra-parietal area (VIP) is involved in reaching, and the anterior intra-parietal sulcus (AIP) is involved in grasping of objects. VIP has significant recurrent cortico-cortical projections with area F4 (of the inferior premotor cortex) whereas AIP has recurrent cortico-cortical projections with area F5.

2.2 The two visual streams: the ventral stream and dorsal stream

Objects in the visual field compete for processing within a network of 30 or more cortical visual areas (Desimone & Ungerleider, 1 989). These areas have been organized into two parallel and functionally different cortical processing streams, the dorsal and ventral stream (Ungerleider & Mishkin, 1982). They proposed that the dorsal stream computes a location attribute of a stimulus, while the ventral stream computes other visual attributes and is responsible for object recognition and pattern discrimination. Therefore, the ventral stream was called the 'what' system and the dorsal stream was called the 'where' system. Support for Ungerleider and Mishkin's (1982) position has been derived, for example, from experiments in which monkeys with lesions in the ventral stream showed impairments in visual pattern recognition (Iwai, 1985). In contrast, the same study showed that the visual discrimination abilities were intact for monkeys with dorsal stream lesions. However, the latter type of lesion led to a greater impairment in the monkey's ability to use spatial information in their control of visuomotor behaviour.

The split of the what-where visual pathways has some basis in the differential projections from retinal magno- and parvocells to the two systems of the magno and parvo layers of the lateral geniculate nucleus (LGN). The fastest-reacting magnocellular nerves have wide receptive fields and so gather information more quickly than parvocellular nerves. This makes them good for picking up the sudden changes in light intensity, which signals, for instance, a movement. However, the slower parvocellular cells have a tight receptive field that makes them good in processing information about, for example, colour and contour. In turn, this makes them computationally appropriate for detailed perception. Furthermore, the separation of magno and parvo pathways is not symmetrical between the two visual streams. The dorsal system is dominated by magnocellular projections whilst the ventral system receives roughly equal inputs from both pathways (Merigan &

Maunsell, 1993). The asymmetrical distribution of magno and parvo projections between the ventral- and dorsal streams alone suggests that the dorsal stream is a quick system, which is able to process less detailed visual information, whereas the ventral stream is slower and processes visual information in higher detail. However, the anatomical separation of 'what' and 'where' streams starts in V1 in the striate cortex. V1 is the first projection region of the LGN neurons into the cortex and it processes low-level visual information such as bars and edges. The ventral stream starts with the basic shape and colour filters in areas like V2, V3, and V4, and then runs into the temporal lobe areas such as inferior temporal area (IT). Cells in IT have very large receptive fields and therefore they appear to specialize in object recognition (Tanaka, 1993). In contrast, the dorsal route terminates in PPC. The visual information from V1 to PPC is inputted via areas such as MT which is sensitive to motion and depth analysis. The receptive fields become also larger along the dorsal stream. This suggests that the dorsal system is able to process also global object properties, such as size and shape, not only location (where) attributes of objects as it was proposed by Ungerleider and Mishkin (1982).

More recently, Goodale and Milner (1992) presented a reconception of the functions subserved by these two visual streams. According to their view, both streams can process visual information about object features such as size, shape, and orientation. Similarly, spatial relations of objects can be processed in both streams. They proposed that the two streams should be separated in relation to their differential contribution to perception and motor control. The ventral stream was suggested to be more involved in the construction of long-term perceptual representations, giving objects functional and semantic dimensions. On the other hand, the dorsal stream was said to be more involved in action control, and to use the visual information about object location, size, shape, and orientation in order to control actions such as reaching and grasping a visual object. Particularly, the dorsal stream was assumed to be involved in on-line (or better 'real-time') operations, whereas the ventral stream might have a role in the longer-term (or better off-line) modulation of behaviour. This functional specialization of the two streams led Milner and Goodale (1995) to term them the 'how' and 'what' systems. This view of functional separation of the two visual streams has received support from, for example, electrophysiological studies (Logothetis & Sheinberg, 1996; Perret, Benson, Hietanen, Oram & Dittrich, 1995; Sakata, Taira, Mine & Murata, 1992) and neuro-imaging studies (Puce, Allison, Asagari, Gore & McCarthy, 1996; Matsumura, Kawashima, Naito, Satoh, Takahashi, Yanagisava & Fuguda, 1996).

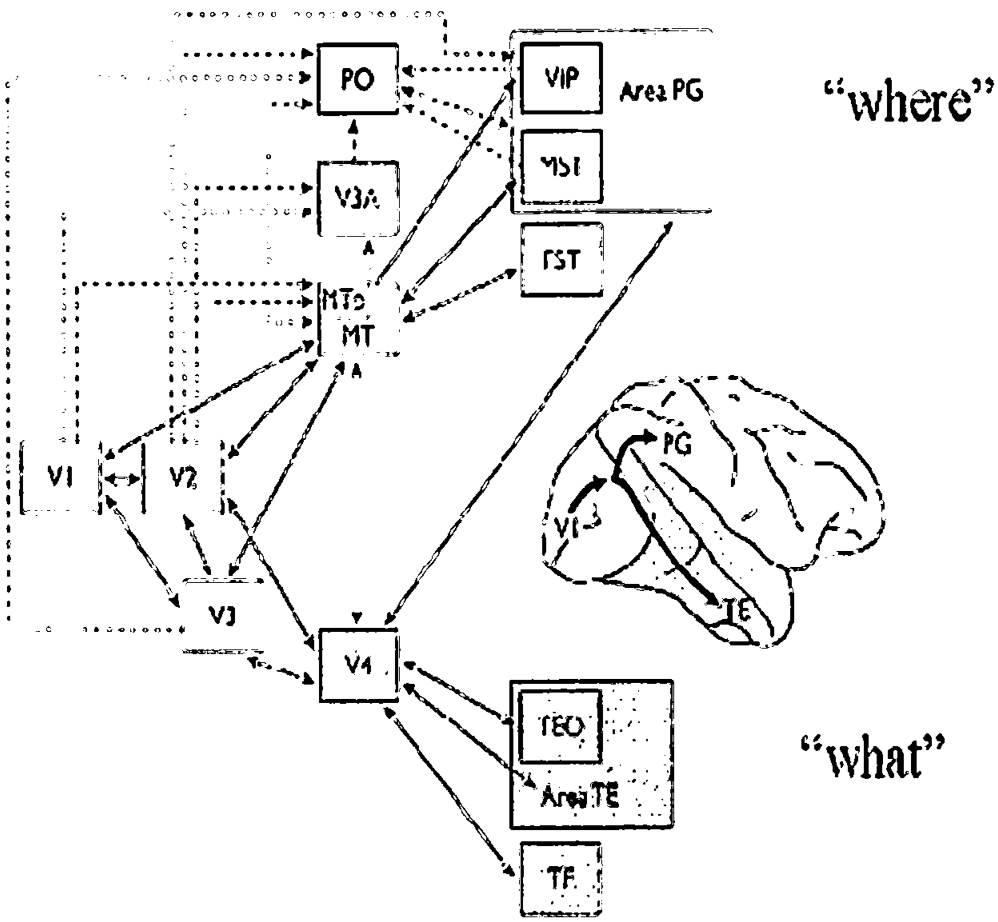


Figure 2.2 The illustration of "what" and "where" pathways (adapted from Ungerleider and Mishkin, 1982).

2.2.1 Allocentric and egocentric functions of the two streams

Visual information needs to be coded in rather different ways for the purposes of the ventral and dorsal stream. Firstly, the required actions must be matched to the location and disposition of the object with respect to an observer. Furthermore, observers and objects often move relative to one another. Therefore, the egocentric coordinates of, for example, location, size, shape and orientation attributes of the goal object can change drastically from moment to moment. As a consequence, it would be efficient to compute the required coordinates for action control immediately before the movements are initiated. Similarly, it would be inefficient to store these coordinates for more than a few milliseconds before executing the action. Therefore, the control of action requires frequently updated information about action relevant attributes of visual object with respect to the observer's moving body parts such as the eye, head, body, or limb (Colby, 1998). In other words, these computations must be organized in real-time within egocentric frames of reference. Because the dorsal stream is assumed to operate primarily for action control, it may be assumed that objects are represented egocentrically, in the dorsal stream, and these representations need to be frequently updated in relation to moving body parts. In contrast, such frequent updating would not be useful for constructing long-term perceptual representations, which typically require access to stored representation of objects. In fact, perception has a much longer time course and influences long-term memory. Allocentric coding would be the most appropriate candidate for such perceptual purposes (Milner & Goodale, 1995). In allocentric representations, locations and items are represented in reference frames that are extrinsic to the viewer and are experienced perceptually as stable regardless of the observer's movements in relation to the surrounding objects. Although the ventral stream has a very high acuity for object detail, its spatial abilities in relation to our body movements are quite poor (Jeannerod & Biguer, 1982). Therefore, for instance, Milner and Goodale (1995) suggested that the visual object should be represented allocentrically in the ventral stream. In addition to recognition processes, the allocentric coding may be appropriate for guiding actions that rely on off-line object information. Particularly, functional or semantic object attributes, when they are required in action control, are supposedly extracted from the ventral stream (Milner & Goodale, 1995). In other words, the ventral stream may be assumed to play important role in object-directed movements that at least partly rely on semantic properties of the object (e.g. grasping a hammer by the handle).

2.2.2 Neuropsychological evidence of functional separation of the two visual streams

Neuropsychological evidence for these functionally separable visual processing streams comes, for example, from cases of visual agnosia and optic ataxia. Visual form agnosia results from damage in the ventral stream (a bilateral lesion of the occipito-temporal cortex). Such patients show inability to recognise an object's size, shape or orientation (Goodale & Milner, 1992). Additionally, they appear to lose their perceptual ability to group separated items by means of their spatial interrelationships (Dijkerman, Milner & Carey, 1998), that is, to code their locations allocentrically. However, despite their inability to recognize the shape, size, and orientation of objects, they show surprisingly accurate guidance of hand and finger movements directed at those same objects (Goodale, Milner, Jaobson & Carey, 1991). Without computation of these attributes of objects, such object-directed guidance would be impossible. Because these patients' dorsal stream is intact, it appears that the dorsal stream is involved in patients' object-directed movement guidance. Interestingly, these same patients perform poorly when grasping blocks of different sizes when a delay of 2s or more is imposed on their response (Milner, 1998). In turn, this suggests that the dorsal stream has a very short memory about action relevant object attributes.

In contrast, optic ataxia is caused by the damage in the dorsal system, and demonstrates a converse effect to visual agnosia. Optic ataxia affects the visuomotor control of patients' actions. These patients are unable to form an accurate grip size when picking up objects of different sizes (Jeannerod, 1994). Additionally, patients with optic ataxia are not able to orient their wrist in relation to orientation of the target object (Perenin and Vighetto, 1988). However, the same patient's visual perception of location and orientation (Perenin and Vighetto, 1988), as well as of size (Jeannerod, Decety, & Michel, 1994) remains largely intact. Additionally, Milner, Dijkerman, Pisella, McIntosh, Tilikete, Vighetto and Rossetti (2001) showed that these patients respond more accurately and promptly when making delayed pointing responses to a target. That is, when the patient is using memorized visual information to pantomime a grasp for an object, the performance is significantly improved compared to performance in a non-delayed condition. The healthy subjects show the opposite pattern. This suggests that the ventral stream appears to be involved in off-line object-directed guidance of actions in addition to its functions for perception. Additionally, Jeannerod et al. (1994) have reported a type of motor deficit, which demonstrates that action relevant object information can be extracted from the ventral stream. Those patients had lesions in the dorsal stream, whilst their ventral stream was intact. Interestingly, they could not preshape their grasp when they were asked to reach-to-grasp a graspable cylinder. However, when they were asked to reach-to-grasp familiar objects such as a lipstick they showed relatively adaptive preshape. This suggests that the size information that was guiding a patients' grasping was extracted from the semantic characteristics of the object (e.g. known size of the lipstick).

Taken together, the nature of the deficit of these three different patient populations discussed above, support that view of functional specialization of the two visual streams that was proposed by Milner and Goodale (1995). The dorsal stream was said to process visual information for controlling actions whereas the ventral stream was said to process visual information for constructing perceptual representation. However, Jeannerod et al.

(1994) research shows that there is no clear-cut distinction between this functional separation of the two streams. In fact, the motor system appears to be able to extract visual information for object-directed actions from both the ventral stream (e.g. known size) and the dorsal stream (e.g. egocentric size). Therefore, to perform accurate reaching and grasping to complex objects, the action planning may rely on the integration of the semantic information about the object (the ventral stream) and purely visual on-line information about the object (the dorsal stream).

The deficit of utilization behaviour (UB) shows that even very complex actions, such as writing, can be afforded by a seen object. Patients with UB (Lhermite, 1983) cannot inhibit actions that are facilitated by high-level properties of a seen objects. These patients' action is often triggered by seen object, regardless of the actor's intentions to act towards the object. Patients with UB often perform uncontrolled but correct utilization of common objects that are spontaneously viewed by the patient or placed in front of them by a researcher. For instance, patients may start to use a pencil for writing or reach and grasp a cup and start drinking from a cup that is placed in front of them. UB has generally been associated with frontal lobe damage. Originally, Lhermitte (1983) supposed that UB was linked with prefrontal cortex damage that resulted in the loss of inhibitory control. However, Ishihara, Nishino, Maki, Kawamura and Murayama (2002) argued that UB might be caused by lesion in the sub-cortical white matter of the superior frontal gyrus and could be therefore considered a white matter disconnection syndrome. In sum, neuropsychological evidence from UB suggests that ventral stream inputs can be associated with automatic planning of even very high-level actions such as writing when an object such as a pencil is viewed.

2.3 Action planning and control in relation to the two visual stream hypothesis

It was shown above that, inputs from both visual streams could be involved in computing actions. However, these streams appear to have differential functions in action guidance. The ventral stream appears to be involved in off-line extraction of action relevant object attributes while the dorsal stream is more involved in on-line operations. Glover (in press) developed the planning-control model, which assumes that on-line information can be extracted for action guidance only from spatial object characteristics while non-spatial object characteristics are normally associated with the off-line computing of actions[1]. Furthermore, he proposed that the computing of human movement might be separated into two different stages, movement planning and control. Control can use only spatial information about an object whereas planning is normally related to non-spatial object characteristics (e.g. Glover, 2003). He also argued that movement planning and control could be separated anatomically into two separable subsystems, the planning system and control system. The planning system, which appears to rely on phylogenetically newer

regions in the inferior parietal lobe (IPL) in PPC, generally operates prior to a movement (between the onset of stimuli and the onset of movement). In contrast, the control system that appears to rely on older regions in the superior parietal lobe (SPL) in PPC operates during movement execution. Movement planning uses a richer visual representation than does control, but control is faster and more adaptable (see Glover, 2003). The dorsal stream seems to be better suited for the purposes of action control because it was shown to process object information relatively quickly. Similarly, the ventral stream may offer a better basis for the action planning because it was shown to be involved in constructing richer visual representations. However, the planning-control model maps planning and

[1] [1] *Spatial object characteristics tend to be geometric properties, such as orientation, position, shape and size, that can be gleaned from low-level visual processes. However, non-spatial object characteristics are not entirely visual. They invariably necessitate reference to stored memories about, for example, the function or known size of the object (Glover, in press).*

control specifically onto the IPL and SPL, instead of the ventral and dorsal pathways, and therefore, it is dramatically different from the view proposed by Miner and Goodale (1995).

The planning-control model is largely based on behavioural studies carried out by Glover and Dixon (2001; 2002). Glover and Dixon (2001) examined the effects of an orientation illusion on perception and the two different stages (planning and control) of an action. An orientation illusion for perception is commonly observed when a vertically orientated object is presented over the background that has gating which is oriented at (say) 10 degrees clockwise or counter-clockwise from sagittal. When participants reached and grasped a bar lying on a table over the orientated gratings that were associated with perceptual illusion, the illusion affected only the orientation of the hand at the beginning of the reach but not near its end. This suggested that reaching trajectories are planned through a context-dependent representation but are corrected on-line through a context-independent representation. In other words, the illusion effects planning but not control. In another experiment, Glover and Dixon (2002) found that when participants are presented with objects on which the word "LARGE" or "SMALL" was printed, the word affected the grip aperture only in the planning stage. This research was assumed to show that semantics that are processed in the ventral stream affect the planning but not the control of grasping, whereas adjustments of motor program in control could be affected only by spatial information that appears to be processed in the dorsal stream (e.g. visual online size of the object). Taken together, these two studies suggest that action planning is tightly linked to perceptual processes that supposedly occur in the ventral stream. In contrast, action control is not affected by these perceptual processes and may be, thus, assumed to operate within the dorsal stream.

1.6 Summary

In sum, a variety of elecrophysiological, neuro-imaging, behavioural and neuropsychological researches have shown close integration between vision and action. For example, when a graspable object is presented in the visual field, the action relevant properties of the object such as size can prepare corresponding actions (see Rizzolatti et al., 1998) even when no action upon the object is required. This suggests that vision has a fundamental role in movement planning. In addition, the visuomotor system can be separated into the two functionally separable routes: the ventral and dorsal stream. However, all details of the functional separation of these two streams are not fully agreed upon. The earlier view (Underleider & Mishikin, 1982) suggests that the dorsal stream processes location attributes of visual input, whereas the latter view (Milner & Goodale, 1995) proposes that attributes of shape, size, and orientation can be also processed in this stream. Furthermore, the latter view emphasizes that the function of the dorsal stream is to process visual input for the computing of actions. A wide variety of neuropsychological data (e.g. Jeannerod, 1994) was shown to support the latter view. In general, it may be assumed that the dorsal stream processes egocentrically information about object's such as shape, size, orientation and location for movement control and planning (how), and this representation needs to be updated frequently. In contrast, the ventral stream processes allocentrically and relatively slowly very detailed object information mainly for longer-term object representation (what). However, information that is processed in the ventral stream is also normally involved in action planning (Glover, 2003), or at least semantic action-relevant information about object that is processed in the ventral stream can be used for action preparation (Milner & Goodale, 1995).

CHAPTER 3: OBJECT AFFORDANCES

3.1 The object-related potentiation of action: micro- affordances

In Chapter One, it was shown that S-R compatibility paradigms have been used successfully to demonstrate the integrated nature of vision and action. Furthermore, it was suggested that spatial S-R compatibility paradigms might provide a useful methodological tool for the investigation of affordances (Michaels, 1988). Affordances were described as action relevant characteristics of the object or surface. This affordance which is perceived directly in the object or surface 'affords' actions, taking into account an animals or humans action capabilities at the current moment. Michaels (1988) presented squares (on the computer screen) that were moving either toward the ipsilateral hand or toward the contralateral hand. Participants were asked to perform joystick pushes with their left or right hand either to the actual position (block 1) or to the destination of apparent motion of the squares (block 2). The hand to which square was moving showed facilitated responses, even when the stimulus location on the screen corresponded with the position of the opposite hand at the time of the response. It was suggested that this effect, which was opposite to the Simon effect, was observed because the moving stimulus *afforded catching* of the hand toward which the stimulus was moving.

The theory of affordance has an inspirational role also in developing the empirical ground for this thesis. As stated in Chapter One, the central hypothesis of the thesis assumes that motor activation (or better action plans), which are triggered by action-related object characteristics of a viewed object, forms an intrinsic part of the object representation. Furthermore, the reach-to-grasp action plans that are automatically triggered by seen (graspable) objects were termed 'micro-affordances'. Micro-affordances were proposed to be dispositional properties of a viewer's nervous system in which covert motor activity, which is associated with particular object, forms part of the representation of this object. This central hypothesis of the thesis is based on empirical work carried out by Tucker and Ellis (Tucker & Ellis, 1998; 2001; Ellis & Tucker; 2000), as mentioned earlier. Additionally, a wide variety of other behavioural studies (e.g. Craighero, Fadiga, Rizzolatti, & Umiltà, 1999; Creem, & Proffitt, 2001; Hommel, Musseler, Aschersleben & Prinz, 2001) supports a view of the integration of vision and action that corresponds with the hypothesis of micro-affordance. More recently, this hypothesis is also supported by neuro-imaging studies (e.g. Grezes & Decety, 2002; Grezes, Tucker, Armony, Ellis, & Passingham, 2003; Handy, Grafton, Shroff, Ketay & Gazaniga, 2003). Tucker and Ellis (1998; 2001) introduced two effects of micro-affordance, the object-orientation effect and the object-size effect, that supported their hypothesis of micro-affordance. The following sub-section introduces these two effects.

3.1.1 The object-orientation effect and the object-size effect

Tucker and Ellis (1998) found that simply viewing an object (to indicate whether the object was upright or inverted) that was left or right orientated (one compatible with a right-hand grasp, the other with a left-hand grasp) potentiated responses of the hand most suited to perform a reach-and-grasp action. In other words, these experiments showed that the task-irrelevant orientation of the viewed object speeds up participant's left-right hand responses. This suggested that *"seen objects automatically potentiate components of the actions they afford"* (Tucker & Ellis, 1998, pp.830), regardless of intentions to act. However, when responses were performed with the middle and index fingers of a single hand a significant interaction between object orientation and response was not obtained. This result supported the view that the effect could not be attributed to the abstract left-right coding of the object orientation. Instead, it supported the view that the left-right hand responses were *afforded* by action relevant object property, which in this case is horizontal object orientation.

Similarly, Tucker and Ellis (2001) reported other evidence to support the view that motor preparation may be an intrinsic element in the visual representation of an object. They asked participants to make speeded responses based on the category (manufactured or natural) of the object. Half of the objects in both categories were small and would normally be grasped with a precision grip (e.g. grape, screw) and half were large and would normally be grasped with a power grip (e.g. cucumber, hammer). Participants held the power and precision grip in their dominant hand. The power grip was held by wrapping their middle, ring, and little fingers around it, while the precision grip was held between the index finger and thumb (see Figure 4 for illustration of response device). Participants were asked to judge whether the object was manufactured or natural, responding by pressing the small switch or squeezing the large switch. They found that responses, which were performed with the type of grip that was compatible with the presented object (precision grip-small object/power grip-large object), were significantly speeded. The same effect was observed in bi-manual task when one response device was held in one hand and the other device was held in the opposite hand. Furthermore, the effect was observed regardless of whether objects were presented within the participant's reaching space. The time course of this effect was examined by using a go-no-go paradigm with responses cued by tones and go-no-go trials cued by object category. The compatibility effect was not observed when participant knew in advance (500 ms before the response cue), which response they had to make. Furthermore, 300 ms delay between offset of the go-no-go object and the response cue effectively removed the object-orientation effect, suggesting that the effect diminished rapidly after disappearance of the object from view. In contrast, the distributional analysis revealed that the effect appears to build in magnitude whilst the object remains in view. Furthermore, Derbyshire, Ellis, and Tucker (in submission) demonstrated that the object affordance information can be extracted from the off-line information about objects. In this study, an arrow was used to identify the position of a target object that was previously displayed on a screen simultaneously with three other objects. In the each trial, the set of stimuli consisted of two small objects that were compatible with the precision grip and two larger objects that were compatible with the power grip. Half of the objects belonged into category 'naturally formed' and other half of the objects were 'manufactured'. Participants were instructed to form a visual mental image of the objects. The task was to respond with precision or power grip depending on whether the object, which was previously presented in the pointed position, belonged to category 'manufactured' or 'naturally formed'. Once again responses were executed faster with an object compatible precision/power grip.

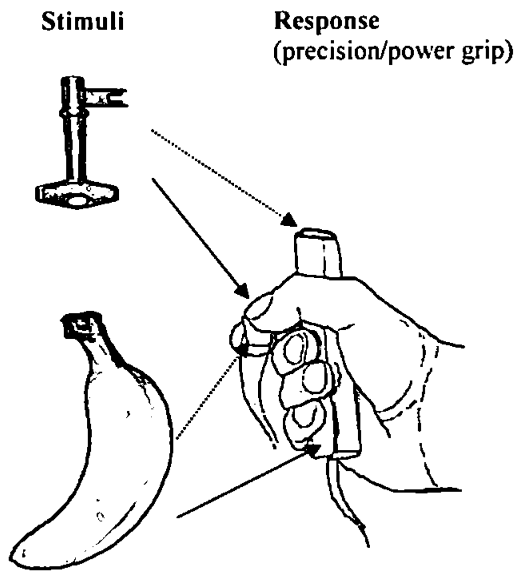


Figure 3.1 In this figure, the participant was instructed to make a dominant hand precision or power grip response to manufactured or natural objects. Within each category, half of the grip responses were congruent (solid lines) with the actions afforded by the objects and half were incongruent (dotted lines).

3.2 High- and low-level affordances

As it was shown in Chapter Two, perception and action can dissociate from one another (e.g., Milner & Goodale, 1995). For example, damage to ventral areas mediating visual processing can selectively disrupt perception but not action to visual stimuli, whereas damage to more dorsal areas of cortex can selectively disrupt action but not the perception of stimuli. However, a question concerns the extent to which these systems remain independent or require communication between each other. Presumably, an *effective* grasp (grasping the object without processing it semantically) can be mediated by the dorsal system alone. However, grasping a hand tool appropriately by its handle requires information from a semantic representational system. Thus, action control often uses semantic information about an object, which does not necessarily fit into anatomically differentiated dorsal and ventral streams. Instead, the fact that knowledge of the identity of an object can help an agent in grasping a goal object suggests interactions between the visual pathways. Therefore, it would be perhaps appropriate to talk about two routes from vision to action (which are in tight interaction), the semantic and visual route. This view was already introduced in Chapter Two.

Humphreys and his colleaques (e.g. Riddoch & Humphreys, 1987; Riddoch, Humphreys & Price, 1989; Rumiati & Humphreys, 1998) have shown additional neuropsychological and behavioural evidence for suggesting that there are semantic and visual routes from vision to action. They proposed that the direct visual route to action operates through associations between learned actions and stored visual representations of objects, which belong to a structural description system, separate from semantic memory. In a study by Rumiati and Humphreys (1998), participants were asked to name or perform gestures to drawings of objects (e.g. writing to a pen) under deadline conditions. That is, when the participant was presented with, for instance, a pen, they were expected to name it or perform a writing gesture within a given time interval. This produces errors and these errors were expected to show what type of representation is available to response processes and to illustrate the type of route used to access the response. The errors could be visual (e.g. "hammer" for "razor"), semantic (e.g. "saw" for "hammer") or semantic-visual (e.g. "match" for "cigarette"). It was found that, in gesturing to pictures, participants made more visual errors and fewer semantic or semantic-visual errors. In contrast, when the stimuli were presented as words only semantic errors arose. The authors suggested that the visual errors resulted from the use of a direct visual route from the object to stored actions, and that semantic errors resulted from an indirect route from the verbal presentation through semantic knowledge to action. Furthermore, it was suggested that the direct visual route may be based on viewer-centered codes located in the dorsal system, whereas the semantic route may be based on object-centered codes located in the ventral system.

Creem and Proffitt (2001) provided additional behavioural evidence for emphasizing the role of the semantic route in action guidance. They ran an experiment in which participants were asked to grasp and pick up a handled object (e.g. a hammer, paintbrush etc.) that was placed on a table in front of them. Although the handle of the object was facing away from the participant, 78 % of grasps were performed in a way that was appropriate for its correct purpose. That is, objects were grasped by their handle. However, when participants were performing a concurrent, semantically challenging task (participants were asked to say the second word of the previously learned word pair) inappropriate grasps were more frequent. In contrast, a visuo-spatial task (devised by Brooks, 1968) did not interfere with grasping. This finding supports the view that a semantic route from stimulus to action is required so that actions can be computed in relation to the function of the object. Furthermore, this may suggest that the object-orientation effect reported by Tucker and Ellis (1998) remains relatively small (the size ranges normally between 10 ms and 20 ms) because the task demands (e.g. upright object-right hand/inverted object left hand) taxes their semantic system during the task.

Tucker and Ellis (2004), additionally, showed that purely semantic information about an object is sufficient to generate affordance based compatibility effects. In their study, participants were asked to categorize names of objects that could be normally grasped with a precision grip or power grip. The same compatibility effect as reported for seen objects was observed. It may be supposed that correct actions in response to words cannot be made without retrieving semantic information. This experiment shows clearly that object information necessary for generation of micro-affordances can be extracted from the semantic route. In sharp contrast, Ellis and Tucker (in preparation) demonstrated that affordance information based on object size could be extracted from purely visual object characteristics without retrieving semantic information. In this study, participants were presented with precision and power compatible novel (3D) objects that did not have any semantic associations. These objects were angular or round shaped. Participants were asked to categorize objects into angular or round categories by pressing the power or precision switch. Responses were performed faster when object size was compatible with the size of the grip. Similarly, Symes, Ellis and Tucker (in submission) showed that object orientation could afford responses even when the object does not have any semantic associations (e.g. functional handle). Interestingly, in this study, left-right responses made to the task-irrelevant orientation of a diagonal line consistently failed to produce the object-orientation effect. However, when a third dimension was introduced responses were speeded when the hand of response corresponded to the orientation of the cylinder. Goal objects need to be graspable (conform to a grasp appropriate shape) and be presented in three-dimensions for there to be object to action compatibility effects. Taken together, these studies (Tucker & Ellis, 2004; Ellis & Tucker, in preparation; Symes et al., in submission) demonstrate that affordance information about size and orientation of the object can be extracted from both visual and semantic object characteristics. Furthermore, these data are consistent with the hypothesis of two information-processing routes from stimulus to action proposed by Humphreys and his colleaques.

Although both micro-affordance effects, the object-size effect and the object-orientation effect, could be extracted from low (or better visual) level information about objects, only object size, not orientation, can be extracted from purely high (or better semantic) level information about objects. In other words, an object size could be easily related to the known size of familiar object (e.g. it is "known" that a key is a small object and is normally grasped with a precision grip) and the purely visual size of the novel object (e.g. small 2 x 2 cm object that is viewed from 50 cm distance would be normally grasped with precision grip). In the current thesis, the level of affordances in which purely visual object-size effect operates is termed *low-level (size) affordance*, whereas the level of affordances in which semantic object-size effect operates is termed *high-level (size) affordances.* In contrast, object orientation can never be associated with purely semantic object information. That is, an orientation is not an intrinsic part of the object. However, object orientation can be recognized at higher and lower levels, the orientation of the axis of elongation offering the lower level (Symes et al., in submission) and the location of the functional handle offering the higher level (Creem & Proffitt, 2001). In the current thesis, the level of affordances at which the occurrence of the object-orientation effect does not require involvement of semantic processes is termed *low-level (orientation) affordances*, whereas the level of affordances at which the occurrence of the object-orientation effect does require involvement of semantic processes is termed *high-level (orientation) affordances.* Finally, it is important to empasize that most of the time both high-level affordance information and the low-level affordance information about an object are simultaneously affording actions, and these sources of information have to be integrated in the visuomotor system for programming correct actions.

3.3 Evidence for primitive affordance codes

Tucker and Ellis (2001) proposed that the hand responses that were potentiated automatically by a visual object may be associated with quite 'primitive' motor representations. In other words, it was assumed that particular properties of the object, such as object orientation and size, might evoke micro-affordances, without affording any particular effector. Symes, Ellis, and Tucker (in press) showed experimentally that this prediction was correct. Their study demonstrated that object orientation could facilitate responses of the left and right foot. Because both the hand and foot responses can benefit from the same response code that is facilitated by an object's orientation, the actions afforded are likely to be of an abstract or primitive rather than specific nature. Importantly, the idea of 'primitive' affordance codes fit well with electrophysiological evidence of a common reference frame within posterior parietal cortex (PPC) for programming movements. For instance, Cohen and Andersen (2002) suggested that both the planning of eye movement and reaching are at least partly coded in the same reference frame. They reported that a high proportion of neurons in the lateral intraparietal area (specialized for saccadic eye movements) and the parietal reach region (specialized for reaching) in PPC code target location in a common eye-centred reference frame. More importantly for the present purposes, Castiello, Bennett, Egan, Tochon-Danguy, Kritikos and Dunai (2000) showed evidence for the existence of effector-independent affordances. Their empirical work was based on fact that different body parts, such as the hand and mouth, can be used to produce a grasping movement. In this study subjects were required to perform a grasping action with different effectors (the mouth or the hand) while the brain was scanned. The study demonstrated activation of the inferior parietal lobe during real and imagined mouth and hand grasping actions. Thus, the authors suggested that their data might provide evidence that different effectors could benefit from the same affordance information, which is represented in the IPL.

3.4 Lateralization of micro-affordances

Grezes and Decety (2002) used positron emission tomography (PET) to study whether the object-orientation effect covaries with activation in motor areas. In their study, participants were presented with familiar graspable objects (e.g. tools) and participants carried out various tasks [the one used by Tucker and Ellis (1998) (indicating whether the object is upright or inverted), motor imagery (imaging grasping each object that was presented every 3 seconds), and silent object naming task (naming each object that was presented every 3 seconds]. Non-objects were presented in the base-line condition. Grezes and Decety (2002) found that the viewing of familiar objects, irrespective of the task, versus viewing of non-objects, was associated with activation of specific cortical areas. It was suggested that this activation can be interpreted as partial involvement of motor representation in the visual object representation. For example, the IPL that was previously shown to represent effector-independent affordances (Castiello et al., 2000) was one of those cortical areas that were activated during stimulus presentation. Significant ventral stream activation was not associated with the viewing of objects. This suggested that that sensory input to a parietal system could activate the object relevant motor representation without retrieving semantic information about objects. More recently, Grezes et al. (2003) used fMRI technique to study whether the size of the object-size effect covaries with activation in motor areas. In this study, participants carried out the task that was used by Tucker and Ellis (2001). The ususal compatibility effect between grip size and the object size was observed. Also the greater the reaction time difference between incongruent and congruent trials the greater was activity in specific areas in the left hemisphere. These areas were, for instance, the inferior prefrontal-, and the premotor areas. Additionally, areas in (left) parietal cortex, such as the supramarginal gyrus, were correlated with the congruency effect. Both of these brain-imaging studies reported by Grezes and her colleagues (2002; 2003) provided support for view that micro-affordance effects indeed reflect motor involvement in visual object representation.

The fact that Grezes et al. (2003) associated affordances with activation of areas in the *left hemisphere* is a particularly interesting detail. Typically, frontal and parietal areas in *the right hemisphere* are specialized in the covert orienting of attention (Heilman & Van Den Abell, 1980). These areas are involved in the directing of attention in both ipsilateral and contralateral directions (Corbetta, Miezin, Shulman & Petersen, 1993). Lesions in the right posterior parietal area impair the ability to disengage the focus of covert attention from the fixated location (Posner et al, 1984). Furthermore, as it was stated in Chapter One, covert orienting of location-based attention is linked to the preparation of movements such as saccades and reaching (e.g. Tipper et al., 2000; Beauchamp et al., 2001). Therefore, it seems that the right hemisphere is predominantly involved in computing the location-based coordinates for movement planning. In contrast, it is well known that the left hemisphere dominates higher-level motor planning (Castello et al., 1999). For example, Rushworth, Nixon, Renowden, Wade and Passingham (1997) linked the left parietal cortex, particularly the supramarginal gyrus, with attention, which is involved in programming manual movements from one movement in the sequence to another. This type of attention was termed 'motor attention'. In their study, Rushworth et al. (1997) compared the effect of left and right parietal lesions on the ability to engage and disengage motor attention. It was found that patients with lesions in the left hemisphere were unable to disengage the focus of motor attention from one movement in the sequence to the next. The patients with lesion in their right hemisphere, however, did not show this type of inability. Rushworth et al (1997) proposed that attention for eye movements and limb movements may depend on distinct neural systems that are lateralized. Therefore, it appears that the two hemispheres have clearly separable functions in movement programming.

Handy et al. (2003) reported additional brain-imagining evidence for integration of visual and motor representations, as mentioned earlier. Importantly for the present purposes, this study also suggested the important role of the left hemisphere in affordance generation. In short, Handy et al. (2003) presented simultaneously two task-irrelevant objects, one in the right visual field (RVF) and one in the left visual filed (LVF), while participants maintained their fixation to the central fixation point. After 650 – 850 ms one of these objects was replaced by a stimulus for 100 ms. Participants were asked to respond to the target location with their left or right hand while ignoring the objects. The non-targets were from two different categories, manipulable (e.g., tools) and non-manipulable (e.g., animals) objects. Systematic changes in the amplitude of the lateral occipital P1 (positive, early) were observed which indicated that spatial attention was orientated to a particular location in the visual field during dual object presentation. Interestingly, it was found that spatial attention was systemically drawn to manipulable but not to non-manipulable objects in the RVF. Therefore, this experiment suggests that the left hemisphere is predominantly involved in recognition of object affordances. However, it was noticed that objects in the category of manipulable objects conform also to a grasp-appropriate shape. Therefore, the data do not show whether the visual field asymmetries in the processing of action-related object attributes are related to high or low-level affordances.

Taken together, it is important to emphasize that processes related to the integration of vision and action are often lateralized. The right hemisphere seems to be superior in movement programming that is related to processes of spatial attention (Corbetta, Miezin, Shulman & Petersen, 1993; Posner et al., 1984; Heilman & Van Den Abell, 1980). In contrast, the left hemisphere seems to operate dominantly in programming more complex (e.g., reach-to-grasp actions) visually guided movements (Rushworth et al., 1997) that may be tightly linked to object-based affordances (Handy et al., 2003; Grezes et al., 2003). The fact that object affordances appears to be computed predominantly in the left hemisphere while the right hemisphere seems to offer the neurological basis for computing location-based (visually guided) actions has important implications in understanding the way objects in the visual field are represented for actions. Therefore, these aspects of lateralization form one of the key issues for the empirical work of the present thesis.

3.5 Computational model (FARS) of affordances

Fagg and Arbib (1998) modelled parietal-premotor interactions in primate control of grasping. This model contributes to understanding how visual information about object affordances could be transformed for the motor system for the generation of motor behaviour. Because this model fits well with our view of micro-affordance, it will be introduced in detail in this section. The FARS (Fagg-Arbib-Rizzolatti-Sakata) model, as it was called, was based on simplified but neurologically plausible neural networks. In particular, the model was based on interaction between several regions, mainly in the PPC and the premotor area, that are found to be involved in the computing of object-directed grasping. Furthermore, the model concentrates on interaction between the anterior intra-parietal area (AIP) and area F5 of the inferior premotor cortex, both of which are associated with grasp preparation. The function of AIP and F5 in visuomotor integration was introduced in Chapter Two.

In short, the FARS model hypothesized that the AIP is the first stage in the process of visually guided grasp programming. The AIP initiates the computing of affordances (or set of affordances) when it receives visual information about the object. Furthermore, AIP is responsible for integrating object information, relevant to appropriate actions, from both the dorsal and ventral streams for the formation of affordances. The low-level (e.g. visual size) information about objects is imported from the posterior intraparietal area (PIP) while the high-level (e.g. known size) information about an object is imported from the inferior temporal lobe (IT). This idea was based on some neuropsychological findings from ventral lesion studies (e.g. Goodale & Milner, 1992; Castiello & Jeannerod, 1991) and neurophysiological research (e.g. Sakata, Taira, Kusunoki, Murata & Tanka, 1997). According to the model, the grasp related activity pattern is passed to F5 which then selects one of the specified grasps under the influence of various constraints. These constraints include, for example, information about object-affordances inputted from AIP, task information, and working memories for recently executed grasps. The working memories of recently executed grasps have a particularly important role in the formation of the affordance because the information about selected and executed grasp is fed back to AIP to suppress other affordances facilitated by visual stimuli. This feedback information is continually updating the affordance representation in AIP. If the executed grasp differs from the one that was initially programmed by inputs from AIP, the representation for this initial grasp representation in AIP is suppressed. However, if the executed grasp matches the active affordance representation in AIP, the representation is facilitated. In addition, the model assumes that cells in neuron populations, which are normally involved in encoding a single grasp, exchange excitatory connections to support their mutual co-activation. On the other hand, cells that are not normally involved in encoding the same movement exchange inhibitory connections. These inhibitory and excitatory connections ensure that only those cells that are involved in encoding a single grasp are allowed to achieve a significant level of activation at any one time. Therefore, the selection of a single grasp is enforced even by the representation of an object that is associated with several affordances (e.g., wine glass which can be grasped by a precision or power grip).

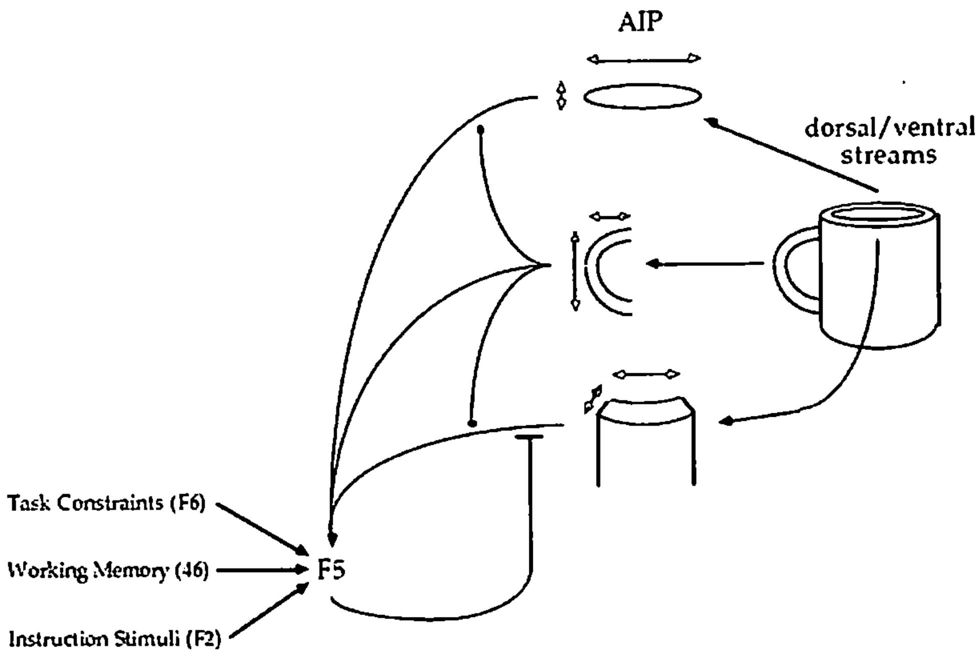


Figure 3.2 According to the FARS model, AIP uses visual inputs to extract affordances, which highlight the features of the object that are relevant to grasping it. F5 applies various constraints to select a grasp for execution and to inform AIP of the status of its execution (i.e., updating AIP's active memory). (adapted from Fagg & Arbib, 1998).

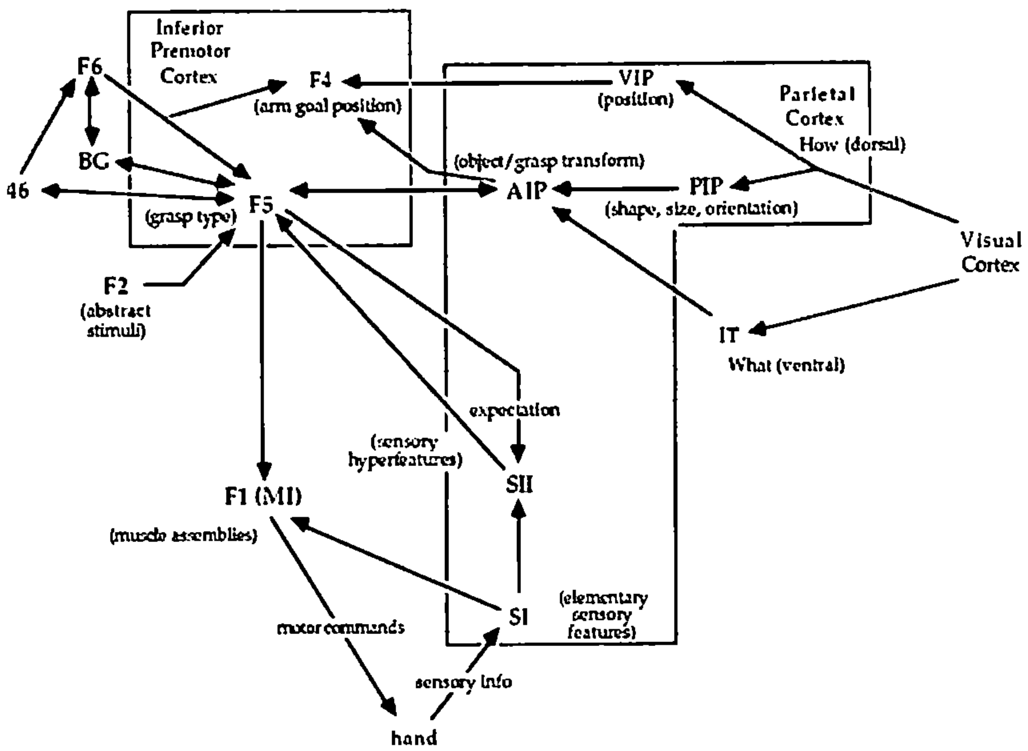


Figure 3.3 The complete FARS model. (adapted from Fagg & Arbib, 1998).

In sum, the FARS model describes visuomotor transformation mechanisms that may be responsible for micro-affordance effects. For example, the FARS model suggests that several different affordances activated by a single object can compete for resources that are responsible for computing object-directed actions. It follows that micro-affordance effects may reflect the winner of these competing affordances. Furthermore, the model makes some further suggestions about the way affordances are constructed. For example, it suggests that the task and the previously executed response have a role in the affordance generation. Most importantly, the model emphasises that the effects may not be associated exclusively with inputs from the ventral or dorsal pathways. Instead, the motor system may receive the necessary information for affordance generation simultaneously from both systems.

3.6 Two competing accounts of the object-orientation effect

Chapter One showed the importance of attention in the response coding account of the Simon effect. The premotor account of attention was offered as an explanation for the facilitation of the response code in the Simon effect. However, the same premotor account was used to explain how allocation of attention to graspable objects may prime actions that are compatible with the action relevant properties of the object. Therefore, the premotor account was offered as a theoretical basis for location-based selection of stimulus for action control as well as object-based selection. Because attention was shown to play such an important role in the Simon effect (Nicoletti & Umiltá, 1994) and object-based visuomotor priming effects (Craighero et al., 1999), it is reasonable to assume that certain mechanisms or elements of attention are important in all S-R compatibility effects, including the effects of micro-affordance. Hence, the present thesis asks whether attention has similar importance in micro-affordance effects, and if it does, whether attentional mechanisms are similar or different to those of the Simon effect and visuomotor priming effect. However, to explore more closely those similarities and/or differences in attentional mechanisms, it is particularly important to notice that there are also differences between the Simon effect and effects of micro-affordance. Whilst both effects reflect compatibility between certain stimulus and response dimensions, it may be presumed that the object-size effect is related to object-based information (i.e., information that allows grasp planning in relation to intrinsic object attributes such as size and shape). In this case, it may be supposed that when attention is focused on the object, the size of the object retrieves an appropriate response (e.g. precision grasp) from 'motor memory'. Therefore, the object-size effect may be related to attentional mechanisms similar to those of the visuomotor priming effect. In contrast, the object-orientation effect may have a similar location-based origin to the Simon effect. For example, the location of the handle component of the orientated object may be assumed to offer a basis for shifting attention to left or right. This in turn may result in facilitation of left or right hand responses in the same way as a directional attention shift to the stimulus location facilitates responses in the Simon effect. The uncertainty whether the object-orientation effect is related to location-based or object-based mechanisms of attention offers a basis for the empirical work of the present thesis. This idea is described in more detail in the next sub-section.

3.6.1 The attention shift account and the object-based account of the object-orientation effect

Our perception appears rich and detailed only in the foveal region. Therefore, it is reasonable to assume that focused attention would be implicitly or explicitly moved to the functionally most relevant region, such as a handle, within the goal object. As reported above, the premotor account of attention suggested that this kind of orienting of attention automatically prepares all effectors that are involved in achieving current behavioural goals, such as manual reaches and saccadic eye movements, to move to the location of the stimulus (Rizzolatti et al., 1994). Therefore, it was argued that the theory could be easily used to explain the facilitation of response code in the Simon effect. However, as mentioned above, the object-size effect cannot operate purely in such location-based coordinates. Furthermore, in the case of the object-orientation effect, it may be assumed that the object must be processed at the semantic level in order that attention is shifted to the handle component of the object so that this grasp point can generate the response code. That is, the object's function has to be recognized in the semantic route from vision to action so that the grasp point can be located within the goal object.

As already mentioned, Handy et al. (2003) have suggested the role of visual attention in the transformation of visual representations into object-specific motor programs. Their finding showed that manipulable objects, such as tools, automatically facilitate the orienting of attention to the location of the object. It follows that if the manipulable objects are capable of attracting attention, it is also possible that action-relevant parts of the object, such as a handle, are capable of attracting attention within the object. In other words, once a motor affordance of the object is recognised, this can affect attentional selection at the level of the whole object and consequently attention may be orientated towards the behaviourally most relevant part of the object. In fact, Anderson, Yamagishi and Karavia (2002) reported behavioural evidence favouring the attention shift account of the object-orientation effect. They suggested that an attention-shift to the most task-relevant part of the object is responsible for the automatic generation of response codes in the object-orientation effect. In their study, participants were presented with stimuli of 2D white-on-grey images of objects and non-objects. The object stimuli consisted of clockwise- or anticlockwise-orientated scissors, an analogue clock, and a wine glass. The non-object stimuli were symmetrical or asymmetrical circular luminance patches with a small patch either side of it. Participants were required to judge the orientation of the object responding with their left or right hand. The clock and non-object were predicted not to afford actions whereas both the scissors and wine glass were. That is, because according to the micro-affordance account only scissors and wine class include information about possible left-right hand actions. However, all object types were observed to produce the object-orientation effect. It was suggested that orientation compatibility effects arose whenever a response spatially corresponded with the most visually salient area of a stimulus. The essence of their argument was that left-right hand responses were effected by the most salient or functionally relevant object feature (e.g. the handle of the scissors or the patch of the non-object) that were used to judge object orientation.

If it is expected that both micro-affordance effects, the object-orientation effect and the object-size effect, are actually based on similar mechanisms, it might be expected that an attention shift does not play a role in the object-orientation effect. That is, because the object-size effect was assumed to operate necessarily at the object-based level. Therefore, an alternative account of the object-orientation effect, which corresponds with the premotor account of the visuomotor priming effect, may explain the object-orientation effect. This account proposes that visual information about global object properties (e.g. orientation and size) generate the right-left or precision-power response code, which in turn causes the effect. According to this view, the participant does not need to process the viewed object at any semantic level in order to locate the functional handle. Rather the attentional selection processes within the visual route from stimulus to action may be sufficient to generate the left-right response code (at the object-based level).

3.7 Objectives

The empirical work of the thesis focuses on aspects of attention in object affordance effects. The first aspect of attention that is explored in the present thesis focuses on the roles of endogenous and exogenous attention in micro-affordance effects. Focused attention, which is normally inseparable from endogenous attention, has an important role in perceptual processes (i.e., feature integration). However, the importance of focused and/or endogenous attention in visually guided movements has not been studied to the same extent. Additionally, it is not known whether a visual object can facilitate actions exogenously. These aspects of attention, which constitute a main theme of the present thesis, will be studied primarily by manipulating the degree to which exogenous and endogenous attentional resources are allocated to the object. The second main aspect of attention that will be explored is associated with location-based and object-based mechanisms. It has been argued, for example, that the object-orientation effect may be the result of implicitly or explicitly orientated attention shifts to the direction of the most salient or functionally relevant part of the object (Anderson et al., 2002). This account was assumed to suggest the importance of semantic object attributes in micro-affordance effects. Consequently, this account was assumed to emphasize the role of semantic route operations in these effects. The alternative account of the object-orientation effect suggests that object-based orienting of attention to the goal object prepares simultaneously the corresponding actions. This action preparation is predominantly linked to the direct visual route processes. We aim to test experimentally which argument may be correct for explaining the micro-affordance effects. This aspect of attention will be examined by observing attentional movements during the prime object presentation. Chapter Four in particular will focus on examining whether object-orientation effect operates at the object-based level.

In addition to focusing on attentional aspects, the thesis also aims to investigate whether object affordance might be lateralized. The influence of object affordances on systems that are controlling different hands is examined particularly because processes that are related to the construction of object affordances appear to be lateralized (e.g. Handy et al., 2003; Grezes et al., 2003). In addition, the time course of object affordances will be examined in relation to different hands. These time courses are assumed to have some important implications for understanding the way a visual object is represented for controlling effectors, and the way attention operates in constructing this representation. Time courses were assumed to show, for example, whether allocation of endogenous attention to the object is required for updating the motor representation. Chapter 5 will particularly focus on examining these aspects of lateralization in object affordances. Furthermore, Experiments 1-6 employ the object-orientation effect in exploring these aspects of object affordances while Experiments 7-9 focus on investigating the same ideas in relation to the object-size effect.

CHAPTER 4: EXPERIMENTS 1-6

4.1 Experiment 1

One way to assess the role of endogenous attention in the generation of object affordance effects is to test whether they could be observed even when the prime object (the object that is supposed to afford responses) is task-irrelevant and therefore participants are not required to allocate their attention endogenously to the object. Tucker and Ellis (1998) demonstrated that object orientation facilitates corresponding right-left hand responses even when orientation is a task-irrelevant stimulus dimension, as already stated. This study is of central importance in Experiment 1. Importantly for the present purposes, Tucker and Ellis (1998) asked participants to respond with their right or left hand to the object category. Therefore, participants were required to allocate their attention endogenously to the object. Experiment 1 tests whether similar effect could be observed even when the object does not need to be categorized, and consequently participants are not required to allocate their attention endogenously to the object. Tucker and Ellis (2001) also showed that the object-size effect appears to increase with time whilst the task-relevant object remains in view, and diminishes rapidly after the object is removed from view. However, the time course may be different when the object is not task-relevant because it would not be efficient to update the motor representation of the task-irrelevant object. In fact, updating of a motor representation of the object that is not relevant to the ongoing task would interfere with actions that are associated with the task when the participant is attempting to optimize performance on the task. Importantly, the paradigm used in Experiment 1 allows observation of the time course of any motor representation that is activated by the task-irrelevant object. The time course of response activation is measured by varying the onset time (300 ms and 1100 ms) between the prime object and target. Finally, if the object-orientation effect were to be found with the task-irrelevant prime object, the paradigm would provide an experimental basis for further manipulation (i.e., engaging attentional resources to the competing item during the prime presentation) and observation (i.e., observing the orienting of attention during the prime presentation) of attention during the prime presentation. Therefore, Experiment 1 attempts to establish the framework for the studying attentional aspects of object affordances.

As mentioned in Chapter One, abrupt onset of peripheral stimuli normally captures resources of exogenous attention automatically even when the stimulus is irrelevant to the task. Increased saliency and novelty of the stimulus increases the attentional capture. Furthermore, attentional capture is increased when the stimulus includes action-relevant attributes, which makes the object manipulable (e.g. tools) (Handy et al., 2003). Therefore, in Experiment 1, the likelihood of attentional capture is increased by using 20 different kinds of manipulable objects as prime stimuli. In addition, objects are presented in full colour on a white background to increase their saliency. Furthermore, it was mentioned in Chapter One that when a stimulus is displayed at the location to which attention is focused, perceptual processing of the stimulus is enhanced even in the absence of endogenous allocation of attention to this stimulus. Similarly, we predict that when object is displayed so that the geometrical centre of the object is positioned on the foveal region of the visual field, processing of motoric aspects of the object representation is enhanced. Therefore, the geometrical centre of the prime object is displayed at the same location as the target in Experiment 1. Taken together, it is predicted that the centrally presented manipulable prime object is capable of capturing resources of a participant's exogenous attention to the degree, which is sufficient for generation of the object affordance effect. Furthermore, the time course of this effect is assumed to be short because it would not be efficient to update the motor representation of the task-irrelevant object.

4.1.1 Method

Participants

Twenty-two participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naive as to the purpose of the experiment. All participants but one were right handed according to self report.

Apparatus and Stimuli

The display and timing was controlled by a RM-Accelerator-Intel: Pentium 2 processor computer, interfaced to a Mitsubishi Diamond Pro900u 19inch colour monitor. The height of the monitor was adjusted so that each participant was looking directly at the centre of the display. The prime object stimuli comprised 20 graspable household objects. Ten were common kitchen objects and ten were common garage objects (see Appendix 2 for a list of objects used). All objects were photographed twice in two horizontal orientations that were compatible with a right-hand and left-hand grasp. Therefore, 20 * 2 = 40 slides made up the object set. All objects were presented in their original colour against a white background with resolution of 1024x768 pixels and their length was between 20.4° and

22.6° of visual angle. All objects were centralised on a monitor and appeared at 22.9 degrees from vertical. The target stimuli consisted of a centrally positioned black fixation point (0.8° of visual angle) with a grey cross inside. The change of the grey cross into a horizontal or vertical line indicated to participants that they had to response with their left or right hand depending on which mapping they were allocated. The target appeared at the prime object centre.

Design and procedure

The participant was seated at a table in a darkened room with his/her eyes 55 cm from the centre of a monitor and with the index finger of each hand resting on two response buttons (30 cm apart and 15 cm in front of the monitor) of a keyboard. Participants responded by pressing the left (z) or right (2) key of a standard computer keyboard with the corresponding index finger. The experiment consisted of 480 trials in which each of the 20 objects appeared twenty-four times in orientations compatible with right or left hand grasps. Each trial was initiated with the presentation of the fixation point. The participant was asked to focus upon this point as the target was to be presented in the same location. After 1000 ms the fixation point was replaced by the prime object. Object order was randomised for each participant. The duration of the object prime object presentation was randomised between SOA 1 (300 ms) and SOA 2 (1100 ms) so that there were 240 trials in both conditions. After this varying onset time of the prime the fixation point re-appeared over the prime object for 50 ms. This was to capture participants attention to the position where the target was going to appear. After that, the cross inside the fixation point changed into vertical or horizontal line for 180 ms (orientation discrimination task) and then changed back to the cross. This change of the target line back to the cross was to maximise the probability that that participants were fixating to the target area throughout the trial. Participants were instructed to make push-button responses with the right or left hand depending on whether the target was a horizontal or vertical line. Each participant was randomly assigned to a mapping rule of target (vertical or horizontal line) to hand of response (left or right). Both the object and the fixation point remained in view until the participant responded, or until 3000 ms had passed and the trial was timed-out. Error responses were immediately followed by a short beep-tone from the computer. The experiment began with a (around 10) practice trials to familiarise the participant with the required hand response and to ensure that each participant was able to discriminate the briefly presented target.

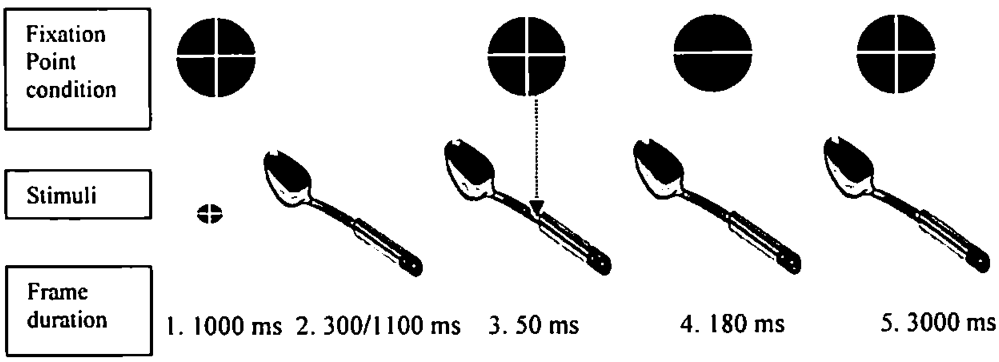


Figure 4.1 The illustration of design (Experiment 1). The fixation point is disproportionately large in the illustration for clarity. The point was displayed over the central area of the object. The location of the point is illustrated with the dotted arrow.

4.1.2 Results

Response times

Reaction times (RTs) were cropped for each participants's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. One participant was removed from the analysis because his/her error rate exceeded 2 SD from the error rate means. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object orientation (leftwards or rightwards), duration of the prime (300 ms or 1100 ms), hand of response (right or left), and the between participants factor of mapping rule (M1: Left-hand/horizontal line, Right-hand/vertical line and M2: Left-hand/vertical line, Right-hand/horizontal line).

The analysis revealed significant main effects of hand of response and SOA. The data showed that right hand responses (M=474.87 ms) were performed faster than the left hand responses (M=497.09 ms), F(1,19)=9.29, *p*=.007, *MSE*=20686.39. Additionally, it was found that responses were made faster in SOA 300 (M=482.45 ms) than in SOA 1100 (M=489.51 ms), F(1,19)=5.90, *p*=.025, *MSE*=2089.16. Importantly, the data revealed a significant object-orientation effect (interaction between the object orientation and the hand of response). Participants made faster right-hand responses when the object orientation was also to the right (M= 473.98 ms) rather than to the left (M= 475.76 ms). Similarly, participants made faster left-hand responses when the object was orientated to left (M= 493.39 ms) rather than to right (M= 500.78 ms), *F*(1,19)=5.41, *p*=.031, *MSE*=881.93. Although the analysis did not reveal a significant three-way interaction between object orientation, SOA, and the hand of response [*F*(1,19)=1.53, *p*=.231, *MSE*=276.32] we carried out separate analysis of the simple interaction effects at each SOA because the difference, if any, between affordance effects at different SOAs was one of the central focuses of the current experiment.

Analysis (a repeated measures ANOVA) for RTs in SOA 300 revealed a significant main effect of hand of response. Right-hand responses were faster (M = 471.19 ms) than left-hand responses (M = 493.70 ms), F(1,19) = 9.75, *p* =.006, *MSE*=10620.29. The two-way interaction between hand of response and object orientation was also significant. Participants made faster right-hand responses when the object orientation was also to the right (M=468.51 ms) rather than to the left (M=473.87 ms). Similarly, participants made faster left-hand responses when the object was orientated to the left (M=489.23 ms) rather than to the right (M=498.18 ms), F(1,19) = 7.24, *p*=.014, *MSE*=1072.77. This interaction is displayed in Figure 4.2. A similar analysis for RTs in SOA 1100 revealed a significant main effect of hand of response. Right-hand responses were made faster (M=478.55 ms) than left-hand responses (M=500.47 ms), F(1,19)=7.22, *p*=.015, *MSE*=10069.77. However, interestingly the object-orientation effect (an orientation by hand of response interaction) was not observed when the prime object was displayed for 1100 ms (see Figure 4.2), F(1,19)=.437, p=.516, MSE=85.47.

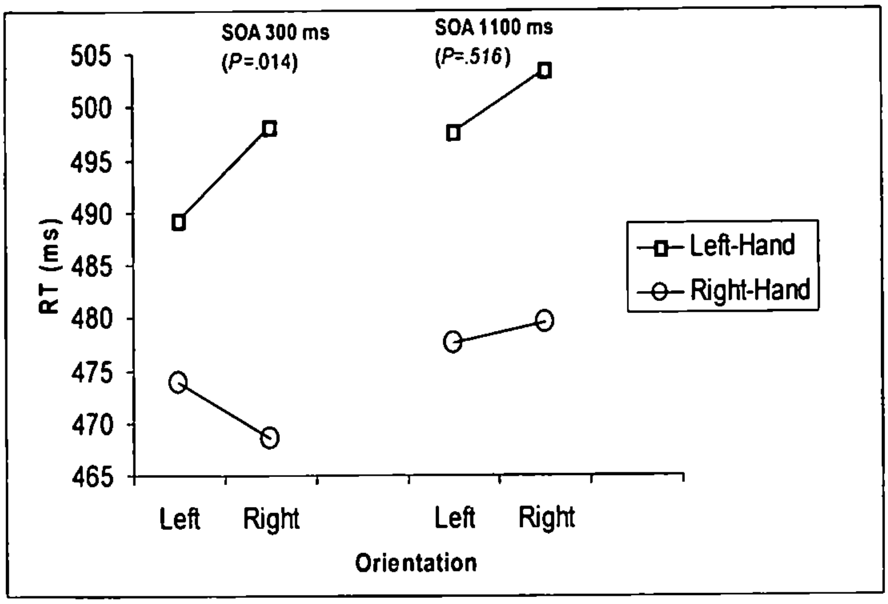


Figure 4.2 Mean RTs by hand of response and object orientation (in SOA 300 ms and 1100 ms) for Experiment 1.

A separate analysis (a repeated measures ANOVA) was conducted for objects whose handle lies along the principal axis of the object (e.g. hammer and knife). We had two reasons to carry out this analysis. Firstly, to find out whether objects whose handle lies along the principal axis of the object could facilitate orientation compatible responses. Secondly, to confirm statistically that these same objects could be used in Experiments 3 and 6 that further investigate the role of attention in object affordances. Therefore, objects such as mugs, jugs, and pans were excluded from the analysis. Again, the two-way interaction between responding hand and the object orientation was significant in SOA 300, F(1,19)=8.31, p=.010, MSE=3965.44. Participants made faster right-hand responses when the object orientation was also to the right (M=463.71 ms) rather than to the left (M=478.08 ms). Similarly, participants made faster left-hand responses when the object orientation was also to the to left (M=487.29 ms) rather than to right (M=496.71 ms). However, the effect was absent again in SOA 1100, F(1,19)=.12, p=.738, MSE=49.92. This result suggests that a larger object-orientation effect may be observed when objects whose handle does not lie along the main axis of the object are excluded from the analysis. These interactions are displayed in Figure 4.3.

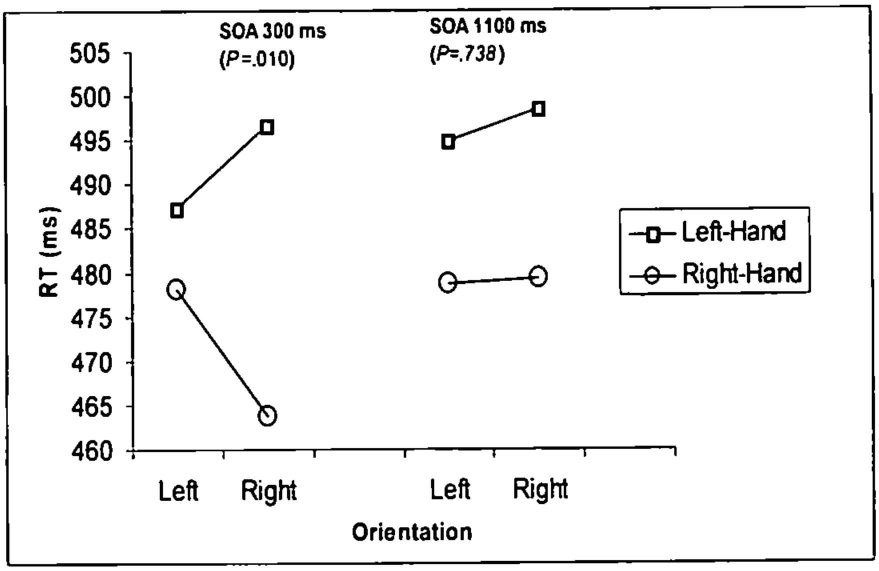


Figure 4.3 Mean RTs by hand of response and object orientation (in SOA 300 and 1100 ms) for Experiment 1. Those objects whose handle does not lie along the main axis of the object are excluded from the analysis.

Errors

The mean error rate was 5.05%. Analysis of percentage error rates did not reveal significant main effects or interactions when all SOA conditions were included in the analysis or when the data were analysed separately for RTs in the two SOAs. The two-way interaction between object orientation and hand of response [$F(1,19)=.003$, $p=.959$, $MSE=.018$], and the three-way interaction beween object-orientation, SOA and hand of response [$F(1,19)=1.27$, $p=.273$, $MSE=3.074$] were both insignificant. Error rates in corresponding and non-corresponding conditions are displayed in Table 4.1.

Means Table for Errors

Orientation	Response	%	SE
	SOA 1		
Left	Left	4.62	.84
Left	Right	5.52	.77
Right	Left	4.87	.75
Right	Right	5.27	.78
	SOA 2		
Left	Left	5.47	.91
Left	Right	4.58	.91
Right	Left	5.17	1.09
Right	Right	4.86	.67

Table 4.1 Mean error rates for Experiment 1 as a function of object orientation and hand of response.

4.1.3 Discussion

The results of Experiment 1 show that the perceptual elicitation of actions takes place even for visual inputs that are not the intended target of subsequent overt behaviour. When the prime object was displayed for 300 ms, the orientation compatible responses were facilitated even when the object orientation and the object itself were completely irrelevant to the task. Interestingly, the object-orientation effect, in SOA 300 ms, appeared larger when objects, whose handle does not lie along the principal axis of the object, were excluded from the analysis. This suggest that the orientation of the axis of elongation may play a more important role in the object-orientation effect than the location of the functional component (i.e., handle) of the object.

The object-orientation effect was not observed in the longer SOA (1100 ms). This suggests that the effect diminishes rapidly after the prime onset. This result is consistent with the prediction that when the object is irrelevant to responses, the time course would be opposite to that of the pattern found by Tucker and Ellis (2001) (i.e., the effect increases whilst the object remains in the view). The prediction was based on the view that it would not be efficient to update the motor representation of the task-irrelevant object. It is tempting to propose that the processes that are updating the motor representation are tightly linked to the allocation of attention to the object. This view assumes that when the object is task-relevant, attention is allocated endogenously to the object and consequently the motor representation is updated until the execution of the response. In contrast, when the object is task-irrelevant, the abrupt onset of the prime object may capture attentional resources sufficiently to trigger the object-related action plan. However, after the initial attentional capture, attention is not kept endogenously on the object and consequently the action plan is not kept active.

What Experiment 1 suggests is that the abrupt onset of the stimuli, which includes affordance information and is presented in the focal visual field, captures resources of attention to a degree, which is sufficient for the observation of the object-orientation effect. This suggests that the object affordance effects can be generated even when the allocation of endogenous attention to the prime is minimal or absent. However, if this object is not behaviourally relevant, the action plan that is triggered by the object is not required to be kept active. Therefore, the results of Experiment 1 show that the object orientation is capable of facilitating the orientation compatible responses even when the allocation of endogenous attention to the prime is minimal or absent. However, most importantly, the orientation effect in SOA 300 ms allows us to use the same paradigm and set of stimuli in Experiment 2 to observe the effect of the manipulation of focused attention by a central fixation point to the generation of affordance. It is predicted that if the fixation point remains over the prime, the resources of focused attention are allocated decreasingly to the prime. This in turn is expected to suppress the influence of the prime orientation to responses.

4.2 Experiment 2

The results of Experiment 1 suggested that the orientation effect could be observed even when the allocation of endogenous attention to the prime is minimal or absent. However, it still remains unclear whether resources of focused attention are needed in the generation of the object affordance effects or whether these effects could be observed for a peripheral object. Handy et al. (2003) demonstrated that peripherally presented graspable objects grab attention even when they are to be ignored, as mentioned earlier. Therefore, it may be assumed that an objects potential for action (affordance) could be recognized at the level of exogenous attention, and consequently after this recognition, attentional resources are drawn to the location of the graspable object. However, we also asked whether actions could be afforded outside of focused attention or whether resources of focused attention are required to this affordance generation. In fact, Symes et al. (in press) suggested that some level of focused attention has to be allocated to the object so that it could afford responses. In general, it was examined whether the behaviourally irrelevant prime objects that were used in Experiment 1 could similarly prime left or right hand responses even when attention was focused on a different item. In particular, it is predicted that if the orientation effect found in Experiment 1 is related to the allocation of focused attention to the prime object, it should be suppressed when attentional resources are allocated to a behaviourally more relevant item when the prime object is presented. In other words, the benefit of the prime object presentation on motor preparation is predicted to be minimal or absent when the task does not require any disengagement from the fixation target and the fixation is presented during the prime object presentation. In the present paradigm, the fixation point offers all relevant information for carrying out the task. In this case, it could be expected that the participant does not have either external (the offset of fixation point) or internal (the task requirement) need to disengage from the fixation object. In fact, because the response-cueing target is presented at the fixation point, optimal performance would be facilitated by fixating the target location throughout the trial. Thus, the experiment examined whether the correspondence effect found in SOA 1 (300 ms) in Experiment 1 could be replicated when allocation of the resources of focused attention to the prime object is suppressed by presenting a task-relevant fixation point simultaneously with the prime object. If the object-orientation effect is still found when participants are focusing their attention onto the fixation point during the prime presentation, it may be assumed that the allocation of resources of focused attention to the prime may not be necessary for generating the object affordance effects. Similarly, if the effect is observed even when focused attention is engaged on the fixation point during the prime presentation, it may be suggested that a shift of attention to the handle component cannot be responsible for the occurrence of the effect.

4.2.1 Method

Participants

Twenty-two participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naive as to the purpose of the experiment. All participants were right handed according to self report.

Apparatus and Stimuli

Apparatus and stimuli were the same as those used in Experiment 1.

Procedure

The design and procedure were identical to that of Experiment 1 except that only one SOA (300 ms) was used and the fixation point remained over the prime throughout its presentation.

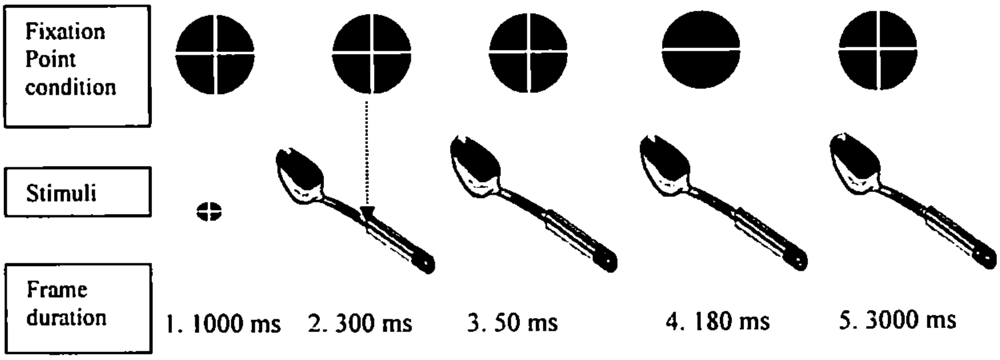


Figure 4.4 The illustration of design (Experiment 2). The fixation point is disproportionately large in the illustration for clarity. The point was displayed over the central area of the object. The location of the point is illustrated with the dotted arrow.

4.2.2 Results

Response times

Reaction times (RTs) were cropped for each participants's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object orientation (leftwards or rightwards), hand of response (right or left), and the between participants factor of mapping rule (M1: Left-hand/horizontal line, Right-hand/vertical line and M2: Left-hand/vertical line, Right-hand/horizontal line). Analysis did not reveal any significant main effects or interactions. The object-orientation effect was completely absent, $F(1,20) = .038$, $p = .848$, $MSE=3.78$. The same pattern of results was observed when those objects whose handle does not lie along the principal axis of the object were excluded from the analysis, $F(1,20)=.36$, $p=.851$, $MSE=11.44$. Because the main focus of the current research was to examine whether the object-orientation effect would be eliminated by the fixation point remaining over the prime, an omnibus ANOVA was carried out to analyze the data of both Experiments 1 (SOA 300) and 2 in a single ANOVA. This analysis revealed a near significant three-way interaction between object orientation, responding hand and experiment indicating that the difference in the orientation effect across the two experiments approaches significance, F(1,39)=3.95, *p*=.054, *MSe*=487.63. The effect of the object orientation (of all prime objects and of objects whose handle lies along the principal axis) on responses is displayed in Figure 4.5.

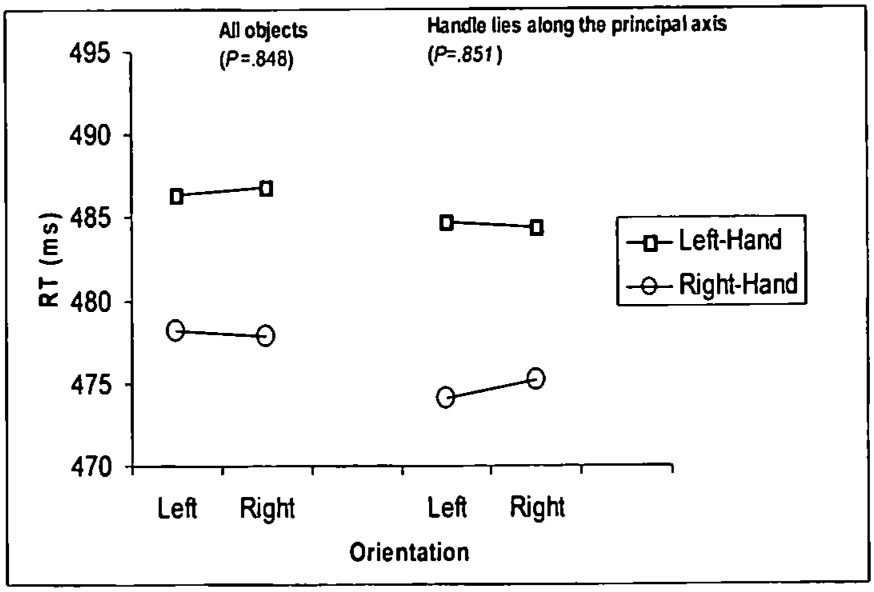


Figure 4.5 Mean RTs for Experiment 2 as a function of object orientation and hand of response (for all objects and for objects whose handle lies along the principal axis).

Errors

The mean error rate was 6.53%. Analysis of percentage error rates revealed a significant main effect of hand of responses. Participants made more errors with their right hand (M = 7.71%) than with their left hand (M = 5.36%), F(1,20) = 20.60, *p* <.001, *MSE*=121.338. However, an analysis did not reveal a significant interaction between object orientation and hand of response, F(1,20)=.14, *p*=.715, *MSE*=505. The percentage of error rates in corresponding and non-corresponding conditions are displayed in Table 4.2.

Means Table for Errors

Orientation	Response	%	SE
Left	Left	5.30	.72
Left	Right	7.50	.85
Right	Left	5.42	.74
Right	Right	7.92	.89

Table 4.2 Mean error rates for Experiment 2 as a function of object orientation and hand of response.

4.2.3 Discussion

The task-irrelevant prime object was expected to capture resources of exogenous attention even when endogenous attention is allocated to the task-relevant fixation point during the prime presentation for reasons that were discussed in Chapter One. However, the results of Experiment 2 suggest the importance of focused attention in the object affordance effects. Experiment 2 demonstrated that the object orientation does not facilitate the orientation compatible responses to the degree, which would be sufficient for observing the orientation effect, when resources of focused attention are allocated to the other object that is more relevant for the current behaviour. This view assumes that the resources of peripheral attention are not sufficient for the effects to be observed and some level of focused attention needs to be allocated to the prime object for the effect to be observed. Alternatively, it could be suggested that the effect was observed in Experiment 1 because participants allocated some minimal level of endogenous attention to the prime, even though this was not required (see Chapter 1 for clarification of the distinction between endogenous, exogenous, and focused attention). According to the same view, the effect was not observed in Experiment 2 because the same endogenous resources of attention were reserved for processing the visual and motor attributes of the fixation point. This view would suggest that the affordance effect cannot be constructed at the exogenous level of attention, and that resources of endogenous attention are needed for the construction of the effect. However, it is important to notice that participants were not required to allocate their endogenous attention to the prime object in Experiment 1. In fact, supposedly the maximal performance in the task was achieved by ignoring the prime object. Therefore, it is not perhaps fully correct to argue that Experiment 1 revealed the orientation effect because participant's endogenous attention was disengaged from the fixation point by fixation point offset, which in turn allowed them to allocate attention endogenously or purposely to the prime object. Instead, it would tempting to suggest that offset of the fixation point reinforced participants to deploy the focused-exogenous attention to the prime object to the degree which was adequate for the effect to be observed. However, this deployment of focused attention was not necessarily intentional but rather operated in an implicit and automatic manner.

It may also be supposed that a goal object needs to be selected attentionally in order that the object could afford actions for reasons that were discussed in Chapter One. For example, the mechanisms of selective attention have to play an important role in the object affordance effects, such as the object-orientation effect, because it may be assumed that only a single object in the visual field can afford responses at one time. For instance, when one has to reach-to-grasp a mug from a table containing several other mugs that all evoke a similar action, mechanisms of selective attention have to exhibit the effects of the target mug, and perhaps inhibit the effects of non-target mugs. As already mentioned, the biased competition model of selective attention (Desimone & Duncan, 1995), which is a focus of the current study, attempts to explain the attentional mechanisms that may be involved in such selection. Nevertheless, it may be expected that only one object can guide actions at one time. It follows that once a goal object (the fixation point) has been selected for goal-directed actions, any competing object (the prime object) cannot simlutaneously afford actions because it has not been selected attentionally. Therefore, it may be concluded that resources of endogenous attention are not necessary for the effect to be observed but rather resources of focused (exogenous or endogenous) attention are necessary for attentional selection and consequently for object-related motor priming. Therefore, it may be assummed that resources of endogenous attention need to be disengaged from the competing item in order that action-relevant properties of the object, which is viewed focally, could afford actions in an automatic manner. According to this model exogenous and endogenous control of attention/actions are competing for the same visuomotor resources in visually guided actions. Perhaps an endogenously attended object has priority over the peripheral object in reserving resources for the visual guidance of actions.

However, most importantly, the results do not show whether the absence of the object-orientation effect, in Experiment 2, could be attributed to the elimination of an attention shift to the handle or the suppression of the object-based priming of the responses. Thus, two different explanations for the elimination of the effect could be identified, the object-based account and the attention shift account. The object-based account is consistent with the premotor account of the visuomotor priming effect reported by Craighero et al. (1999). Craighero et al. (1999) suggested that the allocation of attention to a graspable object may facilitate the hand shape that is most appropriate to the action-relevant characteristics of the object, such as size, shape, and orientation. In turn, this suggests that the object orientation can facilitate right-left hand responses even in the absence of attention shifts. The biased competition model of selective attention (Desimone & Duncan, 1995), which was introduced in Chapter One, may offer a sound explanation why attention could not orient sufficiently to the prime when the task-relevant fixation point remains over the prime in Experiment 2. Under this model, when the fixation point is superimposed over the prime object, and this point is the only action-relevant item in the visual field, the attentional processes that are allocated to the prime should be largely suppressed. Furthermore, this suppression was shown to influence all visuomotor processes, including processes that are associated with the object-directed action control. Therefore, similar suppression mechanisms may explain the absence of the object-orientation effect in Experiment 2.

The alternative explanation for the elimination of the object-orientation effect, in Experiment 2, is that the effect was not absent due to the suppression of the (object-based) attentional allocation to the prime, but rather due to the elimination of an attention shift towards the handle component of the object. For example, Anderson et al. (2002) supported the attention shift account of the object-orientation effect. The orienting of attention that may be responsible for the effect is traditionally assumed to consist of three components, as already mentioned. These components are the engagement of visual attention at a particular stimulus/locus, the disengagement of visual attention from a stimulus/locus, and the shifting of visual attention from one stimulus/locus to another (e.g. Posner & Petersen, 1990). According to this three-stage model, when an individual is attending to an object of interest, attention is assumed to be engaged at the location of the object and simultaneously the attention shift is prevented. Furthermore, the premotor theory of attention suggested that all effectors that are involved in achieving current behavioural goals, such as manual reaches and saccadic eye movement, are automatically prepared by orienting of attention to the location of the stimulus (Tipper, Howard & Paul, 2000). It follows that as long as attention is engaged to a location, the visually guided movements cannot be prepared by orienting of attention to the stimulus location. Therefore, it may be assumed that if the object-orientation effect would be caused by an attentional shift to a handle component, the object-orientation effect should be eliminated when a participant does not have implicit or explicit reason to disengage from the fixation point. The present task did not require any disengagement from the fixation target because participants did not have external (gap) or internal (task requirement) reason to disengage from the fixation point. Additionally, because when the target that discriminates response is presented at fixation, like is the case in Experiment 1, it is best for optimal performance to fixate on the target throughout the trial. This fact also should increase the degree to which participants allocate their endogenous attention to the fixation point. However, further research is required to find out which explanation could be used to explain the elimination of the affordance effect in Experiment 2. In fact, Experiments 5, 6 and 8 further investigate which of the explanations is the correct. However, before this further investigation, Experiments 3 and 4 will attempt to replicate the first two experiments with minor changes in the task and stimuli.

4.3 Experiment 3

The influence of the fixation point in eliminating the compatibility effect, and the absence of the effect in longer SOA were assumed to explain some particularly important aspects in the underlying mechanisms of object affordance effects. Therefore, Experiments 1 and 2 were replicated with some minor changes. In comparison to the design of Experiment 1, which employed a target orientation discrimination task, Experiment 3 employed a target colour discrimination task to change the perceptual and/or cognitive load (see Lavie, 1995 for review of perceptual load) during the prime presentation. The main reason for this change was that the orientation discrimination task might be considered a dubious task when observing the influence of orientation of task-irrelevant stimulus on responses (i.e, explore the effect of prime *orientation* to responses while the target *orientation* is discriminated). That is, to minimize spatial overlap between the prime object affordance and the target. Secondly, Experiment 1 showed that an action related object property could facilitate orientation compatible responses when the onset time between the prime and target is 300 ms. However, the effect was not observed when the target appeared 1100 ms after the prime onset. Experiment 3 attempts to further investigate the time course of the object-related motor activation. Therefore, it aims to replicate the object-orientation effect with an SOA of 300 ms and additionally introduce an SOA of 600 ms. It is predicted that the effect would be absent in the SOA of 600 ms because it would not be efficient to update the motor representation of the task-irrelevant object. Finally, Experiment 3 employs three object categories. Objects in each category have characteristics that can generate orientation-related response code differentially. Category 1 consists of the same familiar objects as those used in Experiments 1 and 2. However, only those objects whose handles extend along their principal axis of elongation (e.g. knife) were used from the previous experiments. These objects can afford responses in two different ways. Firstly, the location of handle can afford responses of the orientation compatible hand. As already mentioned, this kind of affordance is supposedly extracted from the semantic route, which has the capacity to process functional information about an object. Secondly, in category 1, the object's principal axis of elongation can afford responses. This kind of affordance is supposedly extrtacted from the visual route, which has the capacity to process only purely visual information about an object. Category 2 consists of cylinder-like objects whose axis of elongation could afford responses. These objects do not have any higher-level associations. Finally, category 3 consists of familiar objects with handles that do not extend along the object's principal axis of elongation (e.g. mug). Furthermore, as already stated, the semantic route was associated with the ventral stream processes, whereas the direct visual route was associated with the dorsal stream processes. In addition, the ventral stream was assumed to be involved in longer-term object representations while the dorsal stream was assumed to be involved in real-time action control in which the motor representation of the goal object needs to be updated continuously. Therefore, it is possible that different time courses of object-related motor activation would be observed depending on whether the affordance information is imported from the semantic or visual route. Thus, the secondary aim of the experiment is to study whether all objects with differential characteristics indicating the object orientation could facilitate responses of the hand most suited to grasp the object, even when the object itself is task-irrelevant, and if they do, whether these different kinds of objects are associated with differential time courses.

4.3.1 Method

Participants

Twenty-seven participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naive as to the purpose of the experiment. All participants but one were right handed according to self report.

Apparatus and Stimuli

Monitor, response device, and fixation point were same that those used in Experiments 1 and 2. In addition, 1/3 (category 1) of the prime object stimuli comprised the same 10 graspable household objects than those that were used in Experiments 1 and 2 (those whose handle lies along the main axis of the object). Because these objects were observed to be capable of generating the object-orientation effect (in fact, the effect was even larger when only these objects were included in the analysis) their usability as prime stimuli was confirmed. However, this time the experiment employed two more object categories, cylinders and familiar objects with handles that do not lie along the main axis of the object. The second category consisted of artificial 3D cylinders (length between 20.4° and 22.6° of visual angle) (see Figure 4.6), and the third category consisted of ten common kitchen objects (5 mugs and 5 teapots) with handles not lying along the main axis of the object (height between 13.7° and 17.1° of visual angle). Objects that belonged to categories 1 and 3 were photographed twice in two horizontal orientations that were compatible with a right-hand and left-hand grasp. All objects were presented in their original colour against a white background and their length was between 20.4° and 22.6° of visual angle. All objects in categories 1 and 2 appeared at 22.9 degrees from vertical. The cylinder category comprised 10 full colour objects that were in the same left-right orientation as the objects in the category 1. Objects had wood (see Figure 4.6: image 2) or marble textures and they were coloured a natural brown-wood colour. The objects were created using 3D graphics software. Thus, 10 (exemplars) * 3 (categories) * 2 (orientations) = 60 slides made up the object set. All objects were centralised on a monitor and appeared at 22.9 degrees from vertical and were centralised and presented with resolution of 1024x768 pixels on the monitor. Additionally, the stimuli consisted of the fixation point (0.8° of visual angle) with a grey cross inside, and the target that was a red or green dot presented inside the fixation point. The target dot was smaller (0.6° of visual angle) than the fixation point. The fixation point was situated centrally in the monitor. In addition to the central area of the monitor the configuration of the fixation point was determined by the central area of the prime object. That is, the central target appeared on the object centre.

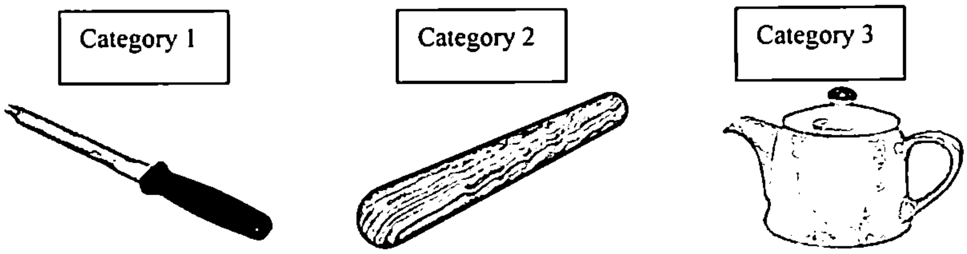


Figure 4.6. The illustration of stimuli for Experiment 3.

Procedure

The procedure was identical to that of the first and second experiments except that two different SOAs (300 ms and 600ms) determined the duration of prime object presentation, and the target was discriminated by colour (red and green). Each trial was initiated with the presentation of the fixation point on white background. The participant was asked to focus upon this point as the target was to be presented in the same location. After 2000 ms the fixation point was replaced by the prime object. The duration of the prime was either 300 ms or 600 ms with equal probability. After this randomly specified SOA period the fixation point was displayed over the prime object for 50 ms in the same location that it occupied before the prime object presentation. This was to cue the participant's attention to target location prior to presentation of the target. The fixation point changed to a target, which was a green or red dot presented inside that fixation point in random order, and after 200 ms the target changed back to the fixation point. The target was presented over the object and both the object and the fixation point remained until the participant responded as instructed. Participants were instructed to respond with their right or left hand to the target colour. Each participant was randomly assigned to a mapping rule of response (right or left) and target (red or green), [(left hand-red target/right hand-green target (M1); or left hand-green target/right hand- red target (M2)]. Objects within the three different categories were presented in randomised order in three separate category blocks. The order of category blocks was randomised and blocks were separated with a 1-minute break. During the break, the monitor displayed text to the participant that indicated the length of the break and instructions for carrying on with the experiment. Error responses were immediately followed by a short "beep"-tone from the computer. If participant did not respond within 3000 ms the next trial was initiated. The experiment began with approximately 10 practice trials to familiarise the participant with the required hand responses. The number of practise trials depended on the time it took the participant to learn the response rule. Figure 4.7 illustrates that sequence of events in a trial.

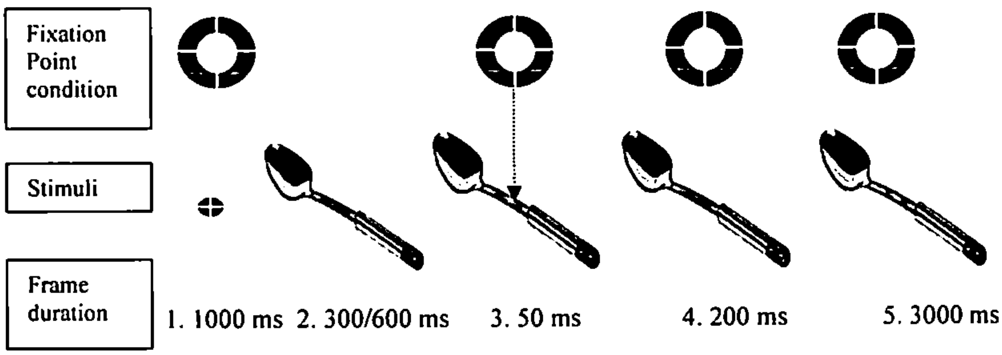


Figure 4.7 The illustration of design (Experiment 3). The fixation point is disproportionately large in the illustration for clarity. The point was displayed over the central area of the object. The location of the point is illustrated with the dotted arrow.

4.3.2 Results

Response times

Reaction times (RTs) were cropped for each participants's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object category (C1, C2 or C3), object orientation (left or right), duration of the prime presentation (300 ms or 600 ms), hand of response (right or left), and the between participants factor of mapping rule (left hand-red target/right hand-green target=M1, and left hand-green target/right hand- red target=M2). The analysis revealed a significant main effect of SOA and hand of response. Right hand responses were made faster (M=377.88 ms) than left hand responses (M=390.19 ms), $F(1,25)=22.51$, $p<.001$, $MSE=24535.04$. Additionally, it was found that responses were made faster in SOA 600 (M=376.94 ms) than in SOA 300 (M=391.13 ms), $F(1,25)=25.75$, $p<.001$, $MSE=32609.62$. In addition, the analysis revealed a significant object-orientation effect (interaction between object orientation and hand of response), $F(1,25)=28.84$, $p<.001$, $MSE=4460.35$. Participants made faster responses with the right hand when the object orientation was to the right (M=375.26 ms) rather than to the left (M=380.49 ms). Similarly, participants made faster responses with their left hand when also the object was orientated to the left (M=387.56 ms) rather than to the right (M=392.83 ms). However, importantly for the purposes of the experiment the analysis revealed also a significant three-way interaction between object orientation, SOA, and hand of response, $F(1,25)=6.14$, $p=.020$, $MSE=1279.43$. This interaction (displayed in Figure 4.8) suggests that the object-orientation effect behaves differentially between two SOA conditions. This interaction was the central focus of the experiment. To examine more closely this three-way interaction we carried out separate analysis of the simple interaction effects at each SOA.

[SOA 1 (300 ms)] Analysis (a repeated measures ANOVA) of RTs in SOA 300 revealed a significant interaction between object-orientation and responding hand. This interaction indicated the occurrence of a significant object-orientation effect. Participant made faster right-hand responses when the object orientation was to the right (M=382.58 ms) rather than to the left (M=390.01 ms). Similarly, participants made faster left-hand responses when the object orientation was to the left (M=391.62 ms) rather than to the right (M=400.32), $F(1,25)=29.65$, $p<.001$, $MSE=5258.76$. Although the analysis revealed also a significant three-way interaction between object orientation, hand of response and mapping

[F(1,25)=5.09, *p*=.033, *MSE*=902.396], the pattern of the orientation effect was positive in both mappings. Additionally, an absence of a three-way interaction between category, orientation and hand of response [F(2,50)=1.82, *p*=.173, *MSE*=346.86] suggested that there were no significant differences in the object-orientation effect between object categories. To examine more closely the absence of this three-way interaction we carried out separate analysis of the simple interaction effects at each category. A significant interaction between object orientation and hand of response was observed in each category. However, in category 3 the effect was significant only on left-hand responses. In other words, participant made faster left-hand responses when orientation was to the left (M=392.06 ms) rather than to the right (M=400.64 ms), F(1,25)=4.39, *p*=.046, *MSE*=893.49 (these differences in object-orientation effect between the responding hands could be seen in Figures 14 and 15). However, the compatibility effect was not significant on right-hand responses (in category 3), F(1,25)=.084, *p*=.774, *MSE*=26.92. The interactions for each object category in SOA 300 are displayed in Figure 4.9.

[SOA 2 (600 ms)] Secondly, analysis (a repeated measures ANOVA) of RTs only in SOA 600 revealed again a significant main effect of hand of response. Right-hand-responses were performed faster (M=369.46 ms) than left-hand responses (M=384.41 ms), *F*(1,25)=24.64, *p*<.001, *MSE*=18093.26. A significant interaction between object orientation and hand of response was not found [*F*(1,25)=2.59, *p*=.120, *MSE*=481.02], suggesting the absence of the object-orientation effect. In addition, the analysis did not reveal a significant three-way interaction between category, object orientation and hand of response [F(2,50)=1.28, p=.288, MSe=367.71], suggesting that there were no significant differences in the absence of the object-orientation effect between object categories. To examine more close the absence of this three-way interaction we carried out separate analysis of the simple interaction effects at each category. The analysis for objects in category 3 revealed a slightly significant interaction between responding hand and object orientation [F(1,25)=4.32, *p*=.048, *MSE*=1007.69]. Similarly to results observed with

objects in category 3 in SOA 300, a significant compatibility effect was observed with left-hand responses [$F(1,25)=7.41$, $p=.012$, $MSE=1845.89$] but not when responses were made with the right-hand, $F(1,25)=.018$, $p=.895$, $MSE=3.72$. In addition, the analysis for objects in category 2 revealed a significant compatibility effect with the right-hand responses [$F(1,25)=10.67$, $p=.003$, $MSE=2082.38$] but not when responses were performed with the left-hand, $F(1,25)=2.54$, $p=.123$, $MSE=754.13$. Although some influence of the object orientation on the orientation compatible responses could be observed even in SOA 600 condition, the results suggest that the overall effect starts to diminish with the increasing SOAs (these differences in object-orientation effect between the responding hands could be seen in Figures 4.8 and 4.9). The interactions between the object orientation and the responding hand for each object category in SOA 600 are displayed in Figure 4.10.

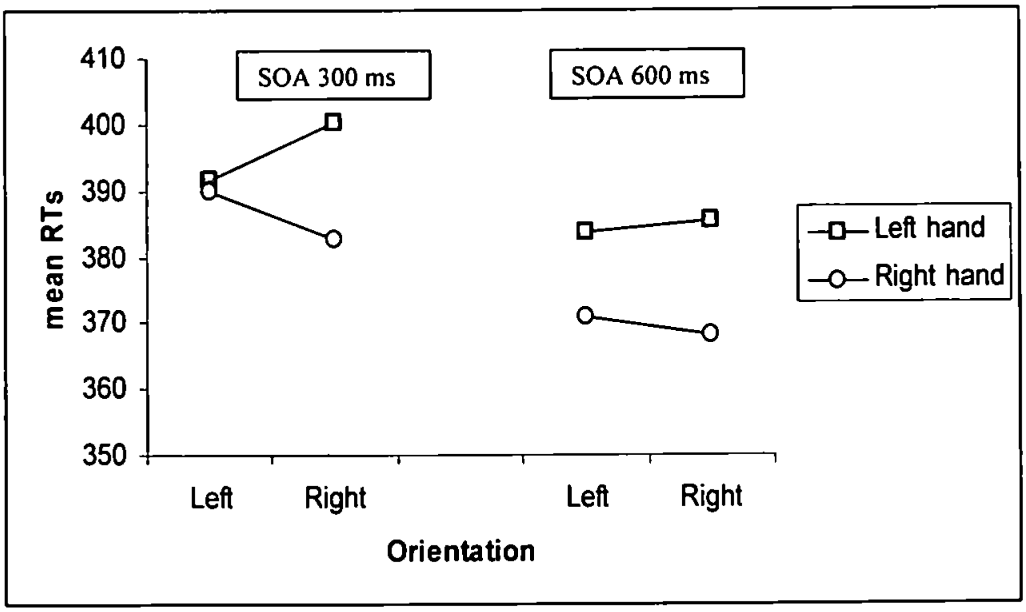


Figure 4.8 Mean RTs in SOA 1 and 2 for Experiment 3 as a function of object orientation and hand of response.

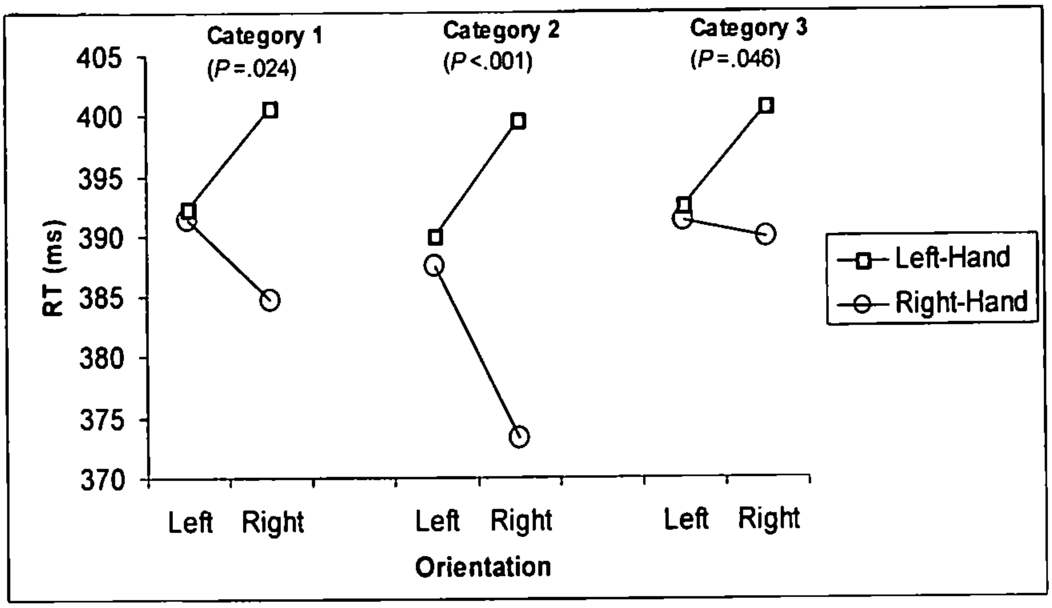


Figure 4.9 Mean RTs for Experiment 3 (SOA 300 ms) as a function of object orientation and hand of response (for categories 1, 2 and 3).

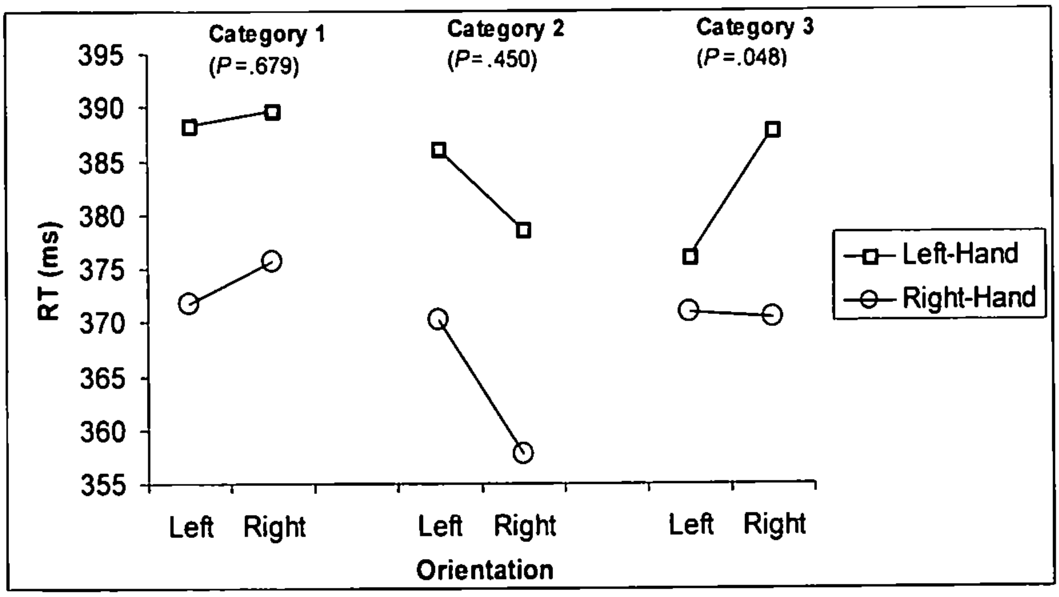


Figure 4.10 Mean RTs for Experiment 3 (SOA 600 ms) as a function of object orientation and hand of response (for categories 1, 2 and 3).

Errors

The mean error rate was 5.68%. Analysis of percentage error rates did not reveal any interesting significant main effects or interactions when both SOAs were included in the analysis or when analysed separately. However, the pattern of percentage of errors in conditions in which the object orientation and the hand of response were corresponding or non-corresponding was similar in both SOAs to that for response times. In SOA 300, participants made fewer errors when right-hand responses corresponded with the object orientation (M=4.61%) than they were not (M=5.65%). Similarly, participants made fewer errors when left-hand responses corresponded with the object orientation (M=4.66%) than when they did not (M=5.51%), $F(1,25)=2.82$, $p=.106$, $MSE=74.79$. Similarly, in SOA 600, participants made fewer errors when right-hand responses corresponded with the object orientation (M=6.30%) than when they did not (M=6.45%). Again, participants made fewer errors when left-hand responses corresponded with the object orientation (M=5.83%) than when they did not (M=6.41%), $F(1,25)=.47$, $p=.499$, $MSE=10.85$. Error rates in corresponding and non-corresponding conditions are displayed in Table 4.3.

Means Table for Errors

Orientation	Response	%	SE
	SOA 1		
Left	Left	4.66	.87
Left	Right	5.67	.79
Right	Left	5.51	1.03
Right	Right	4.61	.65
	SOA 2		
Left	Left	5.83	.75
Left	Right	6.45	.94
Right	Left	6.41	.87
Right	Right	6.29	1.07

Table 4.3 Mean error rates for Experiment 3 (in SOAs 300 ms and 600 ms).

4.3.3 Discussion

The results of Experiment 3 replicated the results of Experiment 1. Additionally, the effect size was similar to that of Experiment 1 even though the perceptual and/or cognitive load was different in the two tasks. In addition, the fact that object categories did not show significant differences in the object-orientation effect suggests that the task-irrelevant object potentiates hand responses most suited to reach-to-grasp the object, regardless of whether the principal axis of elongation or position of the handle is indicating the object orientation. In addition, the overall effect of the object orientation to responses was significantly diminished in the longer SOA (600 ms) as it was in Experiment 1. However, the effect was not diminished in category 3 (mugs and teapots). This finding is consistent with the prediction, which assumes that the time course of object-related motor activation is longer with objects whose orientation affordance needs to be recognized in the semantic route from stimulus to action.

Also the orientation effect did not diminish symmetrically between right and left hand responses at the longer SOA. The orientation compatible responses of the right-hand but not the left-hand were facilitated by the orientation of objects that belonged to category 2 (cylinders) in SOA 600 m s. This finding was not consistent with the earlier prediction which assumed that the time course of object-related motor activation is rapidly refreshed if the orientation affordance is recognized in the visual route from stimulus to action. However, this finding may reflect the superiority of the right hand control system in on-line extraction of action-relevant information about object. This possibility will be discussed in more detail in Chapter 5. In sum, the facts that the object-orientation effect behaved differentially in relation to the hand of response and to the high and low levels of object affordance, suggests that different levels of object affordance may be constructed predominantly in different hemispheres. However, again this speculation will be discussed in more detail in Chapter 5 after further investigation of this aspect.

Finally, it is important to emphasize that although also objects without handle (cylinder) are capable of facilitating orientation compatible responses, it is possible that attention shift is still responsible for the automatic generation of the response code in the object-orientation effect. That is because an orientated cylinder may also be assumed to have region, which is most suitable for grasping with the left or right hand (the region of the object that is closes to the responding hand) and to which attention may orient. Therefore, it remains possible that the response code is activated by attention shift resulting in the object-orientation effect.

4.4 Experiment 4

Experiment 4 examined whether the elimination of the compatibility effect observed in Experiment 2 could be replicated with all three categories that were used in Experiment 3. Additionally, the experiment tested whether an object could facilitate the orientation compatible responses if the objects are present for more than 300 ms (Experiment 2 employed only SOA 300 ms) to guide responses. It is possible that the action-relevant information about an object is processed implicitly for action guidance (e.g., for locating the handle), and the effect of this processing is only delayed in the condition in which the fixation point remains over the prime. A 600 ms SOA was therefore included in this fourth experiment.

4.4.1 Method

Participants

Twenty-four participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each participant prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naive as to the purpose of the experiment. All participants were right handed according to self report.

Apparatus and Stimuli

Apparatus and stimuli were same that those used in Experiment 3.

Procedure

The procedure was identical to that of Experiment 3 except that the fixation point was presented over the prime object throughout the trial in order to engage participant's attention during the presentation of the prime. In Experiment 3, the prime object was displayed for 300 ms or 600 ms without re-appearance of the fixation point and then the fixation point was presented over the object for 50 ms before the target appeared inside the fixation point. However, in Experiment 4, the object was presented together with a fixation point for 300 ms or 600 ms before the target appeared inside the fixation point.

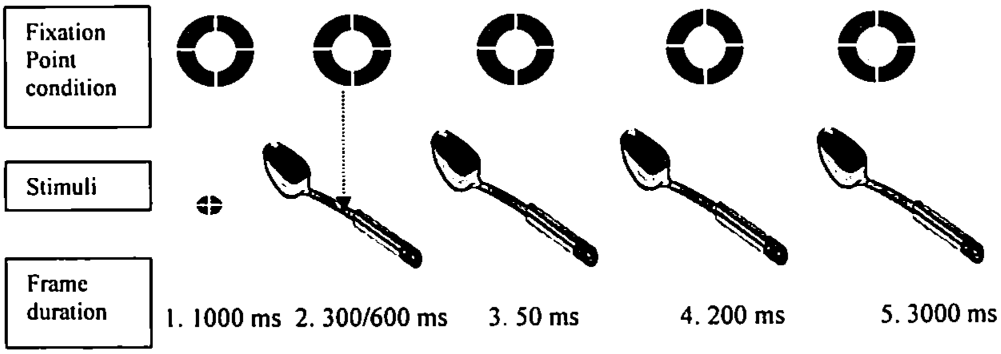


Figure 4.11 The illustration of design (Experiment 4). The fixation point is disproportionately large in the illustration for clarity. The point was displayed over the central area of the object. The location of the point is illustrated with the dotted arrow.

4.4.2 Results

Response times

Reaction times (RTs) were cropped for each participants's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object category (C1, C2 or C3), object orientation (left or right), duration of the prime presentation (300 ms or 600 ms), hand of response (right or left), and the between participants factor of mapping rule (left hand-red target/right hand-green target=M1, and left hand-green target/right hand- red target=M2). The analysis revealed a significant main effects of hand of response [$F(1,22)=18.50$, $p<.001$, $MSE=34436.71$] and SOA, $F(1,22)=45.55$, $p<.001$, $MSE=23084.84$. Right hand responses were performed faster (M=357.55 ms) than left hand responses (M=373.02 ms), and responses were faster in SOA 600 (M=358.95 ms) than in SOA 300 (M=371.61 ms). Additionally, a significant two-way interaction between object category and hand of response was found, $F(2,44)=4.13$, $p=.023$, $MSE=2578.19$. Right hand responses were performed faster in all categories [category 1- right hand (M=363.43 ms), left hand (M=373.19 ms)/ category 2- right hand (M=356.53 ms), left hand (M=369.44 ms)]. However, this reaction time difference between hands was even larger in category 3 [right hand (M=352.69 ms), left hand (M=376.42 ms)]. Most importantly, the analysis did not reveal a significant object-orientation effect, $F(1,22)=.77$, $p=.391$, $MSE=220.78$. In addition, the analysis did not reveal a significant three-way interaction between object orientation, SOA, and hand of response [$F(1,22)=.11$, $p=.744$, $MSE=26.37$], suggesting that the effect was absent in both SOAs. However, because the possible differences between the object-orientation effects in two SOAs was one of the central focuses of the experiment we carried out separate analysis of the simple interaction effects at each SOA.

The analysis (a repeated measures ANOVA) of RTs in SOA 300 revealed that the compatibility effect was absent in both SOAs [SOA 300 ms: $F(1,22)=.26$, $p=.619$, $MSE=47.274$; SOA 600: $F(1,22)=.58$, $p=.454$, $MSE=199.868$] and in every category (see Figures 4.11 and 4.12). However, as can be seen from these figures, a slight effect may be observed in SOA 300 with objects that belong to category 2 and in SOA 600 with objects that belong to category 3. However, a three-way interaction between category, orientation and hand of response was not significant in SOA 300 [$F(2,44)=1.36$, $p=.267$, $MSe=296.41$] or in SOA 600, $F(2,44)=.21$, $p=.808$, $MSe=101.12$. Therefore, it could be assumed that the absence of the object-orientation effect was similar in all categories and in both SOAs. The interactions between the object orientation and the responding hand for each object category in SOA 300 and SOA 600 are displayed in Figures 4.12 and 4.13.

Because the main focus of the current research was to examine whether the object-orientation effect would eliminated by displaying the fixation cross during the prime object display, an omnibus ANOVA was carried out to analyze the data of Experiment 3 (SOA 300) and 4 (SOA 300) in a single ANOVA. SOA 300s were included in the analysis because the compatibility effect was observed only in this SOA. This analysis revealed a significant three-way interaction between object orientation, responding hand and experiment, indicating significant differences in the compatibility effects of the two experiments, $F(1,49)= 10.67$, $p=.002$, $MSe= 2074.04$.

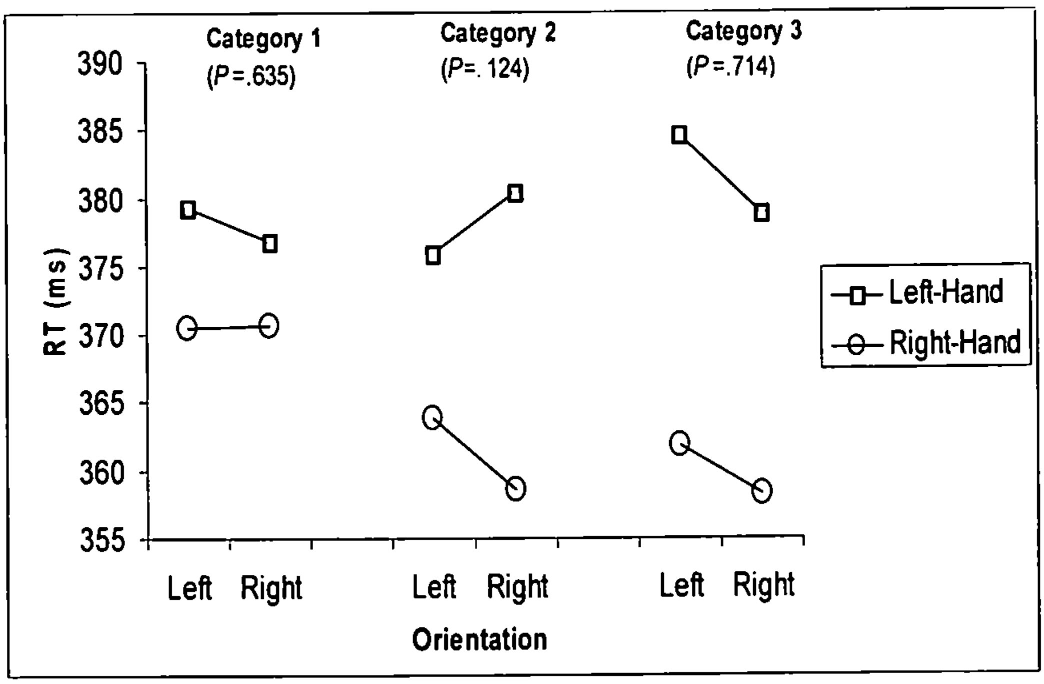


Figure 4.12 Mean RTs for Experiment 4 (SOA 300 ms) as a function of object orientation and hand of response (for categories 1, 2 and 3).

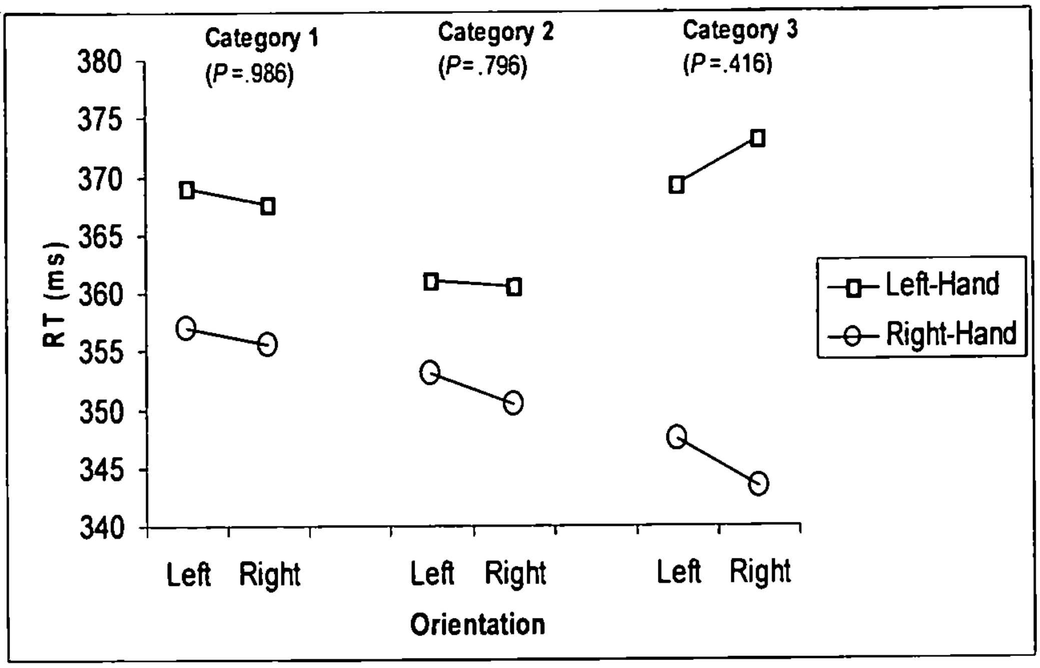


Figure 4.13 Mean RTs for Experiment 4 (SOA 600 ms) as a function of object orientation and hand of response (for categories 1, 2 and 3).

Errors

The mean error rate was 4.37%. One participant did not make any errors. Analysis of percentage error rates did not reveal any interesting significant main effects or interactions when both SOAs were included to the same analysis or when both SOAs were analysed separately. The percentage of error rates in corresponding and non-corresponding conditions are displayed in Table 4.4.

Means Table for Errors

Orientation	Response	%	SE
	SOA 1		
Left	Left	4.91	1.05
Left	Right	3.38	.59
Right	Left	4.67	.82
Right	Right	3.86	.81
	SOA 2		
Left	Left	4.92	1.06
Left	Right	4.17	.89
Right	Left	5.08	.98
Right	Right	3.95	.89

Table 4.4 Mean error rates for Experiment 4 (in SOAs 300 ms and 600 ms).

4.4.3 Discussion

Experiment 4 replicated the results of Experiment 2 in both SOAs and in all object categories. In other words, the object-size effect was eliminated again by keeping the fixation point over the prime. The prime object did not facilitate the orientation compatible responses even when the prime was given more time (600 ms) to guide responses. The result suggest again the importance of focused attention in the micro-affordance effects for reasons that were introduced in the discussion section of Experiment 2. In sum, the results of Experiment 4 show that objects cannot afford responses while focused attention is allocated simultaneously to a competing item, regardless of whether the affordance of the prime is associated with the orientation of the principal axis of elongation or positioned handle of the object. Additionally, the results of Experiment 4 suggests again that attention needs to be at a state of disengagement from the fixation point during the prime presentation for observing the object-orientation effect. However, this does not tell us whether orienting of attention to the entire graspable object is sufficient for generation of the response code or whether attention shift to the handle component of the prime is required to potentiate the orientation compatible hand responses. The purpose of Experiment 5 was to further investigate which explanation is correct.

4.5 Experiment 5

The Simon effect is typically observed in choice reaction time (CRT) tasks in which the identity of the stimulus discriminates the hand of response, as already mentioned. Interestingly, the Simon effect has been rarely reported to occur in simple reaction time (SRT) tasks[2]. In addition, when significant results have been observed in SRT tasks, they have been observed has been much smaller than those commonly observed in choice reaction time (CRT) tasks (see Hommel, 1996 for a review). Typically, in the CRT tasks, responses of hands that are corresponding with the spatial stimulus side are around 20-40 ms faster than responses of non-corresponding hands. However, when the Simon effect has been observed with SRT tasks the effect ranges between 2-6 ms. As it was stated in Chapter 1, various spatial S-R compatibility experiments demonstrate that in choice reaction time (CRT) tasks the correspondence effects are, at least partly, attributed to cognitive factors in response selection (Kornblum et al., 1990). The Simon effect is assumed to occur when the response code, which is activated automatically by location attributes of the stimulus, matches with the required response, which is determined by the stimulus identity. Because the required response is known in advance in SRT tasks, the participant does not need to select response and consequently the effect remains very small or is completely absent (Hommel, 1996). Furthermore, as mentioned earlier, it is widely agreed that the activation of this response code is caused by a directional attention shift to the stimulus location (e.g. Nicoletti & Umiltá, 1994).

Experiment 5 aims to further investigate the attention shift hypothesis in the object-orientation effect by observing whether the object-orientation effect would be decreased or

[2] *In SRT task, responses are performed to a go or no-go signal with a hand that is selected before the onset of the stimulus. Therefore, participants can prepare the response prior to the actual execution of the response and consequently response selection is not involved in the task.*

absent in an SRT task. It was reasoned that if the results did not differ from typical results of the object-orientation effect (between 10-20 ms), it would be possible to argue that it would be entirely based on response code activation and cognitive factors (in response selection) do not play an important role in the effect. This result would consequently suggest that the Simon effect and the object-orientation effect have fundamentally different origins (i.e., the object-orientation effect is not the result of an attention shift). However, if the result does not reveal any effect or the effect is smaller than typical (approximately 2 ms), this would suggest that the effect may result from similar mechanisms as the Simon effect, and it would be likely that an attention shift has a fundamental role in the object-orientation effect.

4.5.1 Method

Participants

Twenty-five participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naïve as to the purpose of the experiment. Twenty-four participants reported that they were right handed.

Apparatus and Stimuli

Apparatus, response device, fixation point, and target were same that those used in Experiment 3 and 4. However, only two categories of prime objects (category 2 and 3) were employed from the previous experiments.

Procedure and design

Experiment 5 used an SRT task in which the colour of the target signalled go and no-go trials. Therefore, subjects knew in advance, which hand they were going to use for their response. Responses were performed with the right or left hand in the first half of the experiment (block 1) and the opposite hand was used for responses in the second half of the experiment (block 2). Half of the participants made right hand responses in the first block and half of the participants made left hand responses in the first block. The design was similar to that of Experiments 3 and 4. Each trial was initiated with the presentation of the fixation point (with a grey cross inside) on white background. After 2000 ms, the fixation point was replaced by the prime. The duration of prime presentation was either 300 ms or 450 ms with equal probability. After this varying SOA period the fixation point was displayed over the prime object for 50 ms in the same location that it was displayed before the prime object presentation. Then the go/no-go signal was displayed inside the fixation point, and after 200 ms, the signal changed back into the fixation cross. The target was presented over the object and both the object and the fixation point remained in view until the participant responded as instructed. Participants were instructed to respond as fast as possible when a green signal (go) was displayed inside the fixation point, and to withhold their response when a red signal (no-go) was presented inside the fixation point. A go signal was displayed in 160 trials in both blocks, and a no-go signal was displayed 80 times in both blocks. Hence, participants completed 480 experimental trials. The order of go/no-go signals was randomised. Error responses were immediately followed by a short "beep"-tone from the computer. If a participant did not respond when the program was waiting for the response the prime object and the fixation point was displayed for 3000 ms before shifting to the next trial. Objects within the two different categories were presented in randomised order in two separate category blocks. The order of category blocks was randomised and blocks were separated with a 1-minute break. During the break, the monitor displayed text to the participant that indicated the length of the break and instructions for carrying on with the experiment. The break text asked participants to respond from now on with the other hand. Participants were asked to keep the hand that was not performing responses on the end of the corresponding side of the keyboard. The experiment began with approximately 10 practice trials to familiarise the participant with the task.

4.5.2 Results

Reaction times

Reaction times (RTs) were cropped for each participants's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object category (C1 or C2), object orientation (left or right), duration of the prime presentation (300 ms or 450 ms), and hand of response (right or left). One participant was removed from the analysis because his/her error rate exceeded 2 SD from the error rate means. The analysis revealed three interesting results. Firstly, two significant main effects were found. The main effect of SOA showed that responses were performed faster in SOA 450 (M=301.32 ms) than in SOA 300 (M=306.06 ms), $F(1,23)=7.60$, $p=.011$, $MSE=2156.82$. Additionally, right-hand responses were made significantly faster (M=300.73 ms) than left-hand responses (M=306.64 ms), $F(1,23)=4.53$, $p=.041$, $MSE=3350.26$. Additionally, the analysis revealed a slightly significant interaction between object orientation and hand of response, $F(1,23)=4.68$, $p=.041$, $MSE=281.47$. Participants made faster right-hand responses when object orientation was to the right (M=299.28 ms) rather than to the left (M=302.18 ms). Similarly, participants made faster left-hand responses when object orientation was to the left (M=306.38 ms) rather than to the right (M=306.90 ms). Obviously, the RT differences are so small in this interaction that it cannot be considered as an effect even though it might be speculated that the pattern of interaction is going to the direction that would be expected from the orientation effect. Additionally, the analysis did not reveal a significant three-way interaction between object orientation, SOA, and hand of response. However, we had reasons to believe that RTs in SOA 300 ms would be more associated with the object-orientation effect than RTs in SOA 450 ms due to the results of Experiment 1 and 3. In addition, because the differential orientation effect between different SOA conditions was one of the main focuses of the experiment we carried out a separate analysis of the simple interaction effects at each SOA.

[SOA 1 (300 ms)] The analysis (a repeated measures ANOVA) of RTs in SOA 300 revealed a significant interaction between object orientation and hand of response. Participants made faster right-hand responses when object orientation was to the right (M= 302.217 ms) rather than to the left (M= 305.94 ms). Similarly, participants made faster left-hand responses when the object was orientated to left (M= 307.28 ms) rather than to the right (M= 308.79 ms), $F(1,23)=5.38$, $p=.030$, $MSE=328.93$. The interaction between object orientation and hand of response in SOA 1 is displayed in Figure 4.14.

[SOA 2 (450 ms)] Secondly, analysis (a repeated measures ANOVA) was carried out for RTs in SOA 450. Interestingly, this analysis did not reveal a significant interaction between object orientation and hand of response, $F(1,23)=.38$, $p=.545$, $MSE=31.25$. The interaction between object orientation and hand of response in SOA 300 and 450 is displayed in Figure 4.14.

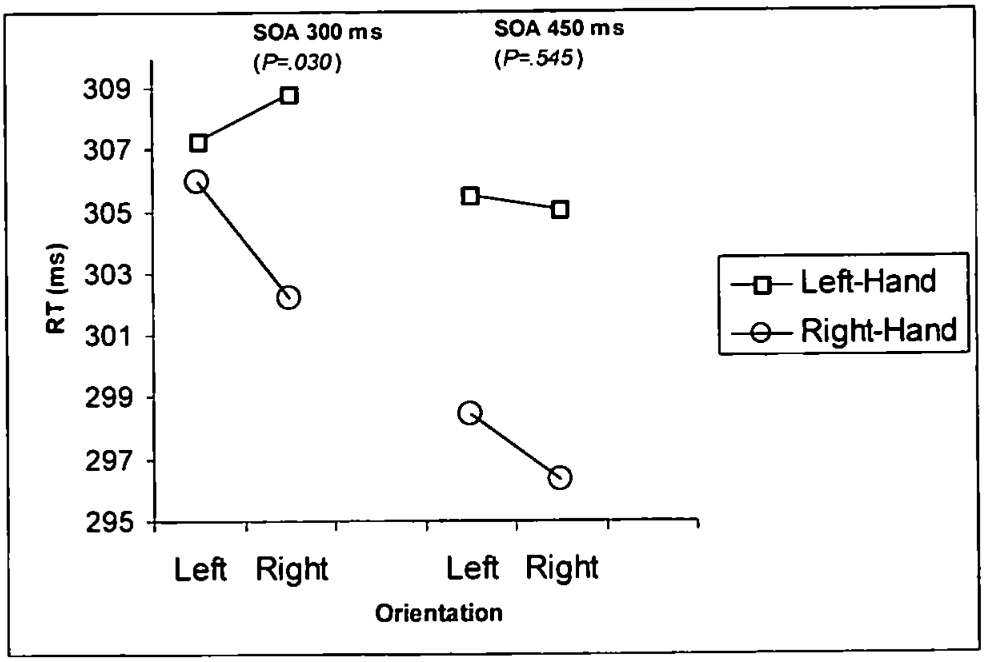


Figure 4.14 Mean RTs for Experiment 5 (SOAs 300 ms and 450 ms) as a function of object orientation and hand of response.

Errors

The mean error rate was really low. After the data of one participant who made 177 errors was excluded from the analysis, the mean error rate was 2.68 %. Analysis of percentage error rates did not reveal any interesting significant main effects or interactions when both SOAs were included to the same analysis. The analysis revealed only two main effects. Firstly, the main effect of object orientation indicated that participants performed more errors when object was orientated to the left (M=3.49%) than to the right (M=1.88%), $F(1,23)=8.93$, $p=.007$, $MSE=250.26$. Additionally, the main effect of object category indicated that participants performed more errors when prime objects belonged to category 1 (M=3.02%) than to category 2 (M=2.34%), $F(1,23)=5.93$, $p=.023$, $MSE=44.01$. However, the analysis did not reveal a significant two-way interaction between object orientation and hand of response, $F(1,23)=1.06$, $p=.314$, $MSE=8.36$. This was true in both SOAs. The percentage of error rates in corresponding and non-corresponding conditions and in both SOAs are displayed in Table 4.5.

Means Table for Errors

Orientation	Response	%	SE
	SOA 1		
Left	Left	3.19	.72
Left	Right	3.68	.65
Right	Left	1.88	.41
Right	Right	1.88	.41
	SOA 2		
Left	Left	2.92	.65
Left	Right	4.17	.78
Right	Left	1.59	.41
Right	Right	2.15	.38

Table 4.5 Mean error rates for Experiment 5 (SOAs 300 ms and 450 ms) as a function of object orientation and hand of response.

4.5.3 Discussion

The results of Experiment 5 suggest that small object-orientation effects could be observed even in an SRT task. When participants knew in advance, which hand they were required to use for responses, the size of the object-orientation effect was approximately 2 ms (in SOA 300). This slight facilitation of orientation compatible responses corresponds with the size of the Simon effect, which has been observed in SRT task. It was assumed that, in the Simon (SRT) task, the slight facilitation of stimulus location compatible responses reflects the automatic activation of the right-left response code, which is generated by an attention shift to the target location. Furthermore, the effect remains small because participants are not required to select their response. It is tempting to suggest that the response selection stage has a major role also in the object affordance effects because the size of the object-orientation effect in the SRT task corresponded to the size of the Simon effect in SRT tasks. If participants know in advance which hand they should use for response, the object-orientation effect remains very small. Hence, it may be suggested that object affordance effects also consist of automatic facilitation of the response code, and the matching of cognitive spatial stimulus (the target identity) to this activated response code. Furthermore, it remains possible that the automatic facilitation of the response code, in the object-orientation effect, is also generated by an attention shift. In other words, the result of the current experiment supports the view that the response code generation in the object-orientation effect consists of two stages. Firstly, the graspable component (e.g. handle) of the object is identified in the semantic route from stimulus to action. After that, orienting of attention to this component generates the response code. Experiment 6 attempts to further investigate this hypothesis.

4.6 Experiment 6

Experiment 6 examines whether the object-orientation effect observed in Experiments 1, 3 and 5 could be the result of an attention shift to the most graspable region in the prime object (the handle or the closest region of the orientated object to the responding hand). Experiment 6 employed a cueing paradigm to test this research problem. For example, Posner (1980) used the cueing paradigm to examine mechanisms of attention. He showed that a reflexive orienting of attention to a cued peripheral location results in the facilitated processing of other stimuli near that location. In this paradigm, participants performed a simple response following the detection of the peripheral target. Participants were asked to attend to the central fixation point until the target appeared. Before the onset of the target, the cue stimulus was displayed in the location of the target in the left or right side of the fixation point or in the opposite side of the fixation point. If the cue was presented in the target location 50-200ms prior to the target onset, the target was detected and discriminated faster than when the target location was not cued prior to the target onset. This effect was called 'facilitatory cueing effect' (FCE). It is widely agreed that perceptual processes are facilitated in the cued location because when the target is presented in the cued location shortly after the cue offset, attention is still orientated to the cued location. That is, because attention has no time to disengage and re-orientate from the cued location back to the fixation point. However, typically there is also another consequence when attention is oriented to a cued location. When attention is removed away from the cued location, the return of attention back to the cued location is inhibited. This effect is called 'Inhibition of Return' (IOR) (Posner et al., 1985). This effect usually begins approximately 300 ms after the presentation of a peripheral cue and may last even longer than 2000 ms (Tipper, Grison & Kessler, 2003). It is widely agreed that IOR reflects an evolutionarily important involuntary control of orienting reflex, which encourages orienting towards novel locations and discourages attention from re-orienting back to the previously attended location. IOR has been demonstrated to occur in a wide variety of situations. The inhibitory effect has been observed when subjects move their eyes as well as when the eyes maintain fixation while a target is detected (Posner & Cohen, 1984). Additionally, IOR effects have been observed when participants have to discriminate the shape (Lupianez, Milan, Tornay, Madrid, & Tudela, 1997) or colour (Law, Pratt, & Abrams, 1995) of the target in order to select the hand of response. Finally, Bennett and Pratt (2001) showed that IOR spreads beyond the cued location to affect the cued hemifield and the region around the cued location.

In the IOR studies that were mentioned above, the orienting of attention was inhibited to the location of the cue. However, in addition to these location-based effects, the inhibition has been also found to move with an object (Tipper, Driver, & Weaver, 1991), and spread across an object's surface (Jordan & Tipper, 1999). These studies show that similar inhibitory mechanisms apply to object-based levels of attentional selection. Particularly, the fact that even the return of attentional orienting to the region within the object could be inhibited (Jordan & Tipper, 1999) allows us to use the oriented tool as a cue stimulus. The idea of Experiment 6 is that if attentional orienting to the handle is responsible for the occurrence of the object-orientation effect, this orienting should be observed in facilitation (FCE) and inhibition (IOR) of the target discrimination when the prime object is displayed as cue and the following target is presented at the handle location. In other words, it is predicted that if the object-orientation effect is based on response code generated by an attention shift, the attentional return to the location of the handle of the object should be inhibited when the duration between the offset of the prime object (cue) and onset of the target is sufficiently long. In contrast, when this duration is very short, it is predicted that discrimination of the target in the handle location should be facilitated.

Experiment 6 uses the same prime objects that formed the category 1 object set of Experiments 3 and 4. These familiar tool-like objects, whose handle lies along the main axis of the object, produced the object-orientation effect in Experiment 1 and Experiment 3 (SOA 3 00 m s). Although also o ther o bject c ategories w ere a ssociated with t he o bject-orientation effect in Experiment 3, these objects were selected for the current experiment because they are assumed to include both the on-line visual affordance (orientation of the main axis of elongation) and semantic affordance (right-left located handle). However, because we want to use the same prime objects in Experiment 6 as those used in Experiments 1 and 3, and because these objects were presented in their full natural colours, we cannot employ the colour discrimination task in Experiment 6. This is because the uncontrolled colour of the cue objects may confound with discrimination of the target in cueing tasks. For example, Law, Pratt, and Abrams (1995) who managed to observe IOR in the colour domain noticed that responses were slower when cue and target were the same colour than when the cue and target were different colours. Therefore, colour is not probably the best target attribute if the cue object includes many different colours. Instead we use targets that are an upright or upside down T.

In a nutshell, the prime objects, which were observed to facilitate orientation compatible hand responses, are displayed as cue stimuli for 300 ms (which was shown to be sufficient prime onset duration for the occurrence of the object-orientation effect). Then the offset of the cue object is followed by onset of the target, presented in a location, which was or was not previously cued by a handle or top component of the cue object, with 50 ms or 700 ms delay. It is predicted that if orienting of attention to the handle location is responsible for the occurrence of the object-orientation effect, the target discrimination should be facilitated in SOA 50 ms condition and inhibited in SOA 700 ms condition when the target appears in the location where the handle of the cue object was previously located.

4.6.1 Method

Participants

Nineteen participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naive as to the purpose of the experiment. All participants but one were right handed by self report.

Apparatus and stimuli

Apparatus, response device, and fixation point were the same as those used in earlier experiments. Furthermore, the prime objects were same as those, which formed the category 1 object set of Experiments 3 and 4. The target was a normal or upside down white T (0.9° x 0.9° of visual angle) and was presented inside a black circle (1° of visual angle). The target appeared inside one of four grey-lined boxes (2° x 2° of visual angle) that were positioned to the lower/left, upper/left, lower/right, or upper/right corner of the screen.

Procedure and design

The viewing distance and height were identical to the previous experiment. The trial started with the presentation of a fixation point. The participant was asked to focus upon this point throughout the trial. Participants understood that maintaining fixation at the central locus was the most efficient strategy when attempting to detect a brief target. Four grey-lined boxes (7° of visual angle left and right from the fixation and 22.9° above and below the horizontal meridian) appeared to the screen simultaneously with the onset of the fixation point. These boxes indicated four locations in which the target could appear and were displayed until the execution of the response. After 2000 ms, the centralised cue object was presented on the screen. The duration of the cue object presentation was 300 ms. In half of the trials the fixation point remained over the cue object and in the half of the trials the fixation point was absent during the cue object presentation. The trial order of these two fixation point conditions was randomised. After the offset of the cue, the fixation point re-appeared for 50 ms (SOA 1) or 700 ms (SOA 2). The order of SOAs was randomised. Participants were required to make a manual right or left hand response on the basis of the target stimulus, which was presented for 700 ms inside the one of the four target boxes located around the fixation point. Responses were executed by pressing with the right or left hand index finger the "z" or "2" keys on a keyboard that was located in front of the participant on the table where the screen was located. In mapping 1, participants were instructed to respond to T with their right hand and to the upside-down T with their left hand. The mapping was reversed for half of the participants. Horizontal distances between target positions were longer than vertical distances between target positions because the orientation of the cue object was not presented diagonally, and it was necessary for the purpose of the study to present the target in exactly the same location as the handle- and top-part of the object. However, each target position was equally distant from the fixation point, and right and left positions of the targets were in the same vertical and horizontal meridian. The four target boxes disappeared and the grey-lined circle around the fixation point appeared after the response was executed. This was to give visual response feedback to participants. If participant made a wrong response, the response was immediately followed by a short error-tone from the computer. If participant did not respond, the slide was displayed for 2000 ms before shifting to the next trial. This was to motivate participants to respond. Accuracy and speed of response were emphasised equally to the participants. The experiment began with an approximately 10 practice trials to familiarise the participant with the required task.

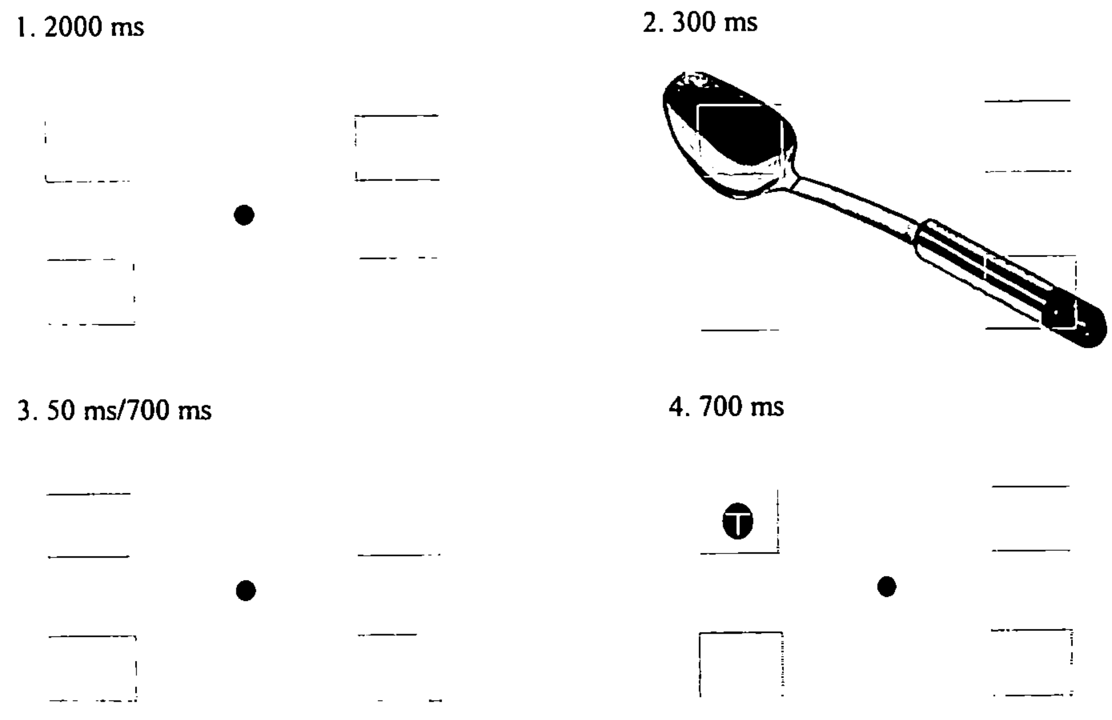


Figure 4.15 The illustration for design of Experiment 6. In this example, the target (T) appears to upper/left position (4.), which is cued by top component of the object (2.).

4.6.2 Results

Response times

Reaction times (RTs) were cropped for each participants's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of fixation point condition (with-point and without-point), target position (lower/left, lower/right, upper/left, upper/right), object orientation (left or right), hand of response (right or left), delay of the target onset (50 ms or 700 ms), and the between participants factor of mapping rule (M1: right-hand/T right side up-left-hand/T upside down; M2: right-hand/T upside down- left-hand/T right side up). Two participants were removed from the analysis because their error rate exceeded 2 SD from the error rate means. The analysis revealed a significant main effect of response, fixation point condition, target position, and SOA. The right-hand responses were made faster (M= 599.23ms) than left-hand responses

(M= 627.91 ms), $F(1,15)=31.22$, $p<.001$, $MSE=222932.70$. Responses were performed faster when the fixation point was absent during the cue presentation (M=610.16 ms) than when the point remained over the cue (M=616.98 ms), $F(1,15)=10.45$, $p=.006$, $MSE=12609.76$. Similarly, responses were performed faster in SOA 700 (M=609.67 ms) than in SOA 50 (M=617.47 ms), $F(1,15)=4.87$, $p=.043$, $MSE=16504.75$. Finally, the main effect of target position was significant, $F(3,45)=3.33$, $p=.028$, $MSE=8197.81$. The pattern of this main effect suggested that the target that appeared in the upper/right position was discriminated faster (M=606.48 ms) than targets that appeared in other locations [lower/left (M=619.90 ms), upper/left (M=614.11 ms), lower/right (M=613.79 ms)],

In addition, analysis revealed a significant two-way interaction between hand of response and mapping. Although right-hand responses were made faster in both mappings, the difference between right and left hand responses was larger in mapping 1 [right-hand (M=569.37 ms), left-hand (M=613.11 ms)] than in mapping 2 [right-hand (M=629.08 ms), left-hand (M=642.71 ms)], $F(1,15)=8.60$, $p=.010$, $MSE=61422.89$. Additionally, the analysis revealed a significant interaction between target position and responding hand, indicating the occurrence of the Simon effect. Participants made faster right-hand responses when the target was presented in the right-hand side (upper-M=585.54 ms, lower-M=591.17 ms) rather than in the left-hand side (upper-M=605.38 ms, lower-M=614.83 ms). Similarly, participants made faster left-hand responses when the target was presented in the left-hand side (upper-M=622.83 ms, lower-M=624.97 ms) rather than in the right-hand side (upper-M=627.42 ms, lower-M=636.41 ms), $F(1,15)=7.87$, $p<.001$, $MSE=20731.69$. The absence of a significant three-way interaction between fixation point condition, target position and hand of response [$F(3,45)=.667$, $p=.576$, $MSE=676.39$] suggested that the Simon effect was significant in both fixation point conditions. The interaction between the target position and object orientation (cueing effect) was not significant [$F(3,45)=1.45$, $p=.242$, $MSE=1706.97$] as it would be expected because both SOAs were included to the analysis. However, the analysis revealed a significant three-way interaction between target position, object orientation, and SOA [$F(3,45)=5.29$, $p=.003$, $MSE=7240.94$] suggesting that the cue affected the target discrimination differently in the two SOAs. Because the experiment was examining the facilitatory and inhibitory cueing effects, this interaction was the central focus. To examine more close this three-way interaction we carried out separate analysis of the simple interaction effects at each SOA.

It was predicted that the cueing effect would be observed in the cued locations in the lower visual field if an attention shift to the handle location is responsible for generation of the object-orientation effect. Therefore, a separate (ANOVA repeated measures) analysis of simple interaction effect was carried out for targets that appeared in upper and lower visual fields at each SOA.

[SOA 1 (50 ms): LFV] Firstly, the data for targets that appeared in LVF (lower/left-lower/right) were analysed to examine the FCE. This analysis (a repeated measures ANOVA) revealed a significant two-way interaction between target position and object orientation indicating the facilitatory cueing effect. The target that appeared in lower/left location was discriminated faster when the cue object orientation was to the left (in other words, the location was previously cued by handle component of the object) (M=615.72 ms) rather than to the right (M=632.20 ms). Similarly, the target that appeared in the lower/right location was discriminated slightly faster when the orientation (of the cue object) was to the right (M=617.60 ms) rather than to the left (M=620.66 ms), $F(1,15)=6.14$, $p=.026$, $MSE=6469.75$. The facilitatory cueing effect was observed regardless of whether the fixation point was removed or remained over the cue object, (three-way interaction between fixation point condition, target position, and object orientation), $F(1,15)=2.35$, $p=.147$, $MSE=1629.78$.

[SOA 1 (50 ms): UVF] Secondly, the data for targets that appeared in the UVF (upper/left-upper/right) were analysed to further investigate the facilitatory cueing effect. This analysis (a repeated measures ANOVA) revealed a significant interaction between object

orientation and target position indicating the facilitatory cueing effect. The target that appeared in the upper/left location was discriminated faster when orientation of the cue object was to the right (in other words, the location was previously cued by the top component of the object) (M=606.11 ms) rather than to the left (M=625.61 ms). Similarly, the target that appeared in the upper/right location was discriminated slightly faster when orientation of the cue object was to the left (M=607.65 ms) rather than to the right (M=613.90 ms), [$F(1,15)=11.89$, $p=.004$, $MSE=10979.89$]. This suggests that the discrimination of the target is facilitated when the target location is previously cued by the top component of the cue object. The facilitatory cueing effect was observed regardless of whether the fixation point was removed or remained over the cue object, (three-way interaction between fixation point condition, target position, and object orientation), [$F(1,15)=.03$, $p=.845$, $MSE=31.12$]. The mean reaction times of target discrimination in cued and un-cued target positions in SOA 50 are displayed in Figure 4.16.

[SOA 2 (700 ms): LVF] Thirdly, the data for targets that appeared in LVF (lower/left-lower/right) were analysed to investigate the presence of IOR. This analysis (a repeated measures ANOVA) did not reveal a significant interaction between cue object orientation and target position [$F(1,15)=1.06$, $p=.320$, $MSE=1446.14$], regardless of whether the fixation point was removed or remained over the cue object, (three-way interaction between fixation point condition, target position, and object orientation) $F(1,15)=.26$, $p=.616$, MSe=186.72.

[SOA 2 (700 ms): UVF] Fourthly, the data for targets that appeared in UVF (upper/left-upper/right) were analysed to further investigate the presence of IOR. This analysis (a repeated measures ANOVA) did not reveal a significant two-way interaction between object orientation and target position [$F(1,15)=.235$, $p=.635$, $MSE=575.02$] regardless of whether the fixation point was removed or remained over the cue object, $F(1,15)=.79$, $p=.388$, $MSE=355.23$. The failure to observe the significant two-way interaction between object orientation and target position in both (lower and upper) visual fields suggests the

absence of IOR. The mean reaction times of target discrimination in cued and un-cued target positions in SOA 700 are displayed in Figure 4.17.

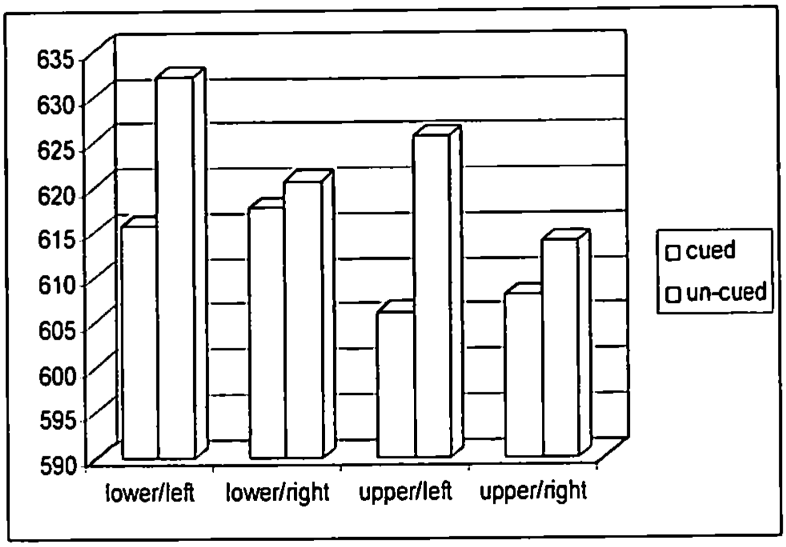


Figure 4.16 Mean RTs for Experiment 6 (SOA 50 ms) as a function of target location and cue object orientation (i.e., cued when the object is orientated so that either top or handle component appeared at the target location).

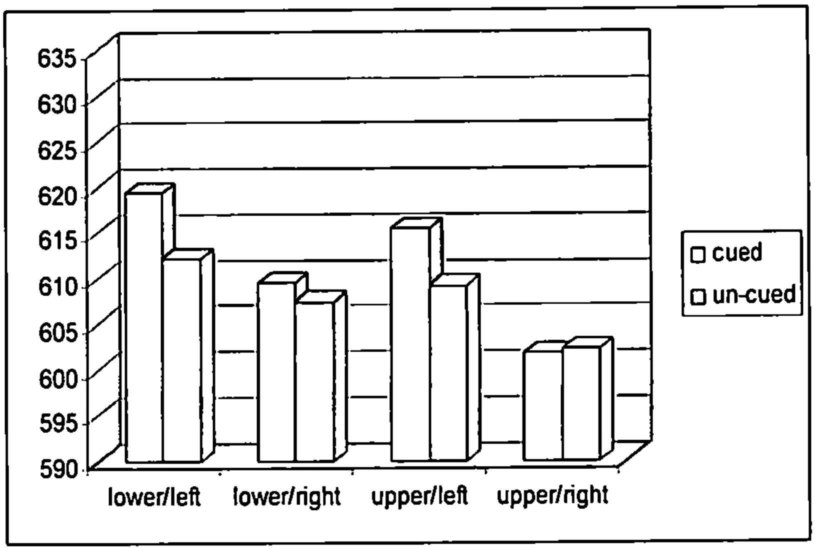


Figure 4.17 Mean RTs for Experiment 6 (SOA 700 ms) as a function of target location and cue object orientation (i.e., cued when the object is orientated so that either top or handle component appeared at the target location).

Errors

The mean error rate was 4.18% after two participants whose error rate exceeded 2 SD from the error rate means were excluded from the analysis. The analysis revealed a significant main effect of fixation point condition and target position. Participants made more errors when the fixation point was absent during the cue presentation (M=4.30%) than when the fixation point remained over the cue object (M=3.59%), F(1,15)=4.74, *p*=.046, *MSE*=137.34. Additionally, participant made more errors when target appeared in lower/left (M=5.20%) and lower/right (M=4.75%) position than when it appeared in upper/left (M=2.96%) and upper/right (M=2.87%) position, F(3,45)=6.81, *p*<.001, *MSE*=393.58. Additionally, the analysis revealed a significant interaction between target position and responding hand. This interaction reflected the occurrence of the Simon effect. Participants made fewer errors with the right-hand when the target was presented in the right-hand side (upper-M= 2.02%, lower-M= 2.28%) rather than in the left-hand side (upper-M= 3.69% , lower-M= 7.14%). Similarly, participants made fewer errors with the left-hand when target was presented in the left-hand side (upper-M= 2.22%, lower-M= 3.27%) rather than in the right-hand side (upper-M= 3.72%, lower-M= 7.22%), *F*(3,45)=9.28, *p*<.001, *MSE*=993.12. When an analysis (a repeated measures ANOVA) was carried out separately for errors in SOA 50 and SOA 700, it did not reveal any significant effects in SOA 50 ms when only lower target positions were included to analysis *[SOA 1 (50 ms): LFV]*. However, an analysis for targets in UVF at SOA 50 ms *[SOA 1 (50 ms): UVF]* revealed a significant interaction between the orientation of the cue object and target position. This interaction showed that participants made more errors when the target appeared in the upper/left position and orientation was to the right (in other words, the location was previously cued by the top component of the object) (M=4.09%) rather than to the left (M=2.64%). Similarly, participants made more errors when the target appeared in upper/right position and orientation was to the left (M=3.68%) rather than to the right (M=2.24%), *F*(1,15)=5.09, *p*=.039, *MSE*=142.41. An analysis for targets in LVF in SOA 700 ms *[SOA 2 (700 ms): LVF/UVF]* did not reveal any significant effects.

Table means for RTs and error rates

Target position	Lower/left			Lower/right			Upper/left			Upper/right		
Condition	ms	SE	er%	ms	SE	er%	ms	SE	er%	ms	SE	er%
SOA 50: Fix. Point on												
Cued	609	11	5.9	618	18	5.7	600	12	4.4	608	18	4.7
Un-cued	623	14	5.3	613	14	6.2	626	13	3.5	606	13	1.5
Fix. Point off												
Cued	622	19	3.7	617	15	5.4	612	17	3.8	608	12	2.6
Un-cued	641	16	4.0	628	14	2.9	625	16	1.8	622	16	2.9
SOA700:Fix. Point on												
Cued	615	16	5.2	605	15	5.9	612	17	2.0	608	21	2.6
Un-cued	605	15	5.4	604	19	5.4	608	13	2.0	600	14	2.9
Fix. Point off												
Cued	623	19	5.3	613	20	2.4	619	23	2.9	596	16	1.8
Un-cued	619	18	6.8	611	18	3.9	610	16	3.2	604	17	3.9

Table 4.6 Mean RTs and error rates for Experiment 6 as a function of SOA condition, fixation point condition (on/off during the cue object presentation), target location, and cue object orientation (i.e., cued when the object is orientated so that either top or handle component appeared at the target location).

4.6.3 Discussion

Experiment 6 produced several interesting results. Firstly, the target was discriminated faster when the target location was previously cued by the top or handle component of the object. This suggested that FCE (facilitatory cueing effect) was associated with the surface of the entire cue object and not just its handle. The FCE was larger when the leftmost target positions (upper/left-lower/left) were cued by the handle or top component of the object than when the rightmost target positions (upper/right-lower/right) were cued. However, the discrimination of targets that appeared in the rightmost locations was also slightly facilitated. This suggests that attention does not orient just to the handle component of the object during the cue object presentation. Instead, attention seems to orient to the entire cue object. Secondly, a significant FCE was observed even when the fixation point was presented over the cue object, suggesting that similar attentional orienting towards the cue object occurred in both fixation point (onset/offset) conditions. Consequently, this suggests that the suppression of (peripheral) exogenous orienting of attention to the prime object was not fully responsible for elimination of the object-orientation effect in Experiments 2 and 4. Rather the engagement of endogenous attention to the fixation point may have suppressed the allocation of focused attention to the prime, which in turn may have eliminated the object-orientation effect. Thirdly, a significant inhibitory effect was not observed with the target locations that were cued in upper or lower visual field, regardless of whether the fixation point was absent or remained over the cue object. However, as Figure 8 shows the target discrimination is slightly slowed down in the lower/left, lower/right, and upper/left cued target locations, when the target appears 700 ms after the cue offset. This inhibition is largest in the same cued locations (lower/right-upper/right) in which the facilitatory effect is also largest. This fact suggests that the experiment was not sufficiently powerful for observing the IOR effect. The attention shift account of the object-orientation effect predicted that targets, which appear in the location that was previously cued by the handle component of the object, would be discriminated faster than targets that appear in any other location in SOA 50 ms. Similarly, the same account predicted that these same targets are discriminated slower than targets that appear in any other location in SOA 700 ms. However, the spread of facilitatory cueing effect over the entire cue object region, and the absence of IOR effect were both contrary to the attention shift account of object-orientation effect. The result suggests that an attention shift to the handle location could not explain the object-orientation effect that was observed in Experiments 1 and 3. Rather attentional mechanisms that are involved in generation of the object-orientation effect may operate at the object-based level.

However, one might suppose that the two paradigms, the one that was used to observe the object-orientation effect and the one that was used in the present experiment, are so different that the cueing paradigm may not be a reliable method to study attentional orienting during the object-orientation effect. Therefore, it is important to justify the use of the cueing paradigm for the present purposes. Firstly, in the traditional cueing paradigm, the cue is presented for 50-200 ms. As mentioned above, the FCE is normally observed when the target is displayed approximately 50-200 ms after cue offset while IOR is observed when the target is displayed approximately 400-2000 ms after cue offset. Therefore, the FCE is normally observed when the time between onset of the cue and onset of the target varies between 100 ms – 400 ms, and the IOR is normally observed when the time between onset of the cue and onset of the target varies between 450 ms and 2200 ms. In the present experiment, the cue was displayed for 300 ms and the target appeared 50 ms or 700 ms after cue offset. Therefore, in SOA 50 ms condition, the time between onset of the cue and onset of the target was 350 ms, and in SOA 700 ms condition, the time was 1000 ms. Hence, the onset and offset time of both the cue object and the target was suitable for observation of both cueing effects in Experiment 6. Secondly, the task in Experiment 6 required choice RT responses with the same keys of the keyboard as it was used in Experiments 1 and 3. Therefore, motor-readiness was similar in all of these experiments. Thirdly, participants did not have more need to relocate the attention from the initial fixation location during the cue object presentation in Experiment 6 than they had during the prime object presentation in Experiments 1 and 3 in which the target was displayed inside the central fixation point. This was, because the target was equally likely to appear at any of the four locations in Experiment 6. In addition, participants understood that maintaining fixation at the central locus was the most efficient strategy when attempting to detect a brief target in Experiments 1, 3 and 6. As a consequence, it was expected that the same attentional processes than were operating during the prime object presentation in Experiments 1 and 3 were similarly operating during the cue object presentation in Experiment 6.

4.7 General discussion for Experiments 1-6

The experimental work in this Chapter aimed to investigate the degree to which resources of endogenous and exogenous attention are involved in the object affordance effect. The second primary aim was to study whether the object-orientation effect is constructed at the object-based level of attention like the object-size effect. This section attempts to discuss how the experimental work succeeded in answering these research questions.

Firstly, the series of six experiments contributed to our understanding of the attentional mechanisms that are involved in object affordance generation. The results of Experiments 1, 3 and 5 suggested that the object-orientation effect could be observed with task-irrelevant objects. Therefore, it appears that the effect could be generated in the absence of forced allocation of endogenous attention to the object. In turn, this was assumed to suggest that when the object is displayed in the focal region of the visual field, the object captures exogenous resources of attention sufficiently, that the action-related properties of the object could prepare actions. However, the effect was diminished when the onset time of the prime object was more than 300 ms. In other words, the activation of automatically triggered action plan began to diminish shortly after the onset of the prime object. As mentioned earlier, the motor representation needs to be constantly updated so that visual objects can guide movements in real time. Furthermore, it would not be efficient to keep this motor representation active when the object is not the goal of actions and interest. Therefore, it was suggested that because, in the present studies, the prime object was absolutely irrelevant for the current behaviour, the visuomotor system did not keep the motor representation active. As a consequence, the object-orientation effect was diminished in the longer SOA conditions (450 ms; 600 ms; 1100 ms). However, Experiment 3 suggested that this diminishment of the effect was also related to the hand of response and the object category. Interestingly, the results of Experiment 3 suggested that although the overall effects was diminished in longer SOA (600 ms), the right hand control system may still have access to continuous updates of low-level affordance information about the prime object in the longer SOAs. In turn, this finding may reflect the superiority of the right hand in the on-line control of actions (e.g. Goodale, 1988). This finding is particularly interesting, and is therefore further investigated in the experimental work of Chapter 5. In sharp contrast, the system that programmes left hand responses appeared to have superior access to higher-level affordance information about the prime object in shorter and longer SOAs. The findings that the right hand responses are more facilitated by low-level affordances and the left hand responses are more facilitated by high-level affordances may suggest that these different levels of affordances may be constructed predominantly in different hemispheres.

Additionally, the results of Experiments 2 and 4 suggested that the object-orientation effect is suppressed when a competing task-relevant item is presented simultaneously with the prime object. This suggests that competition for attentional resources between the prime object and the item that is presented over the prime object favours the one that is behaviourally more relevant for carrying out the task and, consequently, allocation of focused attention to the task-irrelevant object is suppressed. It could be argued that this, in turn, could be observed in a suppressed object-orientation effect. However, this result still left open the question of whether the effect could be the result of attentional orienting towards the most affordable component of the object or whether the absence of the effect could be explained by the suppressed allocation of attentional resources to the entire object. In fact, results of Experiment 5 supported the earlier account. Finally, the results of Experiment 6 showed that the latter (object-based) account appears to be a better explanation for the generation of the object-orientation effect. This view is discussed in the next sub-section.

Because the results of Experiment 6 suggested that the elimination of the object-orientation effect in Experiments 2 and 4 could not be explained by elimination of the attention shift, another explanation is required. The biased competition model of selective attention (Desimone & Duncan, 1995) may help to explain the absence of the object-orientation effect in Experiment 2 and 4. As stated earlier, under this model, the effect may have been absent because the attentional processes necessary for constructing a motor representation for the prime object were suppressed by allocation of resources of focused attention to the competing item. In other words, it is likely that the object-orientation effect was absent in Experiments 2 and 4 because the motoric preparation of actions linked to the prime object onset was suppressed when a behaviourally more relevant object had won the biased competition for the resources of focused attention. Goal-directed actions have to imply a mechanism that selects the target from competing items in the scene. Since typically only one object can be the target of goal directed actions at any one time attentional competition ensures that the behaviourally most relevant one is selected. Therefore, the view that only the item which has won the biased competition among neuron populations in the visuomotor system could afford viewer's actions at the one time is consistent with results of Experiments 1-4.

4.7.1 The object-based account of the object-orientation effect confirmed

The results of Experiment 6 strongly suggests that an attention shift to the handle of the prime cannot be used as the only explanation for the object-orientation effect found in Experiments 1, 3 and 5. In fact, the results suggest that the effect appears to be operating at an object-based level. As stated above, Anderson et al. (2002) argued that an intentionally performed attention shift to the most salient object feature (e.g. handle) led to the object-orientation effect. However, the results of Experiment 6 showed clearly that attention does not orient dominantly to the handle region of the object during the prime presentation. This is because, Experiment 6 showed the significant facilitatory cueing effect to the locations of the top and handle regions of the object, rather than only to the location that was cued by the handle region of the object. It is likely that the effect that was found by Anderson et al. (2002) was caused by an attention shift. However, in their experiment, not only was the object itself important for carrying out the task, but also the orientation of the object had to be explicitly identified in order to perform the task correctly. Therefore, it would be tempting to suggest that the experimental task that was used by Anderson et al. (2002) required participants to orient their attention. In contrast, the object-orientation effect that was observed in Experiments 1, 3 and 5 was observed even though both the object orientation and the object itself were irrelevant to the task. Taken together, the fact that a facilitatory cueing effect was observed on all target locations suggests that orienting of attention to the target was facilitated by the entire cue object region and that object orientation can afford corresponding manual responses without an attention shift if a paradigm similar to those in Experiments 1 and 2 is employed.

The fact that the inhibition of return was not found to the handle (or any other) location suggests also that attention does not orient particularly to the handle region of the object during the prime presentation. However, the absence of IOR may be related to weaknesses of the present design in observing the IOR rather than to the absence of the attentional orienting during the prime presentation. Although IOR has been found with, for example, shape discrimination task (Lupianez et al., 1997) many researchers have reported difficulties in observing the effect in choice RT tasks (e.g. Egly, Rafal, & Henik, 1992). However, Lupianez, Milliken, Solano, Weaver, and Tipper (2001) argued that the time course of the effect differs between different types of discrimination tasks depending on perceptual difficulties in determining the identity of the target. The more difficult the perceptual task, the longer SOA is needed to observe IOR. However, the 700 ms SOA that was used in Experiment 6 has been reported to be sufficiently long even in the most difficult perceptual tasks (e.g. when participants have had to discriminate between letters, Pratt & Abrams, 1999; or discriminate between x and +, Pratt, Kingstone, & Khoe, 1997). In fact, determining whether the target T is the right way up or upside down should not be any more difficult than those tasks that were associated with IOR effects in studies reported by Pratt and Abrams (1999) and Pratt et al (1997). The second factor that might have decreased the power of Experiment 6 in observing the IOR effect was that the cue object covered a wide area in the visual field to both the right and left side of the fixation point. Typically, both the object-based and location-based IOR have been observed when the cue has been displayed in the right or left side of the fixation point. Nevertheless, the fact that the significant FCE was associated with top and handle components of an object suggests that even if the design would have been inappropriate for observing the IOR, attention does not orientate dominantly to the handle during the prime object presentation. Because the object cued two target locations simultaneously, and because the choice reaction time task was employed to measure the IOR, it is very likely that the experiment was simply not sufficiently powerful for observing the IOR. Finally, this idea is also supported by the fact that inhibition of responses was largest in the same cued locations in which facilitatory cueing effect was also largest.

The results of Experiment 6 showed that the target location compatible responses were performed faster than the target location incompatible responses. This kind of compatibility effect has been called the Simon effect, as already stated. However, as stated above, also FCE was observed in the same experiment. There is an obvious problem in the simultaneous occurrence of these two effects. If the attention shift account of the Simon effect is correct, it may be assumed that attention has to shift to the target, from the initial fixation point position, when the target is displayed. According to the attention shift account of the Simon effect, the effect cannot be observed without this kind of shift. However, traditionally it is assumed that the FCE is observed because the previous cue stimulus (in this case the prime object) cues attentional orienting to the location where the following target is then presented. In other words, attention is already orientated to the target location when the target is presented. In turn, this results in faster target detection and discrimination. The question is how attention can be orientated to a cued location (i.e., handle- and/or top of the object), resulting in the FCE and be simultaneously focused on a fixation point, resulting in the Simon effect. It would be tempting to suggest that two attentional processes that are operating in parallel are responsible for co-occurrence of these effects, the pre-attentive processes of exogenous attention and processes of endogenous attention. It is possible that pre-attentive (or better, peripheral) processes (intrinsic in exogenous attention) that are spread over the entire cue object facilitate the target discrimination. The pre-attentive processes of exogenous attention are often linked to grouping objects in the visual field (e.g. Pylyshyn, 1994). Grouping factors (or better, low-level Gestalt factors) such as common three-dimensional surface (see Baylis & Driver, 1993), co-linearity (Mattingley, Davis & Driver, 1997) connectedness, common shape, common contrast polarity, common region (Humphreys, 1998) and known shape (Ward, Goodrich & Driver, 1994) link the stimuli for constructing the coherent object representation. This pre-attentive processing, which is computed simultaneously over the whole visual field, parses the display into objects among which attention may choose (Pylyshyn, 1994). Attention can operate at the level of object only after pre-attention has played its initial role in linking the stimuli. Furthermore, these linking processes are actively building the object representation even when endogenous and/or focused attention would be engaged simultaneously to the fixation point. It is possible that the target discrimination processes could be facilitated when the target appears in the same area to which these pre-attentive (peripheral) resources are allocated. In contrast, it is possible that while these pre-attentive processes are constructing the peripheral cue object, the endogenous attention is still focused on the fixation point location, and when the target is displayed, the shift of focused attention to the target results in the Simon effect. Therefore, it may be assumed that the Simon effect is caused by the shift of endogenous and/or focused attention to the target, while FCE is associated with orienting of peripheral (exogenous) attention to the entire cue object.

Interestingly, the FCE was larger when the target appeared in the left visual field (LeVF) than when it appeared in the right visual field (RVF). These same two locations in the LeVF were also associated with larger inhibitory effects (see Figures 4.16 and 4.17). However, because both target locations that were positioned in the RVF were also associated with the slight cueing effects, it may be proposed that these differential cueing effects between target positions in the RVF and LeVF may reflect visual field asymmetries. For instance, the right hemisphere shows superiority in visuospatial attention (Heilman & Van den Abell, 1980), which in turn may predict larger spatial cueing effects in the LeVF. Therefore, it is suggested that the entire cue object facilitated the target discrimination, and the LeVF was associated with larger cueing effects due to visual field asymmetries. The asymmetry that was found between left and right visual fields in this paradigm (where separate positions in the left and right visual fields are cued simultaneously by an orientated object) warrants further investigation.

4.7.2 Does the dramatic influence of a fixation point reflect the dominant role of the dorsal stream in object afforances?

Craighero, Fadiga, Umiltá and Rizzolatti (1996) showed that orientation of a prime facilitates initiation of grasping responses when responses are performed to a clockwise or anticlockwise oriented target bar and the prime orientation matches the orientation of the target bar. In this study, participants reached out to grasp an unseen target bar with a precision grip 100 ms after viewing a prime with congruent, incongruent or neutral orientation with respect to the target. A verbal cue before the trial conveyed to participants the orientation of the target. Interestingly for the purposes of the present thesis this priming effect occurred even when the prime was task-irrelevant and responses were initiated to a colour change of the fixation cross, which was displayed over the prime. In other words, Craighero et al. (1996) demonstrated that the orientation of the prime object could prime hand responses even when attentional resources are allocated to the competing object during the prime presentation. This result is inconsistent with the results of Experiments 1-4. However, this inconsistency may reveal some important aspects of the nature of mechanisms that are generating the effect in Experiments 1 and 3. Interestingly, Cant, Westwood, Valyear, and Goodale (in press) suggested that the priming effect that was found by Craighero et al. (1996) reflects memory-guided movements (memory-guided actions can be planned at any time using visual information delivered by the perceptual system) instead of visually-guided movements (visually guided movements use 'real time' visual information gleaned just before the action is initiated). That is, because in their study participants are executing their responses 100 ms after offset of the prime, and therefore participants are required to store the prime object information in memory (the prime information is not visually accessible during the execution). Consequently, it was suggested that the priming effect found by Craighero et al. (1996) does not reflect visuomotor priming but rather is a textbook example of perceptual priming. In fact, Cant et al. (in press) showed experimental evidence in favour of this view. When they used a paradigm similar to that of Craighero et al. (1996) they did not find evidence for priming of visually guided movements (the prime remained in the visual field during the movement). However, memory-guided movements (the prime was removed from the visual field before onset of the movement) were associated with the priming effect. It may be speculated that allocation of attentional resources to the fixation point during the prime onset does not influence memory-guided movements because attention is not focused to the fixation point anymore during memory-guided movements. Rather the peripheral prime object that has been supposedly constructed by pre-attentive perceptual processes can be retrieved from perceptual memory and used in memory-guided movements. In contrast, visually guided movements are expected to be more sensitive to attentional modulation of the fixation point during the prime presentation. That is because, when the prime object remains in view until the execution of action and the task-relevant fixation point remains over the prime, attentional resources are allocated to the fixation point instead of the prime during the planning and execution of action. Because these same attentional resources that are allocated to the fixation point are supposedly required in the computing of visually guided movements in relation to the prime, there is not sufficient resources left for processing the action-related attributes of the prime. Therefore, it would be tempting to suggest that the mechanisms of visually guided movements underlie the orientation effect that was observed in Experiments 1 and 3. Furthermore, presumably the ventral stream processes underlie memory-guided movements whereas the dorsal stream processes underlie visually guided movements (see Goodale & Humphrey, 1998 for a review). Therefore, the results of Experiments 1-4 may suggest evidence for a dominant role of the dorsal stream in object affordance generation.

4.8 Summary

Experiments 1, 3 and 5 show that the orientation of a task-irrelevant viewed object could prepare automatically the orientation compatible responses. Therefore, the object can trigger the object-related action plan even when the allocation of endogenous attention to the prime is minimal or absent. However, the activation of this automatically triggered (object-related) action plan is relatively short lived if the focally presented object is task-irrelevant. It is assumed that it would not be efficient for the processes of selective attention, which are associated, for instance, with computing the next limb or saccade movement relevant for the current task, to keep the task-irrelevant motor representation active. Consequently, the motor representation is relatively short-lived. However, surprisingly, the results of Experiment 3 suggested that even though the overall effects were diminished in longer SOAs, the system that controls right hand movements may still have access to continuous updates of low-level affordance information in the longer SOAs. In contrast, the system that controls left hand movements may still have access to continuous updates of high-level affordance information in the longer SOA. This suggested that high and low-level affordances might be constructed predominantly in different hemispheres.

Furthermore, the fact that the effect was eliminated, in Experiments 2 and 4, when a task-relevant fixation point remained over the prime suggested that if attention is focused on this competing item the affordance effect cannot be generated. Consequently, this suggests that the resources of focused attention have a particularly important role in affordance generation. As mentioned in Chapter 1, one of the main functions of focused attention (which is normally inseparable from endogenous attention) is to enhance perceptual processing of the object (e.g., feature integration) (e.g. Treisman & Gelade, 1980). The results of Experiments 1-4 supports the view that the resources of focused attention have a fundamental role also in facilitating pre-movement planning related to the attended object. In other words, when attention is focused on an object voluntarily or when the object is displayed in the foci of attention, not only is the quality of the perceptual object representation improved but also construction of an automatically triggered (object-related) action plan is enhanced. Therefore, these results supports the view that one of the main functions of attention is to link the particular visual inputs with action.

Finally, the results of Experiment 6 suggested that directed attentional orienting is not the only mechanism that could facilitate the orientation compatible hand responses when the viewer is performing a reach-to-grasp action towards an orientated object. The orientation property of a viewed object could facilitate responses of the orientation compatible hand without involvement of attention shift mechanisms. Here we suggest that visual information about the global properties of an object (e.g. orientation and size) that are registered in cell populations in the visuomotor system, capable of processing object-based information, is responsible for the micro-affordance effects. Finally, the facts that the facilitatory cueing effect was observed regardless of fixation point condition and that it co-occurred with the Simon effect suggests that suppressing the allocation of peripheral exogenous attention to the prime object was not alone responsible for the suppression of the object-orientation effect in Experiments 2 and 4. Rather if focused attention is simultaneously allocated to any competing item during the prime presentation the effect that the prime has on action planning is overridden by the endogenous focusing of attention at another object. Therefore, focused attention needs to be in a state of disengagement from the competing item during the prime presentation in order that the presentation of the object could result in motor potentiation effect.

CHAPTER 5: EXPERIMENTS 7-9

5.1 Introduction for Experiments 7-9

Experiments 7-9 aim to further investigate the role of attention in object affordance. Whilst Chapter Four focused on the object-orientation effect, Chapter Five focuses on the object-size effect. The previous six experiments suggested that the object-orientation effect operates at the object-based level of attention. Similarly, it may be assumed that the object-size effect has to operate at this same level of attention. Attention has to be allocated to the object at this level so that the object size can prepare the grip. However, it is theoretically interesting question whether the object-size effect would be observed, like the object-orientation effect, in the absence of the forced allocation of endogenous attention to the object. Also if it were observed, whether this effect would be eliminated when attention is engaged to a fixation point during the prime presentation. If similar attentional conditions influence both effects in the same way, it may be assumed that the same attentional mechanisms underlie both effects.

The experimental work of Chapter Five will also focus on laterality in object affordance. This is because affordances were reported to be constructed predominatly in the left hemisphere (e.g. Handy et al., 2003), and also because the results of Experiment 3 suggested that the high and low levels of affordance appear to influence left and right hand responses differentially. The finding that right hand responses but not left hand responses were facilitated by the orientation of axis of elongation (low-level visual affordance) in the longer SOA may suggests the superiority of the right hand in movement control. Chapter Five focuses on further investigating this asymmetry. Experiments 7-9 employ only novel objects that do not have any semantic associations, thus allowing the assessment of laterality in the case of low level affordances. Also Experiment 9 investigates facilitatory and inhibitory mechanisms of object-guided grasp behaviour. Cueing effects have been typically observed in the facilitation and inhibition of keypress responses. However, it is assumed that if the premotor theory of attention could be extended from orienting of attention to spatial locations to orienting of attention to graspable objects as Craighero et al. (1999) suggested, facilitatory and inhibitory cueing effects might apply also to situations in which grasp type (e.g., precision and power) is cued by the size of visual stimulus. Taken together, Experiments 7-9 aim to further investigate attentional aspects (e.g., facilitatory and inhibitory effects of attention, and exogenous and endogenous levels of attention), and manual asymmetries in object affordances by employing the object-size effect in this research. A short introduction to manual asymmetries is presented below.

5.1.1 Manual asymmetries, reaching and the precision and power grip

Virtually all people prefer one hand to the other in making skilled movements. A majority of the population are more proficient with their right hand than their left hand. The laterality of manual movements has been thought to be product of specialization of each hemisphere for different cognitive, visual, and/or motor information processing functions (e.g. Goodale, 1990). A goal-directed manual aiming task (Woodworth, 1899) has been one of the most common methods in research on manual asymmetries in visually guided movements. This has demonstrated faster and more accurate aiming movement of the right hand (e.g. Fisk & Goodale, 1985; Elliott et al., 1993; see Elliott & Chua, 1996 for a review) and a right hand superiority in making small adjustments to the movement trajectory as the hand approaches the target location (e.g. Mieschke, Elliott, Helsen, Carson & Coull, 2001). This is attributed to a greater ability of the left hemisphere in the processing of perceptual and/or motor information in motor control, that is, during the ongoing movements (Annett, Annett, Hudson & Turner, 1979). In addition, neurophysiological and neuropsychological research has shown that the left hemisphere is associated with the computation of many cognitive-motor processes such as the selection of motor programs for sequential movements (Kimura & Archibald, 1974). However, dominant arm advantage in reaching accuracy is not evident during "ballistic" (low precision, high-speed) movements and could be observed only when the precision requirements of the task are increased (e.g. Carson, Goodman, Chua, & Elliott, 1993; Elliott, Chua, & Pollock, 1994).

Importantly for the present purposes, in a goal directed manual aiming task participants are typically asked to point the target. In this kind of task, participants are more likely to construct a representation of the target position rather than an object for coordinating the pointing. However, in real world movements when visual information about an object is guiding one's actions the goal object is not only pointed to (i.e. reached) but also grasped. Jeannerod (1984) separated human prehension into two independent motor programs, reaching and grasping, that involve separate brain regions. More recently, Jeannerod, Arbib, Rizzolatti, and Sakata (1995) suggested that the planning of reach-to-grasp movements is largely based on analyzing the spatial attributes of the target object such as distance and direction, whereas the planning of grasp is largely based on the analysis of the object's intrinsic properties such as size. For instance, in monkey, the connections between area AIP in the posterior parietal cortex (PPC) and F5ab neurons in the premotor cortex form a parieto-frontal circuit, which transforms visual information about intrinsic object properties such as size, orientation and shape for the derivation of grasp. In sharp contrast, the connections between area VIP in the PPC and F4 neurons in the premotor cortex form circuit, which transform visual information about an object's position for deriving reach (see Rizzolatti, Luppino & Matielli, 1998 for review). Therefore, there appears to be reasonable evidence that when people are planning and executing their actions towards the objects of different positions, sizes, orientations and shapes, the spatial attributes of the target are primarily analysed for programming reaching, while the intrinsic attributes of the target are primarily analysed for programming grasping.

Napier (1956) divided grips into precision and power grips from a functional and a phylogenetic perspective. The precision grip (the use of a thumb-index grip) has developed in primates for manipulation of small objects whereas the power grip has developed for holding and grasping larger objects with high stability. Furthermore, precision and power grips should be planned in relation to the anticipated size of the object. A wide variety of evidence suggests that a precision grip engages neural circuits that are different to those engaged during power grips (e.g. Ehrsson, Fagergren, Jonsson, Westling, Johansson & Forssberg, 2000). Interestingly, some research in monkeys suggests manual asymmetries in computing precision and power grips. For example, Hopkins, Cantalupo, Wesley, Hostetter, and Pilcher (2002) showed that in chimpanzees the right-hand is more frequently used in making precision grip. One of the main research questions of Experiments 7-9 is whether visually guided grasping, not only reaching, would be associated with manual asymmetries in human. In a normal reach-to-grasp paradigm, it is difficult to measure the respective roles of reaching and grasping when studying manual asymmetries. In particular, because we aim to study lateralization in object-directed precision and power grip programming, it is essential that we can observe the effect of the object size on grasping in isolation from reach programming. We suggest that the stimulus-response (S-R) compatibility paradigm presented by Tucker and Ellis (2001) provides a useful methodological tool for the investigation of visually guided precision and power grip in this way.

5.1.2 Summary for objectives of Experiments 7-9

In summary, previous human experiments suggest a right hand superiority in control of skilled and precise movements, and furthermore some monkey experiments suggest right hand dominance in precision grasps. One of the primary objectives of Experiments 7-9 is to investigate whether visually guided grasping, not only reaching, would be associated with manual asymmetries in humans. Furthermore, Experiments 7-9 aim to investigate the same attentional aspects in object affordances that were studied in Chapter Four. In particular, the aspects of endogenous and exogenous attention, and facilitatory and inhibitory attentional processes will be studied in relation to the object-size effect.

5.2 Experiment 7

Given the fact that the right hand shows superiority in high precision visually guided reaching, which, decreases if the precision requirements of the task are lowered, we decided to examine whether similar asymmetries could be observed with visually guided grasping. Tucker and Ellis (2001) did not report manual asymmetries in visually guided grasp behaviour. Their study used primarily an uni-manual task in which both grip devices were held in the dominant hand. In fact, only one experiment was reported that used a bi-manual task and even then, the grasp to hand assignment was counterbalanced in a way that analysis could not reveal asymmetries between hands (personal communication). Experiment 7 aims to replicate the object-size effect (Tucker & Ellis, 2001) with a bi-manual task (e.g. the precision grip is held in the right hand and the power grip is held in the left hand) in which the object is irrelevant to responses. As mentioned above, we have many reasons to assume that the right hand would show superiority in object-guided precision grasps while power grip responses would be computed more symmetrically or would show a left hand superiority. The influence of the object size on precision and power grip responses of the right and left hand will be measured when the precision grip device is held in the right hand and the power grip device is held in the left hand (mapping 2) or when the power grip is held in the right hand and the precision grip is held in the left hand (mapping 1). The object set consists of realistic three-dimensional objects not previously known by the viewer (see Figure 23) instead of real objects because, as mentioned above, the effect of the low-level visual affordances on actions is a central focus of Chapter Five.

In addition, the experiment had several secondary aims. Firstly, in the original Tucker and Ellis's (2001) paradigm the object-size effect was observed when participants were required to categorize the viewed object. Therefore, participants were required to allocate endogenous, focused attention to the object. However, it is not clear whether the same effect could be observed when the allocation of endogenous attention to the object is minimal or absent. In fact, the results of Experiments 1, 3 and 5 showed that the object orientation could afford the compatible responses even in the absence of forced allocation of endogenous attention to the object, that is, when the viewed objects are task-irrelevant. The current experiment examines this aspect of attention by presenting participants task-irrelevant prime objects, and asking them to respond to an arrow, which is superimposed over the prime. Secondly, in the original object-size paradigm participants were asked to respond with a precision or power grip to the object category. Therefore, the grasp type was a task-relevant response dimension, and consequently participants were likely to code their responses explicitly as precision and power grips. However, the current experiment attempts to explore whether viewed objects facilitate the precision and power grip responses even when participants are asked to respond with the right or left hand while they are holding the precision and power grip devices in their hands. That is, the grasp type is a task-irrelevant response dimension, and participants are not likely to code their required responses explicitly as precision and power grips. This task arrangement minimizes the affect of cognitive factors, which are related to response selection, on the effect. Finally, Tucker and Ellis (2001) showed that the object-size effect builds in magnitude whilst the task-relevant object remains in view. However, the time course of response activation in the object-size effect has not been reported in relation to a task-irrelevant object and responding hands. In fact, the results of Experiment 3 suggested that the right hand control system would show superiority in accessing motor updates of the cue object representation in longer SOAs. Therefore, it is predicted that the right hand responses would show similar superiority in the object-size effect in longer SOAs. This will be measured by varying the onset time between the prime object and target.

5.2.2 Method

Participants. Forty-two participants (21 in mapping 1 and 21 in mapping 2) took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naïve as to the purpose of the experiment. All participants signed the participation form by their right hand and additionally explicitly reported that they were right handed.

Apparatus and stimuli. The same apparatus controlled the display and timing as that used in the previous experiments. A response device consisted of small (square of 1.3 x 1.3 cm and 7 mm thin) and large (a cylinder of 18 mm across and 11 cm long) switches (the illustration of the response device can be seen in Figure 5.2). Both switches consisted of slim tactile feedback devices, which clicked when they were pressed. The prime stimuli consisted of 24 artificial 3D objects (see example in Figure 5.1). Each object had a slightly different wood texture and they were slightly different variations of a natural brown-wood colour. Half of the objects were small and therefore more suitable to be grasped with a precision grip [approximately 2.3° (height) x 2.9° (width) of visual angle]. Small objects were in the shape of a ball, cone, cylinder or oil-tank (note: these shape names are given by 3D graphic software and, for example, the object with oil-tank shape does not look like *an oil-tank* when used for the current purposes, and therefore does not have any semantic association). Half of the objects were large and would normally be grasped with a power grip [approximately 17.1° (height) x 4° (width) of visual angle] and conformed to a grasp-appropriate shape. Large objects were in the shape of a cylinder, chamfer cylinder, oil-tank or capsule shape. These objects were created using 3D graphics software. Other stimuli consisted of the fixation cross (1° x 1° of visual angle), which was situated centrally in the monitor, and the target arrow (1° x 1° of visual angle), which pointed either to the right or left in randomised order. All stimuli were presented against a white background and presented with a resolution of 1024x768 pixels on the monitor.

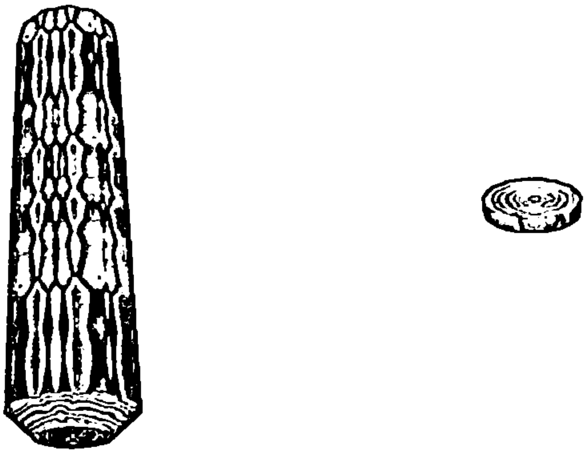


Figure 5.1 The illustration of stimuli (large, small) used in Experiments 7-9.

Design and procedure. Participants were seated in front of a monitor in a dimly illuminated room with their eyes 50 cm from the centre of the monitor. The height of the monitor was adjusted so that each participant was looking directly at the centre of the display. Participants held the large switch in their right hand and the small switch in their left hand (mapping 1) or the small switch in their right hand and the large switch in their left hand (mapping 2). Participants were told to squeeze the large switch with the whole palm and to press the small switch with the index finger and thumb. Participants were instructed to keep both their arms on the table on which the monitor was placed (40 cm apart and 25 cm in front of the monitor). The leads of both switches were attached to the table so that participant's arm placement was consistent. The participants were familiarized with the switches.

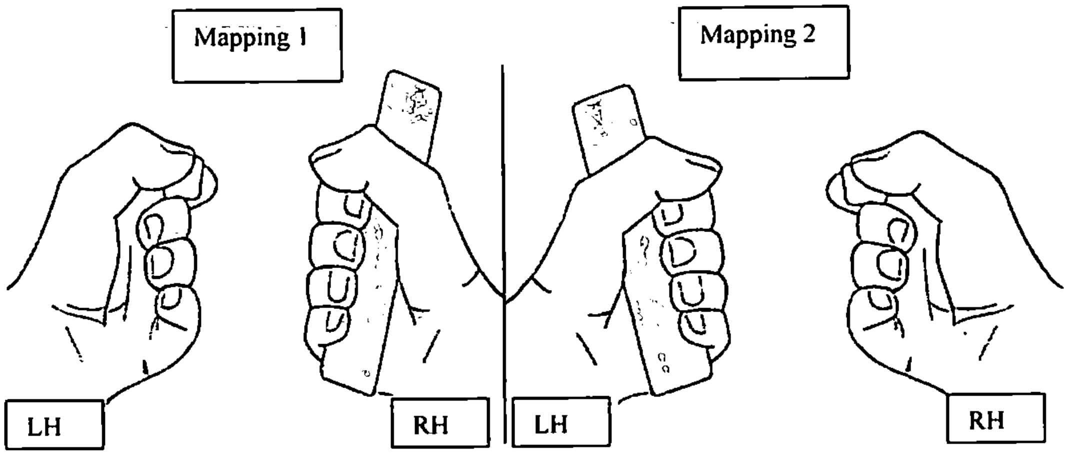


Figure 5.2 The illustration of hand to grip mappings (1 and 2) employed in Experiment 7.

Each trial was initiated by presenting a black fixation cross. After 2000 ms the fixation cross was replaced by a prime object, which was presented in the exactly same central location as the fixation cross. Objects were presented upright (see Figure 5.1), and appeared standing vertically. Therefore they were equally compatible with a right or left hand grasp. Three stimulus-onset asynchrony (SOA) conditions (150 ms; 300 ms; 600 ms) determined the duration of object presentation. After the SOA period the target (the left or right pointing arrow) was displayed over the object in the same location at which the fixation cross was previously presented. After 180 ms the arrow changed back into the fixation cross. Object and fixation cross were presented until the participant responded as instructed. Participants were instructed to respond as quickly as possible with their right hand when they saw the right-pointing arrow at the location at which the fixation cross was previously presented. Similarly, participants were instructed to respond with their left hand when the left-pointing arrow was displayed at the same location. The participant was asked to focus upon the central point through the whole experiment. Participants understood that maintaining fixation at the central locus was the most efficient strategy when attempting to detect a brief target. In addition, participants were told that the objects that were displayed before the appearance of the target were absolutely irrelevant to the task and therefore could be ignored. Error responses were immediately followed by a short "beep"-tone from the computer. Participants were timed out if they did not respond within 3000 ms. A half minute break divided the experiment into three blocks. Each block consisted of a different set of object stimuli. The objects were randomly assigned to one of the three blocks. During the break, the monitor displayed text to the participant that indicated the length of the break and instructions for carrying on with the experiment.

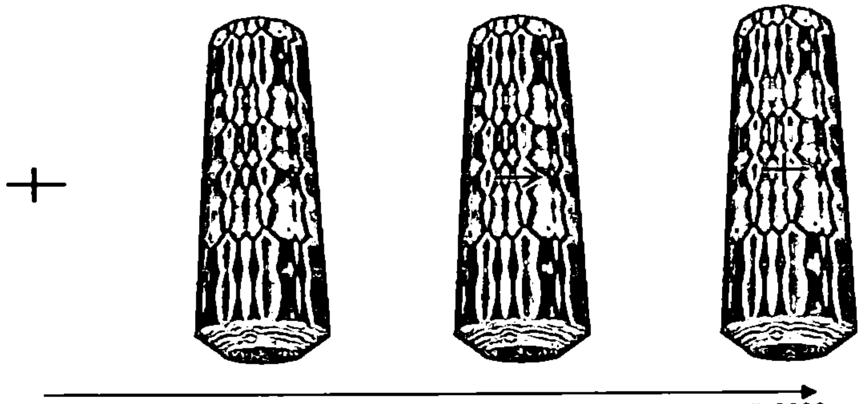


Figure 5.3 The illustration of design used in Experiment 7.

5.2.3 Results

Response times. Reaction times (RTs) were cropped for each participant's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object size (small or large), SOA (150 ms, 300 ms or 600 ms), grip type (precision or power), and the between participants factor of mapping rule (M1: right-hand/power grip, left-hand/precision grip and M2: right-hand/precision grip, left-hand/power grip). The analysis revealed a significant main effect of grip type. The power grip responses were made faster (M=277.74 ms) than the precision grip responses (M= 284.70 ms), $F(1,40)=12.59$, $p=.001$, $MSE=6113.64$. In addition, the analysis revealed three two-way interactions. Firstly, participants made faster responses with the power grip in both mappings (M1: right-hand/power grip, M= 268.57 ms; left-hand/precision grip, M= 280.40 ms, M2: right-hand/precision grip, M= 289.01 ms; left-hand/power grip, M= 286.91 ms), $F(1,40)=6.15$, $p=.017$, $MSE=2984.64$. Secondly, in mapping 1, participants made faster responses when object was large (M=273.32 ms) rather than small (M=275.65 ms), and in mapping 2, participants made faster responses when object was small (M=286.97 ms) rather than large (M=288.94 ms), $F(1,40)=5.16$, $p=.029$, $MSE=581.75$. Thirdly, participants made faster precision grip responses when object was small (M=282.90 ms) rather than large (M=286.50 ms). Similarly, participants made faster power grip responses when object was large (M=275.75 ms) rather than small (M=279.72 ms), $F(1,40)=23.21$, $p<.001$, $MSE=1804.23$. This two-way interaction indicated the occurrence of the object-size effect. However, the analysis also revealed a significant three-way interaction between object size, grip type and mapping, $F(1,40)=27.74$, $p<.001$, $MSE=2156.26$. This interaction is of most interest because the experiment aimed to investigate whether visually guided precision and power grips could be associated with manual asymmetries. Therefore, a separate analysis of the interaction effects in each mapping was carried out.

[Mapping 1] The analysis (a repeated measures ANOVA) did not reveal a significant interaction between object size and grasp type [$F(1,20)=7.84$, $p=.668$, $MSE=.189$] indicating the absence of an object-size effect. The effect was absent in each SOA condition (see Figure 5.4).

[Mapping 2] Most importantly, this analysis (a repeated measures ANOVA) revealed a significant two-way interaction between object size and grasp type [$F(1,20)=34.65$, $p<.001$, $MSE=3952.65$] indicating an overall advantage of precision grasp (right hand) responses for small objects and power grasp (left hand) responses for large objects. Precision grasp responses were faster when viewed objects were small (M=284.06 ms) rather than large (M=293.95 ms). Similarly, responses performed with large switch were faster when viewed objects were large (M=283.93 ms) rather than small (M=289.89 ms). The analysis did not reveal a significant three-way interaction between object size, SOA and grip type [$F(2,40)=1.29$, $p=.286$, $MSE=74.96$], suggesting that all SOAs were associated with the object-size effect. However, because one of the central focuses of the experiment was to

explore manual asymmetries in grasp computing, a separate analysis of the simple interaction effects at each SOA was carried out. The analysis of the simple interaction effects revealed, again, a significant object-size effect in every SOA. The interactions in each SOA condition are displayed in Figure 5.5.

Finally, the analysis was carried out for simple interactions of object size by SOA separately for responses of two hands. This analysis was carried out because a separate analysis of the simple interaction effects at each SOA suggested that the size of the effect was dependent on whether the responses were performed with the left or right hand and whether the object was presented for a short (SOA 150) or long (SOA 600) duration. This analysis revealed a highly significant two-way interaction between the object size and SOA for right hand-precision grasp responses, $F(2,40)=8.89$, $p=.001$, $MSE=375.79$. Additionally, the linear trend between the object size and SOA was highly significant (i.e., the object-size effect on right hand responses increased significantly from SOA 150 to SOA 600), $F(1,20)=23.39$, $p<.001$, $MSE=688.10$. In contrast, when the same analysis was carried out for left hand-power grasp responses the results showed a hint of opposite pattern. The two-way interaction was marginally significant [$F(2,40)=2.95$, $p=.064$, $MSE=155.38$] as well as the linear trend between the object size and SOA, $F(1,20)=4.30$, $p=.051$, $MSE=270.77$. This suggests that the effect was larger on responses performed with the left hand (power grasp) when the duration of object presentation was short. In contrast, the effect was larger on responses performed with the right hand (precision grasp) when the duration of object presentation was longer. These differentially developing and diminishing time courses in mapping 2 (average effects in each SOA) between precision grip/right hand and power grip/left hand are displayed in Figure 5.6.

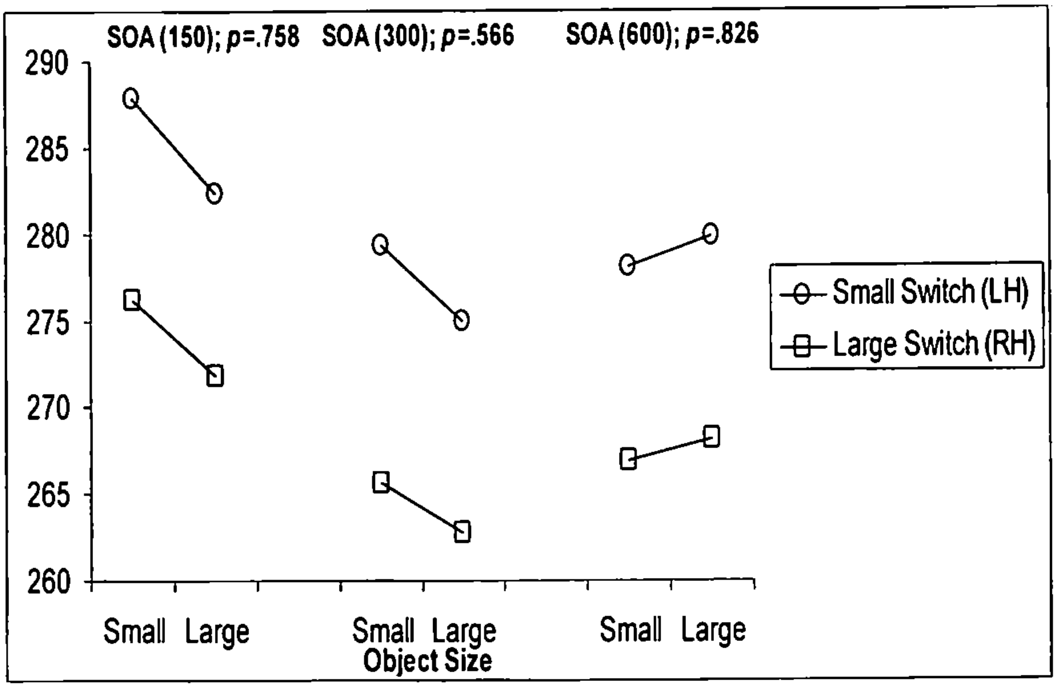


Figure 5.4 Mean RTs for Experiment 7 (mapping 1) as a function of SOA, object size and grip type.

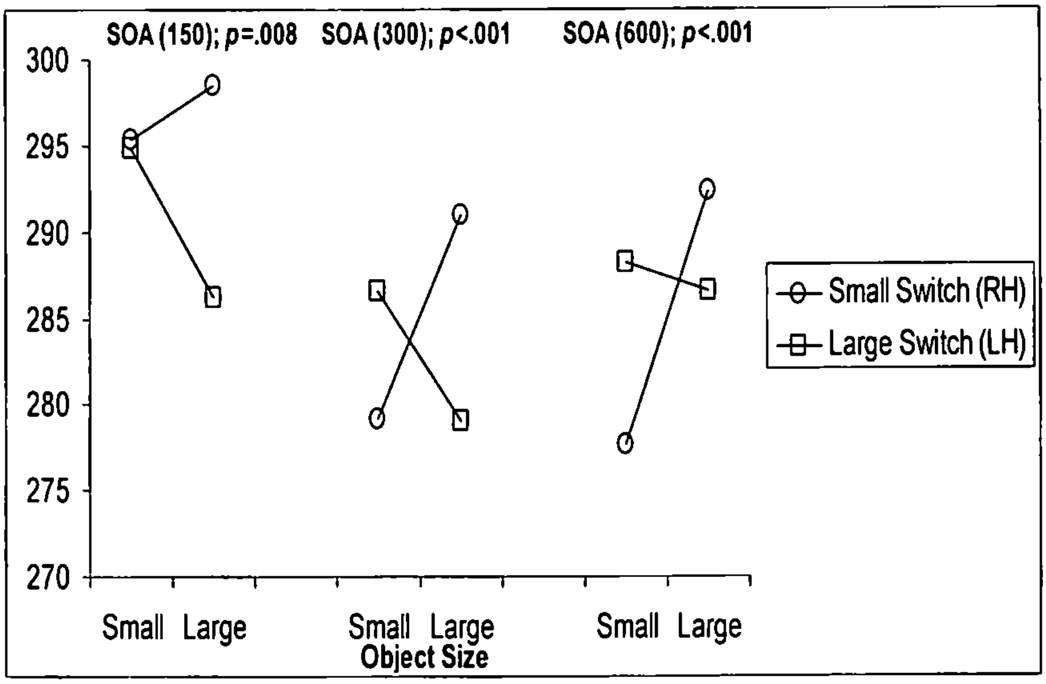


Figure 5.5 Mean RTs for Experiment 7 (mapping 2) as a function of SOA, object size and grip type.

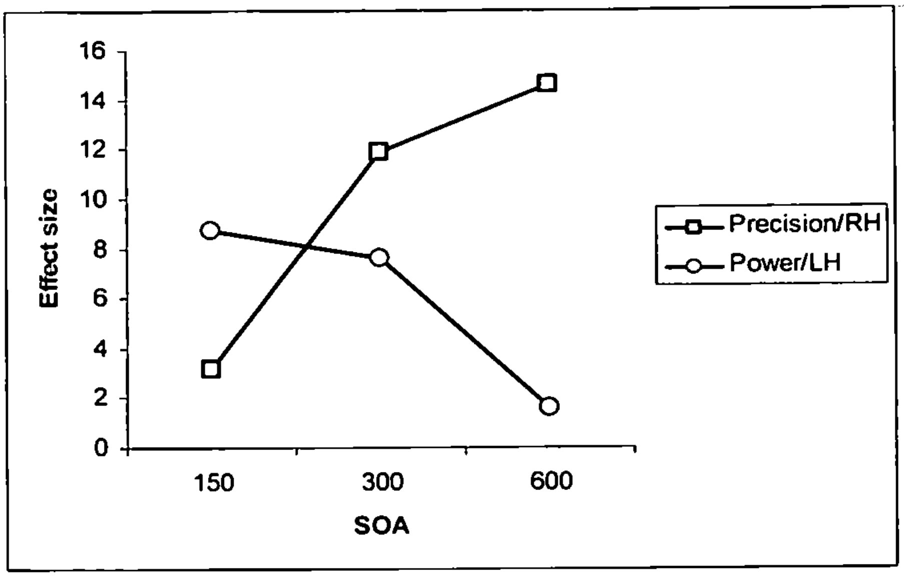


Figure 5.6. Average quintile effect sizes in mapping 2 (incompatible-compatible quintile averages).

Errors. The mean error rate was 2.81 %. Analysis of the error rates revealed a significant main effect of grip type. Participants made more errors with the precision grip (M=3.54 %) than with the power grip (M=2.08 %), $F(1,40)=21.77$, $p<.001$, $MSE=266.76$. In addition, the analysis revealed a significant two-way interaction between grip type and mapping. In mapping 1, participants made less errors with the power grip (M=1.74 %) than with the precision grip (M=4.06 %). Similarly, in mapping 2, participants made less errors with the power grip (M=2.43 %) than with the precision grip (M=3.02 %), $F(1,40)=7.60$, $p=.009$, $MSE=93.14$. However, two-way interaction between object size and grip type was not observed, $F(1,40)=.365$, $p=.549$, $MSE=3.00$. Interestingly, the analysis revealed a significant three-way interaction between object size, grip type and mapping, $F(1,40)=15.75$, $p<.001$, $MSE=129.58$. This interaction is of interest, and therefore a separate analysis of interaction effects at each mapping was carried out.

[Mapping 1] The analysis (a repeated measures ANOVA) revealed a significant two-way interaction between object size and grip type. Participant made fewer errors with the power grip when the object was small (M=1.46 %) rather than large (M=2.03 %). Similarly, participants made fewer errors with the precision grip when the object was large (M=3.48 %) rather than small (M=4.63 %), $F(1,20)=5.39$, $p=.031$, $MSE=46.57$. This was true across

all SOAs (the three-way interaction between object size, SOA and grip type: F(2,40)=2.29, *p*=.115, *MSE*=25.077). This result is surprising because it suggests that when the grip type corresponds with the object size, participants make more errors. This interaction is displayed in Figure 5.7.

[Mapping 2] Analysis (a repeated measures ANOVA) of error rates revealed a pattern of results similar to that for response times in mapping 2. The analysis revealed a significant two-way interaction between object size and grip type. Participant made fewer errors with the power grip when the object was large (M=1.76 %) rather than small (M=3.09 %). Similarly, participants made fewer errors with the precision grip when the object was small (M=2.51 %) rather than large (M=3.53 %), F(1,20)=10.99, *p*=.003, *MSE*=11.15. This was true across all SOAs (the three-way interaction between object size, SOA and grip type: F(2,40)=.71, *p*=.498, *MSE*=4.807). Interestingly, the patterns of the two-way interaction between grip type and object size were opposite in the two mappings. Therefore, it is more likely that the significant two-way interaction in error data in both mappings reflects a two-way interaction between hand of response and object size rather than an interaction between grip type and object size. That is, participants are keener to respond with the right hand when the viewed object is small and with the left hand when the viewed object is large. This interaction is displayed in Figure 5.8.

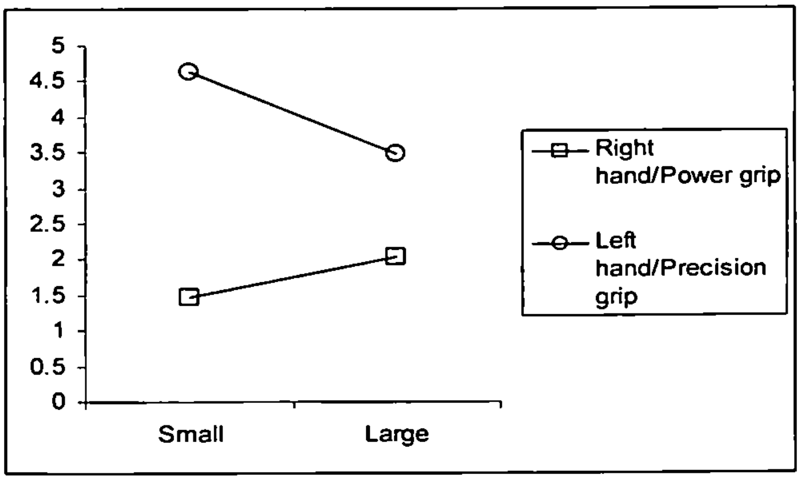


Figure 5.7 Mean error rates for Experiment 7 (mapping 1) as a function of object size and grip type.

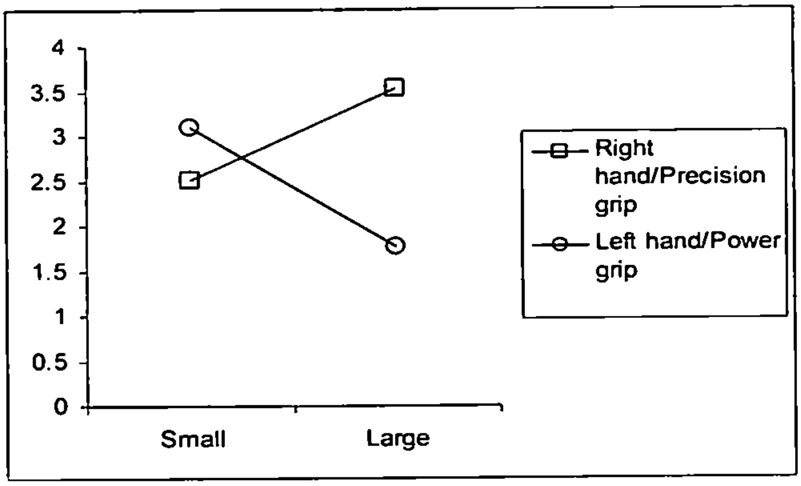


Figure 5.8 Mean error rates for Experiment 7 (mapping 2) as a function of object size and grip type.

5.2.4 Discussion

The main finding of the present experiment was that there seem to be manual asymmetries in precision and power grip programming triggered by a visual stimulus. The object size was observed to facilitate precision and power grip responses in mapping 2 when the precision grip was held in the right hand and power grip was held in the left hand. In contrast, in mapping 1, when the grips were held in the opposite hands, the object-size effect was absent. The fact that viewing small objects was associated with the facilitation of precision grasp responses only when the precision switch was held in right hand suggests dominance of the left hemisphere in the computing of visually guided precision grasps. In contrast, the fact that the large objects facilitated left hand responses only when the power grip was held in that hand suggests that visually guided power grip is computed predominantly in the right hemisphere. As mentioned above, studies examining the visually guided reaching indicate that the right hand is superior in skilled and precise movements. This right hand advantage seems to decrease when also the precision requirements of the task decrease. Our data, which showed manual asymmetries in visually guided grasping is consistent with these earlier suggestions of the nature of manual asymmetries with addition that when the prime object is large enough so that it could be grasped by the power grip, the left hand system appears to show advantage.

In addition to the manual asymmetries in reaction times, also the error data suggested that the left hand system could be facilitated automatically by viewing a visual object that could be the potential target of the power grasp, whereas the right hand responses are afforded automatically by prime object that could be potential target of the precision grasp. In other words, not only was the right hand superior in visually guided precision grip and the left hand in the power grip but also the error data suggested that responses are performed preferably with the right hand when small objects are viewed and with the left hand when large objects are viewed, regardless of whether the hand was holding the precision or power grip.

Interestingly, the left and right hand responses were associated with the differential time courses of the object-size effect in mapping 2. The results of the experiment suggested that the object-size effect associated with the left hand-power grip begins to build shortly after onset of the object and decreases with longer presentation times of the object. In contrast, the effect associated with the right hand-precision grip begins to build slightly later and increases with longer presentation times of the object. This may also correspond to the results of previous research of manual asymmetries in movement planning and control. It has been shown previously that when an aiming movement is decomposed into component parts, the left hand is often faster in the initiation of movement (e.g. Velay & Benoit-Dubrocard, 1999). The left hand advantage in reaction times is often attributed to right hemisphere involvement in the early stages of spatial movement planning (e.g. Hodges, Lyons, Cokell et al., 1997). In contrast, previous research has shown a right hand superiority in online control of visually guided reaching (e.g. Mieschke, Elliott, Helsen, Carson & Coull, 2001), which is attributed to a greater ability of the left hemisphere in the processing perceptual and/or motor information during the ongoing movements (Annett, Annett, Hudson & Turner, 1979) as mentioned above. Our result may reflect the same visuomotor mechanisms that are related to faster planning of left hand responses and superior control of right hand responses. Furthermore, Experiment 3 showed that the orientation of the object's principal axis of elongation (the low-level affordance) facilitates orientation compatible responses of the right hand in the shorter and longer SOAs, whereas the left hand responses were facilitated only in the shorter SOA. The same trend was not observed when the real objects with the functional handles were guiding participants' responses. Therefore, it is likely that the right hand superiority in access to visual updates is associated only with low-level affordances. However, the suggested link between differential time courses of the left and right hand responses, which were found in the present experiment, and the previously established differences in the left and right hand control and planning is rather speculative. That is, because the online control of goal-directed movements is traditionally associated with the effects of stimuli on ongoing movements, whereas in our study movement is not 'going on' during the object presentation. Nevertheless, our data is consistent with the right hand system having access to continuous updates of visual information, whilst the left hand system does not benefit from such closed-loop visual feedback.

Three secondary findings were obtained in the present experiment. Firstly, the object-size effect could be observed even with task-irrelevant prime objects, suggesting that the object size can trigger the grip plan even in the absence of the forced allocation of endogenous attention to the object. This suggests that the same attentional mechanisms may underlie both effects of micro-affordance because object orientation was also observed to facilitate the orientation compatible responses in Experiments 1 and 3. That is, resources of endogenous attention are not required for the generation of the object-size effect but rather resources of focused (exogenous) attention are sufficient for observing the effect. Secondly, it was found that viewed objects facilitate the precision and power grip responses even when the grasp type is a task-irrelevant response dimension. Therefore, the object size is capable of facilitating directly the size compatible grips in the absence of explicit coding of the required responses as the precision and power grips. Therefore, the effect can be observed even when the cognitive factors, which are related to response selection, are minimized. Thirdly, the results showed that the object size can automatically facilitate the size compatible responses even when the object does not have any semantic associations. This result replicates the finding of Tucker and Ellis (in preparation), which showed that the size of a novel object could facilitate the size compatible grip responses when the object is categorized. Therefore, this result supports the view that size could be extracted for grip programming not only from the semantic route from stimulus to action but also from the visual route from stimulus to action. Finally, it should be mentioned that the (bi-manual) object-size effect, which was reported by Tucker and Ellis (2001), was slightly (a few milliseconds) larger than the effect that was observed in mapping 2 in the present experiment even though Tucker and Ellis (2001) included both mappings in their analysis. When both mappings were included to the analysis of the present experiment, the effect was only marginal (around four milliseconds). This suggests that the effect increases in the appropriate mapping (left hand-power grip/right hand-precision grip) when attentional resources are allocated increasingly to the object (categorization task). Alternatively, this suggests that the maual asymmetries reduce when attentional resources are allocated increasingly to the object. In other words, the effect (whose size corresponds with the size in mapping 2 in the present experiment) can be observed in both mappings when the task requires object categorization. These options are discussed in more detail in the general discussion of Chapter Five.

5.3 Experiment 8

Experiment 8 aimed to examine whether the task irrelevant prime objects, which were used in Experiment 7, could similarly facilitate precision and power grips even when attention is focused on a task-relevant item during the prime presentation. In other words, Experiments 2 and 4 are replicated with the grip compatible prime stimuli. Again, it may be expected that if attention were responsible for the object affordance effects, the object-size effect would be partly or fully eliminated by engaging the observer's attention during the prime object presentation. When the task does not require any disengagement from the fixation target and the target is presented during the prime object presentation, it could be expected that the participant has neither external (the offset of fixation cross) nor internal (the task requirement) need to disengage from fixation. In fact, because the target is presented at the fixation cross, optimal performance would be facilitated by fixating the target location throughout the trial. Therefore, depending on how effective the central fixation cross is in suppressing the attentional processes within the prime object in the present paradigm, the object-size effect is predicted to be partly or fully eliminated by presenting the fixation cross over the prime object. Thus, the experiment examined whether the compatibility effect found in Experiment 7 (mapping 2) could be replicated when the attentional resources allocated to the prime object are suppressed by presenting a behaviourally relevant fixation cross simultaneously with the prime object. If keeping the fixation cross over the prime object would have as a dramatic affect on object-based motor priming in the present experiment as it had in Experiments 2 and 4, it may be assumed that the object-orientation effect and the object-size effect involve the same attentional mechanisms.

5.3.1 Method

Participants

Twenty-one participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naive as to the purpose of the experiment. All participants signed the participation form by their right hand and additionally explicitly reported that they were right handed.

Apparatus and Stimuli

Apparatus, response device, and stimuli were same as those used in Experiment 7.

Design and Procedure

The design and procedure were identical to those of Experiments 7 (mapping 2: participants held the small switch in their right hand and the large switch in their left hand) with one small difference. In this experiment the fixation cross was not removed from the display before the appearance of the target.

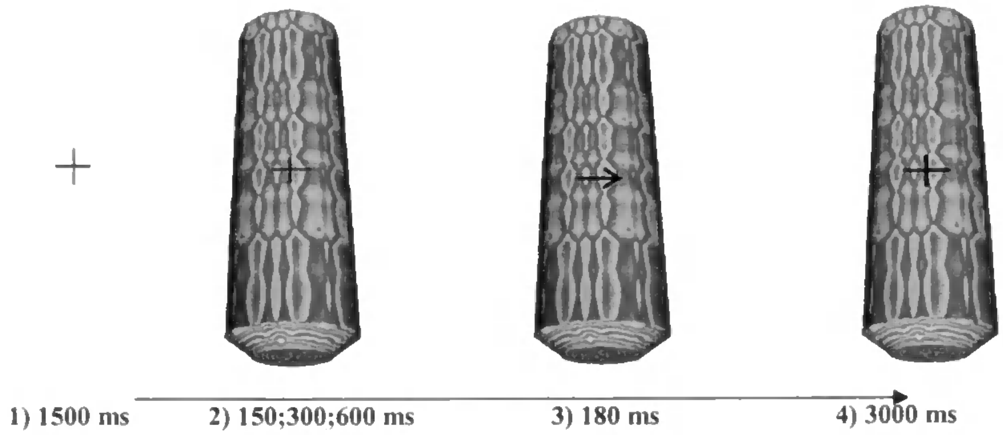


Figure 5.9 The illustration of design of Experiment 8.

5.3.2 Results

Response times

Reaction times (RTs) were cropped for each participant's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object size (small or large), SOA (150 ms, 300 ms or 600 ms), and grip type (precision or power). One participant was removed from the analysis because his/hers error rate exceeded 2 SD from the error rate means. The analysis revealed a significant main effect of SOA. The pattern of RTs in this main effect suggested that responses were performed slower in SOA 150 (M= 310.62 ms) than in SOA 300 (M= 293.42 ms) or SOA 600 (M= 295.89 ms), $F(2,38)=42.51$, $p<.001$, $MSE=6920.74$. The analysis did not reveal any significant two-way interactions. Most importantly, the data did not reveal a significant interaction between object size and grasp type [$F(1,19)=2.55$, $p=.127$, $MSE=200.53$] indicating the absence of object-size effect. In addition, the three-way interaction between object size, SOA, and grip type was not significant [$F(2,38)=.61$, $p=.551$, $MSE=30.70$] suggesting that the object-size effect was absent in every SOA.

Because the main focus of the current experiment was to examine whether the object-size effect would be eliminated by presenting the fixation cross during the prime object display, an omnibus ANOVA was carried out to analyze the data of both Experiments 7 (mapping 2) and 8 in a single ANOVA. Importantly, this analysis revealed a significant three-way interaction between size, grasp-type and experiment indicating significant differences in the object affordance effects of the two experiments, $F(1,39)=11.79$, $p=.001$, $MSE=1140.81$. The interactions in each SOA condition are displayed in Figure 5.10.

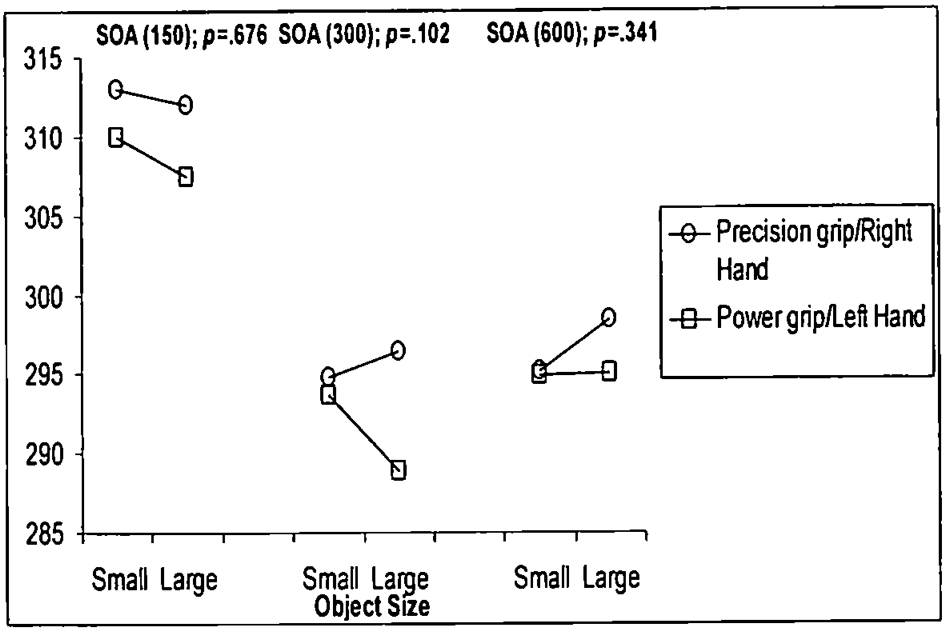


Figure 5.10 Mean RTs for Experiment 8 as a function of SOA, object size and grip type.

Errors

The mean error rate was 1.74 %. Two participants did not make any mistakes. Analysis of percentage error rates did not reveal any significant main effects or interactions. The interaction between object size and grip type in mistakes is displayed in Table 5.1.

Means Table for Errors

Size	Grip	%	SE
Small	Prec./Right	1.90	.31
Large	Prec./Right	1.96	.44
Small	Po./Left	1.65	.36
Large	Po./Left	1.44	.39

Table 5.1 Mean error rates for Experiment 8 as a function of object size and grip type.

5.3.3 Discussion

Most importantly, the results of Experiment 8 showed that the object-size effect is absent when the resources of focused attention are allocated to the fixation cross during the prime presentation. The compatibility effect was suppressed in all SOAs. Therefore, the results of Experiments 2 and 4 were replicated with the object size as the object affordance. These results suggest again the importance of attention in object affordance effects. It is important to emphasize that the replication of results of Experiments 2 and 4 with the object size as the object affordance supports the argument that the object-orientation effect was suppressed in Experiments 2 and 4 due to suppression of object-based allocation of attention to the prime object, not due to suppressed attentional shift to the handle location. That is, because the attention shift cannot be used to explain the object-size effect, and yet the similar elimination of both effects, the object-orientation effect and the object-size effect, was observed when attention was focused on the fixation cross during the prime onset. Therefore, the results supports the view that the same attentional mechanisms underlie the object-orientation effect and the object-size effect.

5.4 Experiment 9

Traditionally facilitatory and inhibitory cueing effects have been produced by orienting of attention to the cue, which is presented to the right or left of the central fixation point. However, it is not known whether similar facilitation and inhibition could apply to situations, in which grasp type is cued by visual stimulus. According to the premotor account of attention, the orienting of attention prepares saccades and all other effectors that are involved in achieving current behavioural goals. In addition, Craighero et al (1999) suggested that the premotor theory of attention may be extended from orienting of attention to spatial locations to orienting of attention to graspable objects. If this assumption is correct, it may be expected that similar facilitatory and inhibitory effects would occur with prime object properties that prepare movements to the location of the object as well and with properties that prepare grasping. Importantly for the present purposes, Tucker and Ellis (2001) observed neither facilitatory nor inhibitory influence of size of the goal object on gasping. They showed that the object-size effect is not observed if the go/no-go object disappears 300 ms before the onset of the response cue. However, the traditional cueing studies, which explore cueing effects of the task-irrelevant stimulus, have been shown to produce the facilitatory effect in 50 ms – 300 ms delay condition while the inhibitory effect has been observed in 300 ms – 2000 ms delay condition. Therefore, it is not clear whether a 300 ms delay, which was used by Tucker and Ellis (2001), would better suit to study inhibitory or facilitatory effect. In fact, a 300 ms delay may correspond to the point at which motor facilitation changes into motor inhibition, and perhaps that was the reason why the objects did not have any observable effect on responses in this delay condition. Therefore, Experiment 9 introduces three different delay times between object extinction and the onset of the response cue. In addition to a 300 ms delay between object extinction and the onset of the response cue, one shorter (50 ms) and one longer (700 ms) delay are introduced to further examine the time course of object-related motor activation after extinction of the prime object. It is predicted that if orienting of attention to graspable objects prepare grasping like orienting of attention to the target location prepares keypress responses; 50 ms delay time would produce a facilitatory cueing effect on grasp responses while a 700 ms delay time would produce an inhibitory cueing effect on grasp responses.

5.4.1 Method

Participants

Twenty participants took part in the experiment and were each run in individual 25-min sessions. All were students at the University of Plymouth and received course credit for their participation. Informed consent was obtained from each subject prior to commencing the task. All participants reported having normal or corrected-to-normal vision and were naive as to the purpose of the experiment. All participants signed the participation form by their right hand and additionally explicitly reported that they were right handed.

Apparatus and Stimuli

Apparatus, response device, and stimuli were same that those used in Experiments 7 and 8.

Design and Procedure

The design and procedure were identical to those of Experiments 7 (mapping 2) and 8 with one small difference. In this experiment, the object was presented only for 340 ms instead of SOAs of 150 ms, 300 ms, and 600 ms. In addition, the object disappeared 50 ms, 300 ms or 700 ms before the target was displayed. During this randomised delay period the fixation cross was presented on the screen. After the delay period, the target was presented, again, for 180 ms before it changed back into fixation cross.

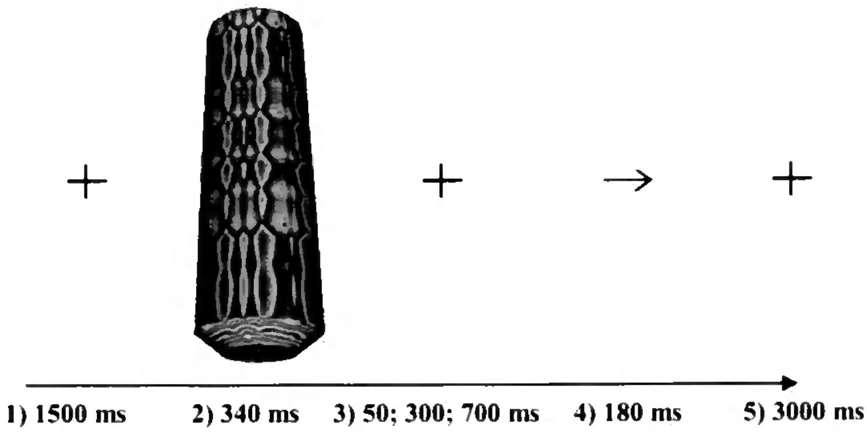


Figure 5.11 The illustration of design of Experiment 9.

5.4.2 Results

Response times

Reaction times (RTs) were cropped for each participant's data (RTs two standard deviations from each participant's overall mean were discarded) and condition means for the remaining data were computed. Error trials were excluded from the analysis. Condition means were subjected to a repeated measures ANOVA with the within participants factors of object size (small or large), SOA (50 ms, 300 ms or 700 ms), and grip type (precision or power). The analysis revealed a significant main effect of SOA, $F(2,38)=38.08$, $p<.001$, $MSE=12801.23$. The pattern of mean RTs suggested that participants made faster responses in SOA 300 (299.00 ms) and SOA 700 (302.24 ms) than in SOA 50 (322.35 ms). The analysis did not reveal any significant two-way interactions. Additionally, a three-way interaction between size, SOA and grasp type was not significant, $F(2,38)=1.11$, $p=.339$, $MSE=121.06$. However, because the central focus of the experiment was to investigate whether the object size influences responses differentially in different SOAs, we carried out separate analyses of the simple interaction effects at each SOA. The separate analysis (a repeated measures ANOVA) for SOA 1 revealed a significant interaction between object size and grip-type [$F(1,19)=5.49$, $p=.030$, $MSE=423.56$] indicating a significant object-size effect. However, the analysis did not reveal a significant interaction between object size and grip type in SOA 2 or SOA 3. The interactions between grasp-type and object-size in each SOA condition are displayed in Figure 5.12.

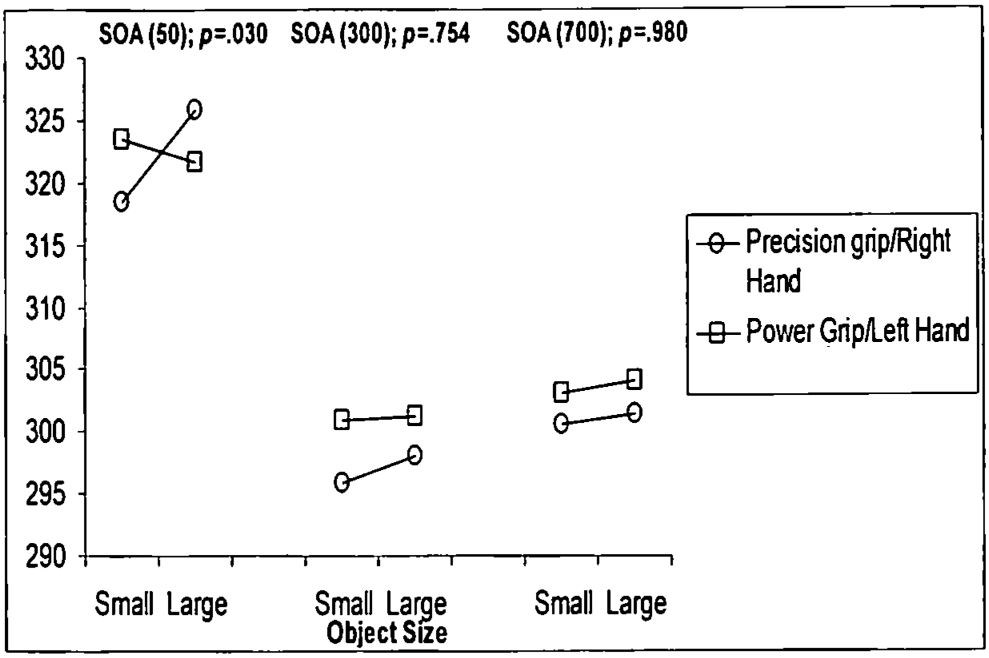


Figure 5.12 Mean RTs for Expriment 9 as a function of SOA, object size, and grip type.

Errors

The mean error rate was 2.21 %. An analysis of error rates did not reveal any significant main effects or interactions. However, the interaction between grasp-type and object-size was nearly significant, $F(1,19)=3.74$, $p=.068$, $MSE=4.54$. This interaction showed that participants made slightly fewer errors when the grip-type and object-size were corresponding than when they were not corresponding. Furthermore, the three way interaction between object size, SOA, and grip type was not siginificant [$F(2,38)=.134$, $p=.875$, $MSE=1.83$] suggesting that the trend of two-way interaction between the object size and the grip type was similar in the each SOA. The interaction between object size and grip type in mistakes is displayed in Table 5.2.

Means Table for Errors

Size	Grip	%	SE
Small	Prec./Right	2.18	.59
Large	Prec./Right	2.82	.79
Small	Po./Left	2.36	.64
Large	Po./Left	1.48	.37

Table 5.2 Mean error rates for Experiment 9 as a function of object size and grip type.

5.4.3 Discussion

The results of Experiment 9 suggest that the object-size effect is still present when the target is displayed 50 ms after the prime object is removed from view. However, this effect is completely eliminated in SOA 300 ms and 700 ms conditions. Furthermore, responses are not inhibited in either of these longer SOAs. These data suggest that the effect disappears shortly after removal of the viewed object, and there is no inhibitory effect when the response is performed after extinction of the task-irrelevant prime object. Additionally, these data suggest that visually guided grasp preparation, which was supposed to be based on orienting of attention to a graspable object, is not controlled by similar inhibitory mechanisms as visually guided movements, such as saccades or reaching, that are supposed to be based on orienting of attention to the target location. Therefore, the inhibitory effect might be characteristic in attentional mechanisms that are related to exploring the viewed scene or object (e.g., inhibiting the return of attention to the location in which attention was previously visited). Finally, the results of Experiment 9 are consistent with view that object affordance effects reflect the real time visuomotor transformations of the dorsal system.

5.5 General discussion for Experiments 7-9

The results of Experiments 7-9, that employed the object-size effect in studying the integration of vision and action, showed that the object size influences responses in the same manner as the object orientation under the same attentional constraints. Firstly, the results of Experiment 7 (mapping 2) showed that the object-size effect could be observed with novel objects even when the object itself is a task-irrelevant stimulus dimension. Because Experiments 1 and 3 also showed that the object-orientation effect could be observed even when the prime object is task-irrelevant, it can be asserted that both effects of micro-affordance can be observed in the absence of the forced allocation of endogenous attention to the prime object. In addition, the results of Experiment 8 showed that the object-size effect is fully or partly eliminated when a behaviourally more relevant item is displayed over the prime object. This finding replicated those results that were observed with the object-orientation effect. These similarities between results of the two different effects of micro-affordance suggest that the same attentional elements underly both micro-affordance effects. However, in addition to showing similarities in underlying attentional mechanisms between the two effects, Experiments 7-9 also suggested lateralization in object affordances. These aspects of lateralization are discussed below.

5.5.1 Lateralization of visually guided grasp behaviour

The results of Experiment 7 showed manual asymmetries in object-guided precision and power grasp behaviour. The object size potentiated corresponding grasp responses only when the precision grip was held in the right hand and power grip was held in the left hand. When the grips were held in the opposite hands, the object-size effect was eliminated. The results of Experiments 7 suggested that object-guided precision grip responses are computed predominantly in the left hemisphere while power grip responses are computed predominantly in the right hemisphere. As discussed above, it has been shown that the right hand is superior in programming motor processes of skilled and precise movements and this right hand advantage decreases when also the precision requirements of the task decrease. The results of the present experiments in which object affordances were used to examine manual asymmetries are compatible with these earlier suggestions of the nature of manual asymmetries. Furthermore, the error data suggested that participants prefer to respond, in general, with their right hand when the prime object is small rather that large, whereas they prefer to respond with their left hand when the prime is large rather than small. Thus, it would be tempting to suggests that the 'small' and 'large' object sizes influence differentially motor planning in the left and right hemispheres resulting in manual asymmetries in the precision and power grip. The finding may have important implications in understanding the way visual objects are represented integrated with the potential actions they afford. Natural selection may favour the cortical organization in which the object attributes (e.g. size) and grasping skills that are linked to this object attribute are represented on one side of the brain so that they could be rapidly accessed or executed.

5.5.2 The relationship between laterally organized precision and power grips and global/local processing

It is often reported that the left hemisphere processes local stimulus information preferentially, while the right hemisphere is specialized for processing the global aspects of sensory input (see Robertson & Lamb, 1991, for review). An alternative explanation of the current results is that they reflect this hemispheric specialization in local/global processing, in which the 'small' (local) stimuli is processed predominantly in the left hemisphere, which in turn facilitates all responses that are programmed in the same hemisphere. Similarly, the 'large' (global) stimuli may facilitate all responses that are programmed in the right hemisphere. In fact, the error data appear to support this argument because they show that right hand responses were more accurate when a viewed object was small, whereas left hand responses were more accurate when a viewed object was large, regardless of whether the hand was holding the precision or power switch. It might be argued that these results do not reflect the affect of object (size) affordance on grasping, but rather the affect of object size to all responses that are programmed in the corresponding hemisphere. However, it is not likely that this view is correct because the same *'small-right hand/large-left hand'* effect was not observed in mapping 1. In fact, in mapping 1, right hand-power grip responses were marginally facilitated by large objects compared to small objects (in SOA 1 and 2) even though the right hand was performing power grip responses, which may be assumed to be relatively easy grasp to make with the dominant hand.

Additionally, it may be argued that the size effect was overshadowed in mapping 1 (RH-power/LH-precision) by the anatomical weakness of the non-dominant hand in performing the precision grip responses. In fact, in mapping 1 (in SOA 1 and 2), the facilitation of the right hand-power grip responses is as would be expected from an affordance effect. According to this view, visually triggered planning and/or control of precision and power grip (i.e., object affordance) is not lateralized, but rather the manual asymmetries are due to the right hand superiority in *executing* precision grip responses. However, the fact that also left hand-precision grip responses appear to be facilitated by large objects does not support this view. In fact, the results suggest that in mapping 1 large objects facilitate responses of both hands in SOA 1 and 2. Interestingly, it is often observed that responses to global targets are faster and more accurate than responses to local targets (e.g., Navon, 1977). It is possible that the main effect of object size in mapping 1 (particularly in SOA 1 and 2) reflects this *global-to-local precedence*. However, it is tempting to suggest that the global-to-local precedence effect is overshadowed by the size affordance effect in mapping 2 when the grip to hand arrangement fits the hemispheric specialization in visually guided precision and power grip programming.

It is possible that the hemispheric specialization in visually triggered planning and/or control of the precision and power grips may have its origin in hemispheric specialization in global/local processing or alternatively precede this hemispheric specialization in global/local processing. For example, often in manipulation movements, in which a precision grip is presumably an integral part, one hand is holding the 'global' object while the other hand is doing precise manipulations with the 'local' component of the object. In fact, the two hands typically have complementary roles, and in about two-thirds of animals observed, it was the right hand that had the role requiring more precise manipulations (see Corballis, 2002 for review). Therefore, it is possible that there is a tight link between laterally organized precision and power grips and global/local processing.

5.5.3 Manual asymmetries in relation to time courses

The object-size effect that was found in Experiment 7 (mapping 2) suggests manually asymmetrical time courses of the object affordance effects. This corresponds with the manual asymmetries in the movement planning and control of reaching that have been found in the previous studies. However, before discussing the results of Experiment 7 (mapping 2), it is important to remind the reader of two fundamental aspects that are related to manual asymmetries in movement control and planning. Firstly, as mentioned in Chapter Two, planning and control are assumed to involve separate brain systems. The planning system appears to rely on regions in the inferior parietal lobe, whereas the control system appears to rely on older regions in the superior parietal lobe (see Glover, in press). Secondly, as stated above, the right hemisphere is suggested to be involved predominantly in movement planning, resulting in faster initiation of left hand responses to visual signals. In contrast, the left hemisphere was assumed to be involved predominantly in movement control resulting in superior on-line control of the right hand (see Boulinguez et al., 2001 for review). Interestingly, the present data suggests that the object-size effect, in relation to the power grip responses of the left hand, seems to develop faster and diminish more rapidly after the onset of the prime object. This result may reflect the same visuomotor mechanisms that are related to the superior planning and the worse control of the left hand in goal-directed manual aiming tasks. In contrast, the advantage of right hand responses in object-guided precision grips seems to build up slower and develop with increasing SOA. This result may correspond with earlier reports of right hand superiority in the online control of goal-directed arm movements. In fact, the result of Experiment 7 (mapping 2) suggests that the right hand system may be guided by action-related low-level object properties, such as size, whilst the object remains in view (or at least for 600 ms after onset of the prime) even when the object itself is a task-irrelevant. A similar superiority of the right hand control system in extracting low-level affordance information was found in Experiment 3. Therefore, our data are consistent with the right hand system having superior access to continuous updates of visual information, whilst the left hand system does not benefit from such closed-loop visual feedback. This in turn might suggest that the established superiority of the right hand in on-line control is more based on visual feedback processes instead of motor feedback processes. Finally, this visual feedback information is presumably imported from the dorsal stream in action control (e.g. Milner & Goodale, 1995), suggesting the tight relationship between the right hand control system and the dorsal stream processes. Taken together, it would be tempting to argue that the same visuomotor mechanisms that support right hand movements during ongoing visually guided arm movements in manual aiming tasks are also responsible, to some extent, for the gradual development of object affordance effects, which are linked to the right hand system. However, the suggested link between differential time courses that were found in the present experiment and the superiority of the right hand in movement control is rather speculative because the obvious differences between the manual aiming task and the present task.

5.5.4 Manually asymmetrical results discussed in relation to previously reported affordance effects

In contrast to the results of Experiment 7, Tucker and Ellis (2001) did not report manual asymmetries in visually guided grasp behaviour even when participants performed responses bi-manually. Nevertheless, the effect they observed was slightly (few milliseconds) larger than the effect that was observed in mapping 2 in the present experiment. When both mappings were included in the analysis in the present experiment the effect was only marginal. This suggests that the effect may increase in the appropriate mapping (left hand-power grip/right hand-precision grip) when attention is allocated increasingly to the object. In fact, it is possible that manual asymmetries were not observed by Tucker and Ellis (2001) because only one experiment in their study used the bi-manual task and even then, the grasp to hand assignment was counterbalanced in a way that analysis could not reveal asymmetries between hands, as mentioned above. Alternatively, it is possible that the maual asymmetries are reduced when attention is allocated increasingly to the object. In other words, it is also possible that the object-size effect was more symmetrical in Tucker and Ellis's (2001) study than in Experiment 7. Therefore, it is important to understand the differences between these two studies that produced these presumably contradictory results.

Firstly, it is important to notice that Tucker and Ellis (2001) used an object categorization task, whereas Experiment 7 used a target discrimination task. The contradictory results may be attributed to the different tasks. In Tucker and Ellis (2001) study, participants were forced to allocate resources of endogenous attention to the object in order to categorize it. In contrast, in Experiment 7, participants were asked to ignore the object. Therefore, they were not required to allocate endogenous attention to the object (certainly not in order to categorize the object). Interestingly, Wuyts, Summers, Carson, Byblow and Semjen (1996) reported that performance of the dominant hand is less affected by allocation of attention than performance of a non-dominant hand. In other words, the correct performance of the left hand requires more attentional resources than the correct performance of the right hand. Therefore, the less attention is allocated to the performance of right and left hands (when performances of two hands are measured in the separate trials) the more asymmetrical performances are expected favouring the right hand. The account of micro-affordance assumes that motor preparation processes are an integral part of object representation. Therefore, it is possible that the more one allocates attentional resources to a visual object, the more one allocates simultaneously attentional resources to these motor preparation processes. It follows that when allocation of attention to an object is decreased, the more asymmetrical results would be expected. In turn, this suggests that when the paradigm requires categorization of the object, like is the case in Tucker and Ellis (2001) study, the increased allocation of endogenous attention to the object also reduces manual asymmetries. The possibility that increased allocation of endogenous attention to the goal object in categorization task would decrease manual asymmetries may warrant further investigation.

Secondly, it is generally agreed that a visual object is processed in stages for recognition. Object recognition involves the extraction of simple visual features of the object, construction of the object's shape, and matching this shape to stored representations (e.g. Farah, 2000). Brain imaging and behavioural studies have suggested hemispheric asymmetries in the processing of these different stages (e.g. Vanni, Revonsuo, Saarinen, & Hari, 1996; Koivisto & Revonsuo, 2003). For instance, Vanni et al. (1996) noted that activity in the right lateral occipital cortex correlated to conscious perception of familiar objects. Importantly for the present purposes, Tucker and Ellis (2001) used only familiar objects. Familiar objects can be associated with high-level affordances, as well as their purely visual size properties (low-level affordances). In contrast, in Experiment 7, the action-relevant size information about objects was extracted from low-level object characteristics. Because semantic attributes and visual attributes may be processed laterally for object recognition, these different attributes may be processed laterally also for action guidance. As a consequence, it is possible that when the goal object is associated with both low and high- level affordances, like is the case in Tucker and Ellis's (2001) study, the object guides actions more symmetrically. In contrast, more asymmetrical guidance would be expected when the goal object is associated with only one of these action-relevant object attributes, like is the case in Experiment 7. In fact, Experiment 3 suggested that when the visually guided actions do not require recognition of the prime object (cylinders), the object affordance effect is more associated with right hand responses. In sharp contrast, when the object needs to be recognized so that the object's orientation can guide actions (mugs and teapots), the object affordance effect appears to be more associated with left hand responses. These asymmetries occurred particularly in the longer SOA (600 ms). Therefore, the results of Experiment 3 support the idea that contradictory results may be associated with the different types of stimuli.

Thirdly, in Tucker and Ellis's (2001) study, participants were asked to respond to object category by pressing the precision or power switch. Therefore, participants were required to code explicitly their responses as precision and power responses. In contrast, in Experiment 7, participants were asked to respond with their right or left hand depending on whether the arrow was pointing to right or left hand side while they were holding precision and power switches in their hands. Therefore, participants were more likely to code explicitly their required responses as left or right hand responses than precision or power responses. It may be assumed that participants are faster in coding responses as left or right hand rather than precision or power grip. Additionally, the directed arrow has been previously associated with automatic hand-motor response activation (e.g. Eimer, 1995; Wascher, Reinhard, Wauschkuhn, & Verleger, 1999). Because, in Experiment 7, participants were required to respond with their left or right hand to the directed arrow, which supposedly facilitates responses, whereas in Tucker and Ellis (2001) study participants were required to respond with the precision or power grip to the object category, responses were performed approximately 200 ms faster in Experiment 7. Therefore, it is possible that activation of object affordance spreads more symmetrically if given 200 ms more time, resulting in contradictory results. Finally, it remains possible that Tucker and Ellis (2001) did not report manual asymmetry of object affordance because that aspect was not simply the focus of the experiment, as stated above. Therefore, it would be important to investigate whether the task used by Tucker and Ellis (2001) leads to similar manual asymmetries, and if it does not, it would be important to examine which factor is responsible for manual asymmetries in Experiment 7.

5.6 Summary

The results of Experiment 7 showed that the object-size effect could be observed with novel objects even when the object itself is a task-irrelevant stimulus dimension and the grasp type is a task-irrelevant response dimension. As stated above, traditionally manual asymmetries in planning and control of visually guided movements have been studied using manual aiming tasks, which employ only the reach component of prehension. However, as already stated, the act of prehension can be separated into two components, grasping and reaching. Importantly, Experiment 7 is a novel paradigm, which allows observation of manual asymmetries in visually guided grasps. Interestingly, when this latter paradigm was employed in the study of manual asymmetries it was found that the right hand is superior in visually guided precision grasps. In other words, the presentation of small objects resulted in the facilitation of precision grasp responses only when the small grip was held in the right hand. In contrast, the planning of the power grip was facilitated when the left hand was performing these grips. These asymmetrical effect are consistent with the previous results of manual asymmetries, which suggests that right hand movements are superior in high precision tasks and this right hand dominance decreases when the task requires lower precision movements.

The results of Experiment 7 also suggested that the visuomotor control system of the right hand might be superior in extracting visual action-relevant object properties in a closed-loop fashion for movement control. Additionally, the results of Experiment 9 showed that the object-size effect diminishes rapidly after offset of the prime object and this facilitation of grasp responses does not result in any inhibitory effect after a relatively long delay period. This showed, perhaps, that the inhibitory mechanisms that operate in the planning of location-based movements do not operate in visually guided grasp planning. Finally, the results of Experiment 8 showed that the generation of the object-size effect is suppressed if endogenous attention is focused on a competing item during the prime object presentation. Therefore, the result of Experiment 8 was consistent with the results of Experiments 2 and 4, which showed that the object-orientation effect is suppressed in the same attentional conditions, suggesting that same attentional mechanisms underly both effects.

CHAPTER 6: GETTING IT TOGETHER

6.1 Summary

This final chapter offers a summary of the previous five chapters and the results of the nine experiments that were carried out to accomplish the main objectives of the thesis. Additionally, this chapter makes recommendations for further investigations. Finally, implications that the empirical work of the current thesis may have on understanding aspects of attention and laterality in visuomotor and cognitive processes are also discussed.

Our account of micro-affordance assumes that the actions an object affords are an intrinsic part of object's representation. The current thesis focused on exploring the nature of visuomotor integration in two effects (the object-orientation and object-size effect) that have previously been shown evidence for the account of micro-affordance. Earlier the behavioural evidence from the Simon effect was cited to demonstrate the integrated nature of vision and action. Furthermore, it was shown that orienting of attention appears to play a fundamental role in integrating stimulus to action. It was also suggested that attention might have an important role in synchronizing connections between visual and motor representations. This evidence led us to assume that attention may have an important role in the effects of micro-affordance. Attention was shown to be controlled by exogenous and endogenous processes and to operate at object-based and location-based levels. These aspects of attention formed the main body of the experimental work of the present thesis. Intuitively, it was assumed that micro-affordance effects would operate at the object-based level because the preshaping of a hand in relation to size of the goal object cannot be computed at the location-based level. This object-based account of the micro-affordance effects, which corresponds with the premotor account of the visuomotor priming effect (Craighero et al., 1999), suggested that orienting of attention to a graspable object prepares the corresponding actions. In other words, it was assumed that under this account the semantic dimensions of the object do not need to be processed (e.g., the functional handle of the object does not need to be located) in order that the object could afford responses. Therefore, it was assumed that the semantic route to action does not need to be involved in extracting affordance information from the object but rather the object affordance information could be extracted from the visual route to action. However, the same premotor account of attention proposes that orienting of attention to a location prepares movements, such as saccades and reaching, which can be programmed at the location-based level (Rizzolatti et al., 1987). Anderson et al. (2002) suggested that this kind of attentional orienting to the location of the handle was responsible for the generation of the response code in the object-orientation effect. Furthermore, it was suggested that if the orienting of attention to the handle location is responsible for the occurrence of the effect, the semantic route from stimulus to action must be involved, in order for the handle to be identified. The ventral stream was assumed to import semantic information about objects (high-level affordances) to the motor system while the dorsal stream imported purely visual infomation about objects (low-level affordances) to the motor system. Therefore, it was assumed that the visual route may correspond with the dorsal stream and the semantic route may correspond with the ventral stream. Therefore, one of the main aims of this thesis was to study similarities and differences between these two effects, and in particular, to find out whether the object-orientation effect could be explained in terms of object-based attention.

The second main aim of the thesis was to examine what kinds of resources of attention (e.g. endogenous, exogenous, focused) are required to generate the micro-affordance effects. The biased competition model of selective attention (Desimone & Duncan, 1995) was adopted in order to examine the roles of exogenous and endogenous attention in object affordances. The model led to the assumption that when endogenous attention is purposively kept on a fixation point during a prime presentation, the allocation of attentional resources to the prime object is suppressed. However, the prime object was assumed to capture resources of exogenous attention, even when endogenous attention was simultaneously focused on another item. Furthermore, it was assumed that the allocation of a participants' attentional resources to the prime would be minimized if the prime was task-irrelevant. Therefore, it was assumed that the paradigm in which a task-relevant fixation point remains over a task-irrelevant prime object or alternatively does not remain over the prime object, would allow us to study the degree to which enogenous and exogenous attention are needed in the generation of object affordance effects.

The third main aim of the thesis was to explore aspects of laterality in object affordances. Previous research has shown that the left hemisphere may have a dominant role in affordance recognition (Handy et al., 2003) and in the generation of the object-size effect (Grezes & Decay, 2002). This evidence led us to assume that perhaps these aspects of laterality might manifest themselves in manual asymmetries in the object-size effect. In particular, the main interest of this research was to explore whether visually guided precision and power grasps would be associated with manual asymmetries.

Experiment 1 was carried out to investigate whether the object-orientation effect could be observed with a task-irrelevant prime object. This was assumed to show whether the object-related motor representation could be activated even in the absence of forced allocation of endogenous attention to the object. Furthermore, the time course of the motor activation was investigated by varying the onset of the task-irrelevant prime object. This was assumed to show whether the allocation of endogenous attention to the object is required for updating the motor representation. Experiment 2 was carried out to study whether resources of (peripheral) exogenous attention are sufficient for observing the object affordance effects or whether resources of endogenous and/or focused attention play an important role in these effects. Experiments 3-4 were carried out to further investigate the same aspects of attention in visuomotor integration. Experiments 5-6 focused on studying object-based and location-based aspects of attention in the object affordances. Experiments 1-6 employed the object-orientation effect in investigation of aspects of attention in the object affordances, whereas Experiments 7-9 employed the object-size effect in investigating these aspects. Experiments 7-9 focused on studying aspects of laterality in the object affordances. The contribution of these experiments to accomplishing the objectives is discussed below.

After discussing new information that the empirical work of the current thesis offered on aspects of attention and laterality in visuomotor integration, the potential contribution of the experimental work to understanding differential roles of the semantic and visual routes in object affordance effects will be discussed. The final part of the thesis offers recommendations for further investigations and a novel model of object affordances in motor planning and control. In addition, this final part proposes that the current knowledge of object affordances may have significant implications for understanding important issues in other research fields of psychology and cognitive neuroscience, such as handedness and language.

6.1.1 Experimental summary

(a) The roles of endogenous and exogenous attention in object affordances

Tucker and Ellis (1998) demonstrated that object orientation is capable of facilitating orientation compatible left-right hand responses when the object needs to be categorized, and consequently endogenous attention is allocated to the object. However, Experiment 1 asked whether the same effect could be observed even in the absence of forced allocation of endogenous attention to the object. The results of Experiment 1 showed that the object orientation is capable of facilitating the orientation compatible responses even when the allocation of endogenous attention to the prime is minimal or absent. However, this result did not show whether a peripheral object is capable of affording actions. In addition, participants' endogenous attention was not controlled during the prime object presentation, and therefore it was possible that the effect was not constructed purely at the exogenous level of attention. Therefore, Experiment 2 was carried out to examine the role of focused attention, which is integral to endogenous attention in normal conditions, in the generation of affordance effect the by keeping a central task-relevant fixation point over the prime. It was predicted that if the fixation point remains over the prime, the resources of focused attention allocated to the prime would be decreased. This in turn is expected to suppress the influence of the prime orientation on responses. It was pointed out in Chapter One that the abrupt onset of a stimulus is capable of capturing resources of exogenous (peripheral) attention. Saliency and novelty of the stimulus are attributes that increase this attentional capture. Furthermore, peripherally presented manipulable objects are capable of capturing exogenous attention even when endogenous attention is simultaneously allocated elsewhere. Therefore, it was assumed that when the manipulable prime object is displayed behind the task-relevant fixation point, the prime object still captures resources of exogenous attention. In fact, the results of Experiment 6 showed that this assumption was correct. That is, because a facilitatory cueing effect was observed, regardless of whether the task-relevant fixation point was or was not displayed over the prime object. However, it was also assumed that when the task-relevant fixation point remains over the task-irrelevant prime object, participants' endogenous attention is focused on this point. Therefore, it was predicted that under these conditions the allocation of focused and endogenous attention to the prime is minimized or eliminated. Importantly, the object-orientation effect was not observed, in Experiment 2, when the fixation point remained over the prime object. It was suggested that, in Experiment 1, the orientation compatible responses were facilitated by object orientation at an exogenous level of attention. However, when attention was endogenously focused to the fixation point during the prime presentation, in Experiment 2, the resources that are needed for the generation of the object affordances were reserved for processing the visual and motor attributes of the fixation point, and therefore the peripheral prime could not facilitate orientation compatible responses. The alternative but less likely explanation for the results of Experiment 1 and 2 was that resources of exogenous attention are not sufficient for the effects to be observed and some minimal level of endogenous attention needs to be allocated to the prime object. It is more likely that the earlier explanation is correct because, in Experiment 1, a participants' response is made easier by ignoring the prime object, and consequently participants are not likely to attend to the object endogenously. Experiments 3 and 4 replicated these results with a different target discrimination task, and with prime objects that were associated with different (high and low) levels of affordance. Experiments 7 and 8 showed that the same attentional mechanisms are operating in the generation of the object-size effect.

(b) Location- and object-based attention in object affordances

It was assumed that the object-size effect would operate at an object-based level because the preshaping of a hand in relation to size of a goal object cannot be computed at a location-based level. However, two contradictory accounts have been used to explain the object-orientation effect, as mentioned above. These are the attention shift account and the object-based account. The attention shift account, which was supported by Anderson et al. (2002), suggests that the attention shift to the most salient or behaviourally most relevant part of the object results in generation of the orientation compatible response code. In contrast, the object-based account suggested that object-based orienting of attention to the entire object prepares simultaneously actions that are compatible with the object orientation. In other words, the object orientation is coded in the motor system in the absence of an attention shift. Although the results of Experiments 1-4 showed that resources of attention need to be allocated to the prime object for the object orientation to facilitate the corresponding responses, these results did not show whether these attentional resources are needed for orienting attention to the handle location or to the entire object. As it has been made clear, the Simon effect results from the matching of a target identity attribute with an automatically activated response code, and the response code in the Simon effect is assumed to be generated by a directional attention shift. Furthermore, the effect is diminished by eliminating the response selection stage from the task. Expriment 5 was carried out to investigate whether the object-orientation effect behaves similarly under the same task conditions. It was reasoned that if the object-orientation effect is diminished in a SRT task (i.e., the responding effector is known in advance before a target is displayed), it is likely that similar attentional processes would form the response code in the object-orientation effect and the Simon effect.

The results of Experiment 5 showed that the SRT paradigm reduces the object-orientation effect as it would be expected if the effect is based on an attention shift. This result supported the attention shift account of the object-orientation effect. However, Expriment 6 was carried out to investigate whether an attention shift to the handle location could be observed during the prime object presentation. Interestingly, the results of Experiment 6 showed that attention does not shift dominantly to any component of the prime object but rather orients to the entire prime object. Consequently, the results of Experiment 6 can be taken as a fairly safe evidence that both micro-affordance effects are operating at the object-based level of attention. This has important implications for the way the response is coded in the object-orientation effect. As mentioned in Chapter One, motor programs for reaching and grasping involve separate brain regions. Furthermore, object-directed reaching appears to be coded mainly in the location coordinates of the target object. In contrast, a object-directed grasp seems to require coding of intrinsic (object-based) object properties, such as shape and size. Because the object-orientation effect also seems to operate at the object-based level, it may be concluded that mechanisms that are responsible for the grasp coding underlie both the object-size effect and the object-orientation effect.

(c) The time course of motor representation in object affordances

The finding that a task-irrelevant object is capable of priming actions allowed the investigation of the time course of object-related motor activation. The results of Experiments 1 and 3 suggested that the overall effect begins to diminish with SOAs that are over 300 ms. That is, when the target appears more than 300 ms (600 ms and 1100 ms) after onset of the prime object, the effect is diminished or eliminated. It was assumed that this might reflect the fact that the visuomotor system has to update the stimuli representation continuously for actions. As mentioned earlier, the motor representation needs to be constantly updated so that visual objects can guide movements in real time. Furthermore, the results of Experiments 1, 3 and 7 led us to assume that the task-irrelevant prime object captures attention automatically when it is presented abruptly in the focal visual field resulting in preparation of the object-related actions. However, this initial object-related motor activation is relatively short-lived when the object is not task-relevant. It was suggested that the effect was diminished in the longer SOAs because it is not efficient to keep the motor representation active when the object is not the goal of actions and interest. In fact, it was assumed that the updating of motor representation of task-irrelevant object might even interfere with the goal task.

The results of Experiments 3 and 7 (mapping 2) suggested however that the compatibility effect depended on the hand of response and the object type. When stimuli consisted of mugs and teapots (real objects that cannot be grasped from the main axis of the object) that had to be processed at a higher level (or better semantic level) in order to localize the handle, the effect was larger for left hand responses and was additionally observed also in the longer SOA. In addition, the results of Experiments 3 and 7 (mapping 2) suggested that when stimuli are novel 3D objects that do not require semantic processing in order to recognize the object affordance (size or orientation), the influence of the object affordance on responses begins to diminish 300 ms after the prime object onset. However, the right hand responses appeared to be still affected by the prime object presentation at the SOA of 600 ms in the case of novel objects. The time course differences that are related to responses of different hands are discussed below in more detail.

(d) Manual asymmetries in object affordances

Manual asymmetries in visually guided movements have been observed, for example, with manual aiming tasks in which participants are asked to point to the location of the visual target (see Elliott & Chua, 1996 for a review). These manual asymmetries in aiming movements were attributed to specialization of different hemispheres in movement control and planning. In right-handers, the right hemisphere was assumed to be involved predominantly in planning of spatial movements whereas the left hemisphere was assumed to be involved more in the movement control. The right hand superiority in reaching accuracy appears to decrease when also the precision requirements of the task decrease (Boulinguez et al., 2001). Handy et al. (2003) and Grezes et al. (2002) reported additional evidence for the lateralized nature of visuomotor processes that are relevant for the current purposes. They showed that the left hemisphere has a dominant role in object affordance generation. This evidence of manual asymmetries and laterality led us to investigate whether the object affordance effects could be associated with manual asymmetries. Indeed, Experiments 3 and 7 revealed some interesting asymmetries. Four (1d-4d) kinds of manual asymmetries were found. These asymmetries are described below.

1d) The results of Experiment 7 showed that the object-size effect can be observed only when the right hand was performing precision grasp responses and the left hand was performing power grasp responses. There were no observable affordance effects with the reverse mapping of grip type to hand, suggesting that the effect reflected S-R compatibility between size of the stimulus and the grasp. This showed that visual object size facilitates asymmetrically precision and power grips resulting in a right hand advantage in visually based planning of the precision grip and a left hand advantage for power grips. In other words, the left hemisphere appears to be involved predominantly in computing visually guided precision grips and the right hemisphere seems to be involved predominantly computing power grips. As discussed above, it has been demonstrated that the right hand is superior in (online) programming of motor processes of skilled and precise movements. This right hand advantage seems to decrease when also the precision requirements of the task decrease. The results of the present experiments in which object affordances were used to examine the manual asymmetries are compatible with these earlier suggestions of the nature of manual asymmetries.

2d) Perhaps most interestingly, the results of Experiment 7 showed that participants made significantly more errors when large objects were presented and right hand responses were required. Similarly, participants made significantly more errors when small objects were presented to the participant and he/she was required to respond with the left hand. This right hand advantage with small objects and the left hand advantage with large objects was observed regardless of whether the responding hand was holding the precision or power grip. Perhaps when the 'small' object is viewed the action-relevant object code travels to the motor system of the left hemisphere, in comparison to the right hemisphere, via weightened connections, and consequently not only the precision grip of the right hand is facilitated but all right hand responses are facilitated. The opposite phenomena may occur when 'large' objects are viewed. Furthermore, this weightened 'small'-left (hemisphere)/'large'-right (hemisphere) connections may be the result of the laterality of the precision and power grips or alternatively laterality of the precision and power grips may be the result of the lateralized size-hemisphere connection. Nevertheless, the two hemispheres appear to have specialized functions in processing 'small' and 'large' attributes of a visual object which in turn benefits right hand-precision grip programming and left hand-power grip programming.

3d) The results of Experiments 3 and 7 showed that object affordance effects have different time courses in relation to the hand of response and the level (high and low) of affordance. When action-relevant properties of the object are extracted from purely visual information, left-hand responses are affected rapidly by these action-relevant object attributes and the motor activation also diminishes rapidly after the prime onset. In contrast, under the influence of the same stimulus, the right-hand responses are facilitated more slowly.

However, this object-related motor activation seems to have a longer time course. It has been shown elsewhere that the right hand shows superiority in online movement control (e.g. Fisk & Goodale, 1985; see Elliott & Chua, 1996, for a review), as already mentioned. However, it is not clear whether the right hand preference could be attributed to the superiority of the left hemisphere for the processing of perceptual or motor information during the movement. Our results may reflect a greater ability of the left hemisphere for the processing of perceptual on-line information, which, in turn, may result in the established right hand superiority in movement control. However, the research, which has shown a right hand superiority in movement control, has employed a manual aiming paradigm in which participants are asked to point to the target. In this kind of task, participants are required to construct representations of target location in order to point correctly. However, in the object-size effect the facilitation of the precision and power grips is based on object-based information about the stimulus. Therefore, the results of Experiment 7 suggests that the right hand is superior not only in online control of movements, which are based on location coordinates, but also with movement control, which is based on object-based visual information. Furthermore, the superiority is at least partly based on a greater ability of the right hand control system in extracting visual information about the object.

4d) The results of Experiment 3 however suggested that the right hand responses are associated with the longer time course of the object-related motor activation only when low-level object characteristics are guiding actions. That is, the right hand responses were influenced for longer by object orientation when the orientation of an object's axis of elongation was guiding a participant's responses. In contrast, the left hand responses were more facilitated by high-level object characteristics. That is, when stimuli consisted of mugs and teapots whose handle needs to be located before the object orientation can be recognized, left hand responses are more influenced by the object orientation. This suggests that high- and low-level affordances may be constructed predominantly in different hemispheres.

(e) The role of the dorsal and ventral streams in the object affordance effects

The visual system of humans and primates has been divided into two major processing pathways, the ventral and dorsal stream. In addition, it has been shown that these streams have differential involvement in object-directed action guidance. The ventral stream is capable of importing semantic information about an object to the motor system and the dorsal stream is capable of importing visual, on-line information about an object to the motor system. One of the secondary aims of the present thesis was to explore how these streams are involved in the generation of object affordances. Firstly, Grezes and Decay (2002) noticed that the object-orientation effect was not associatd with a significant ventral stream activation when brain activations of participants were observed while they performed the task that was used by Tucker and Ellis (1998). This suggested that that sensory input to the parietal system could activate the object relevant motor representation without retrieving semantic information about objects. In turn, this suggests that the object affordance information is extracted mainly from visual object attributes, and consequently the dorsal steam may have the primary role in the affordance generation. However, a variety of neuropsychological (see Goodale & Humphrey, 1998 for review) evidence suggests that the ventral stream can import object information to action guidance, as mentioned above. The ventral stream has to be involved in action planning when, for example, the function of the object has to be processed in order to use the object appropriately (e.g. grasp the knife by the handle and cut with it). Furthermore, for example, the FARS model (Fagg & Arbib, 1998) proposes that the information from the two streams could simultaneously potentiate a different or the same set of affordances. The results of Experiment 1 were consistent with the view that action-relevant information about the goal object is imported predominantly from the dorsal stream in the object-orientation effect. That is, the effect was larger when objects whose orientation could not be recognized from the principal axis of elongation were excluded from the analysis. This suggests that the purely visual (on-line) attributes of the object, which are presumably processed in the dorsal stream, have the primary role in the effect. However, the results of Experiment 3 showed that the object-orientation effect was also observed with objects whose action-relevant orientation is not available directly in the main axis of the object. These studies suggested that object orientation is capable of affording actions regardless of whether object needs to be recognized in order to localize the object affordance (e.g. handle) or whether the affordance information is associated with purely visual object characteristics (e.g. the principal axis of the elongation). However, the results of Experiment 1 suggest that the purely visual information may have priority over the higher-level information when the object is irrelevant to the task. This argument warrants further investigation.

The second attempt to explore the roles of the ventral and dorsal stream in the object affordance effect focused on observation of the orienting of attention during visuomotor priming. In Chapter One, it was shown that two contradictory accounts could be used to explain the object-orientation effect, the attention shift account and the object-based orienting account. The attention shift account of the object-orientation effect suggested that semantic information about the behaviourally most relevant components of the object directs viewers' attention and, consequently, leads to the object-orientation effect. It was assumed that if this account could be shown to be correct, then the ventral stream has a fundamental role in the object-orientation effect. In contrast, the object-based orienting account suggested that the object-size effect is related to attentional mechanisms similar to those involved in visuomotor priming in which orienting of attention to the entire graspable object facilitates orientation compatible responses. Presumably, the dorsal stream is predominantly involved in visuomotor priming when the abstract object orientation facilitates the orientation compatible responses. The results of Experiment 6 showed that the object-orientation effect appears to operate at the object-based level and consequently the result supports the view that dorsal stream inputs may be sufficient for facilitating the orientation compatible responses.

It was assumed that the dorsal stream operates for transforming real-time visual information into action coordinates. In addition, the motor program, which is imported from the dorsal stream, is not stored in memory. In fact, it was assumed that such storage could create interference between competing action plans for multiple objects in the visual array, or between action plans to the same object following a change in the spatial relationship between target and actor. Therefore, the dorsal stream was assumed to have very short memory, and its motor representation is rapidly refreshed after removal of the prime object from view. The results of Experiment 9 showed evidence to support the view that the object-size effect operates predominantly within the rapidly refreshed stream (i.e., the dorsal stream). When the prime object was removed from the visual array, the object-size effect was diminished 50 ms after offset of the prime, and absent 300 ms and 700 ms after offset of the prime. This result suggests that dorsal stream processes underly the effect observed in Experiment 7. In other words, the object affordance effects observed in the experimental work of this thesis reflect real-time visual guidance of actions. Additionally, it was proposed that the motor representation would be rapidly refreshed (even when the prime object remains in the view) when updating of this task-irrelevant object would interfere with the currently required task. The results of Experiment 1 provided evidence for this assumption. The object-orientation effect was observed 300 ms after onset of the prime object but was not observed 1100 ms after onset of the prime. However, the results of Experiments 3 and 7 (mapping 2) showed that the conclusion that the motor representation of the task-irrelevant prime is kept activated only for very short duration might be premature because the diminishment of the effect appeared to depend on the hand of response and the object type.

Although the differential effects of high and low level affordances on response planning (and control) may be linked to the processes of the ventral and dorsal stream, it may be safer to talk about the semantic and visual routes to action instead of the dorsal and ventral routes to action. That is, because of the lack of neurophysiological evidence to support this separation. Therefore, in conclusion, it may be proposed that when the prime object is task-irrelevant, the affordance information can be imported, perhaps simultaneously, to guide actions via the visual and semantic route to action. However, the visual route to action may have the priority over the semantic route to action (at least) when an object, which is task-irrelevant, primes responses.

6.2 The proposed model

We are getting closer to understanding how visual and motor processes interact in building us representations of the external environment in which we can act effectively. It is tempting to propose that the current thesis offers some new knowledge to understand this visuomotor integration. Most importantly, the thesis clarifies some important aspects of attention and manual asymmetries in visually guided movements. A new model of the integration of vision and action in object affordances may be needed to reconcile the previous evidence for visuomotor integration and the findings of the current thesis. Previously proposed models (e.g. Milner & Goodale, 1995; Glover, 2003) do not clearly integrate the relationship between the dorsal and ventral stream, movement planning and control, and high- and low-level object affordances. Therefore, the schematic model that is offered below aims to emphasize interaction between these aspects in visuomotor integration.

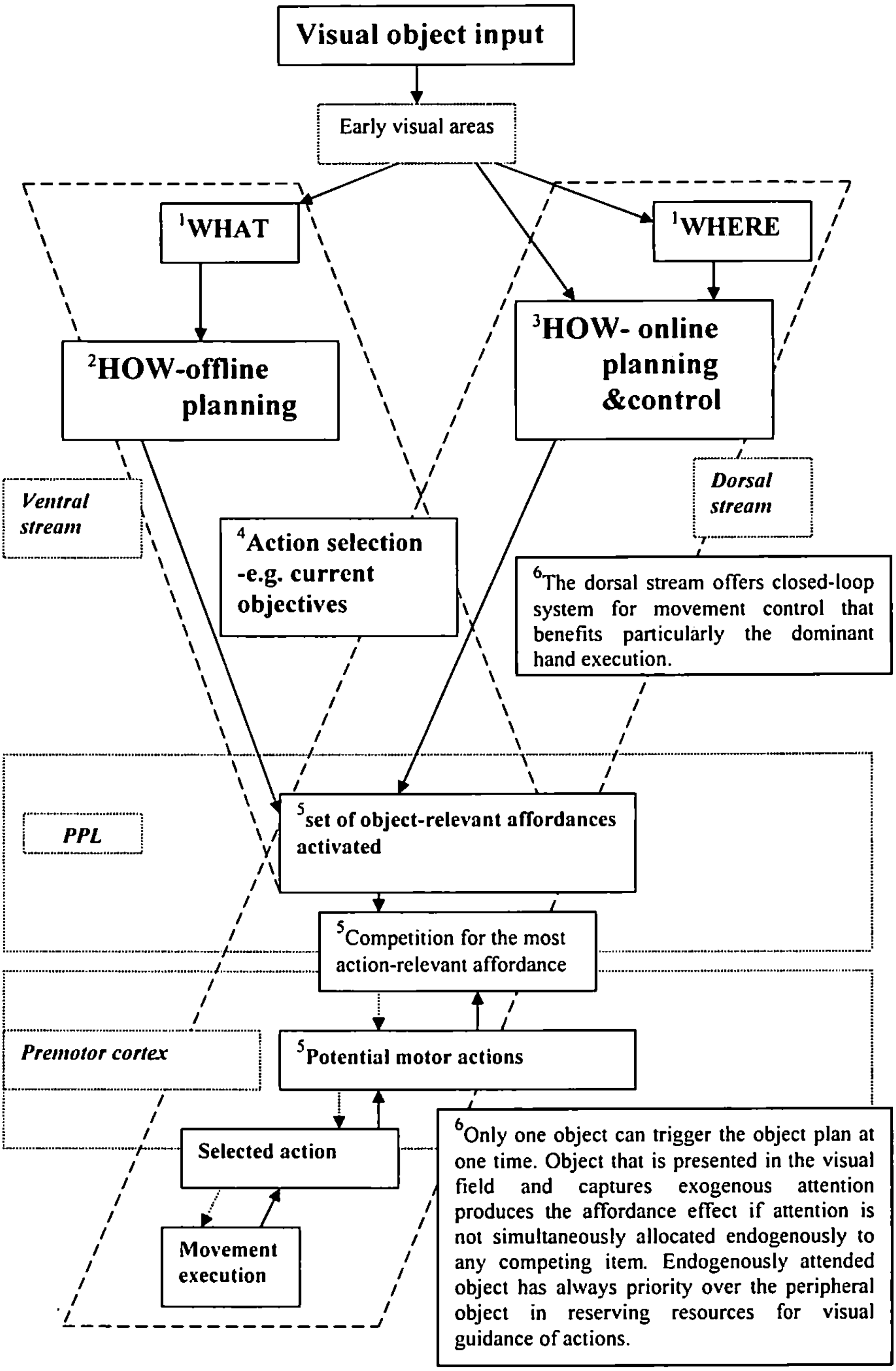


Figure 6.1 The proposed model for affordance generation

1) Ungerleider & Mishkin, 1982; 2) Milner & Goodale, 1995; 3) Glover, in press
4) Kalaska, Sergio & Cisek, 1998; 5) Fagg & Arbib, 1998; 6) The current thesis

This model presents how action-relevant object information guides viewers (performers) actions. Solid arrows are representing information, which is (directly) involved in this affordance generation. Dotted boxes are representing roughly where in the nervous system the operations are occurring. The 'action selection' box refers to cognitive processes that are responsible for e.g. motivational aspects of the currect action, and is not necessarily involved in affordance generation. In other words, the viewer can refrain from acting at all even when affordance is generated in visuomotor system. The ventral stream 'how' information is associated with semantic, action-relevant properties of the viewed object, whereas the dorsal stream 'how' information is associated with on-line/visual, action-relevant properties of the viewed object. The model is a simplification of the neural events that may be occurring in visually guided movements.

In the model, the central part of the affordance generation is the posterior parietal lobe (PPL). As was mentioned in introduction, the PPL can be divided into two main sectors, the superior parietal lobule (SPL; areas: PE, PEc, Peip, MIP, V6A) and the inferior parietal lobule (IPL; areas: PF, PFG, PG, AIP, LIP). The recent publication by Rizzolatti and Matelli (2003) suggests that functional specialization of IPL and SPL divides the dorsal stream into two distinct functional systems: the dorso-dorsal stream (d-d stream) and the ventro-dorsal stream (v-d stream). Rizzolatti and Matelli (2003) made this suggestion on the basis of new anatomical data and a reconsideration of previous functional and clinical data. Areas in the SPL form the d-d stream and damage in this stream leads to optic ataxia (Perenin & Vighetto, 1988), which is a disorder of visually guided movements of the arms towards a goal. The clinical data therefore suggests that the major functional role of the d-d stream is the "on line" control of actions. Rizzolatti and Matelli (2003) noted that the d-d stream has the same characteristics as the dorsal stream proposed by Milner and Goodale (1995). Indeed, this understanding of the dorsal stream has underpinned much of the current model of affordances presented here. In contrast, areas in the IPL form the v-d stream. Lesions in the IPL produce neglect (Perenin & Vighetto, 1988) and ideomotor apraxia (De Renzi & Faglioni, 1999). The dominant aspect of neglect is a deficit in perception. In contrast, patiets who have ideomotor apraxia have difficulties retrieving motor ideas on how to use objects. They also fail to implement the internal representation of a gesture into the appropriate motor actions. For instance, the patient who is able to grasp the object, is unable to produce the same gesture in the absence of the object. This patient data suggests that IPL is involved in perception (particularly in space perception), the organization of motor activities (particularly in the organization of grasping and manipulation), and action recognition and understanding.

6.3 Recommendations for further investigation

Perhaps the most interesting findings of the present thesis that should be a priority for further investigation are those related to manual asymmetries. Tucker and Ellis (2001) did not report manual asymmetries in visually guided grasp behaviour in their study that employed object categorization task, as mentioned above. This was, most likely because only one of their experiments employed bi-manual responses, and even then, the grasp to hand assignment was counterbalanced in a way that analysis could not reveal asymmetries between hands. The alternative option for this failure to observe any asymmetries was discussed above (e.g., increased allocation of endogenous attention reduces manual asymmetries). However, the experimental work of the current thesis developed a novel paradigm that allowed us to study manual asymmetries in object affordances, and the time courses of these affordances in relation to the responding hand. The experimental work revealed four different kinds of asymmetries. However, most of these findings were rather speculative and, therefore, remain a matter for further investigation. The rationale for four different routes for this further investigation is given below.

6.3.1 Laterality, affordances, and movement planning and control

a) Human prehension can be separated into two independent motor programs, reaching and grasping, which utilize different networks (e.g. Jeannerod, 1984). However, a majority of studies that have showed manual asymmetries in planning and control have focused on researching movements that can be computed at the location-based level, such as reaching. There is little or no work, which investigates lateralisation of planning and control at the object level for grasping even though in real-world contexts actions are often performed on objects rather than locations. Importantly for the purposes of the recommended further investigation, the experimental work of the thesis showed that both micro-affordance effects (the object-orientation effect and the object-size effect) operate at an object level. As a consequence, it is likely that both micro-affordance effects reflect grasp programming, if the argument that reaching is computed mainly in location coordinates while grasping is computed mainly at the object level is correct. Therefore, micro-affordance effects may be employed in examining visually guided grasp planning and control. Furthermore, it was found that the left hemisphere is predominantly involved in precision grip programming (triggered by a visual stimulus) whereas the right hemisphere is predominantly involved in power grip programming. These results were consistent with the previously established right hand superiority in programming movements that have high precision demands (e.g. Fisk & Goodale, 1985). However, as mentioned earlier, in addition to the superiority of the right hand control (e.g. Mieschke et al., 2001), right-handed people often show left-hand superiority in manual aiming tasks for movement planning as expressed in movement initiation time (e.g. Haaland & Harrington, 1989; Carson, Chua, Goodman et al., 1995; Velay, & Benoit-Dubrocard, 1999). It is not clear whether the advantage of the left hemisphere in computing precision grips and the advantage of the right hemisphere in computing the power grip could be associated with grasp planning and/or control. Therefore, whether manual asymmetries in the power and precision grip responses reflect the mechanisms of planning and/or control should be investigated. This question could be addressed by having participants make their precision and power responses to categories of familiar objects. Glover and Dixon (2001; 2002) showed that purely visual object characteristics affect both planning and control, whereas semantic characteristics affect only planning. Similarly, it could be assumed that the semantic size of an object influences only grasp planning while objects that do not have a semantic dimension can influence both grasp planning and control. Therefore, to find out whether the results of Experiment 7 reflect lateralization in movement control or planning, it could be replicated using familiar objects as stimuli.

b) The results of Experiments 3 and 7 suggested that the right hand control system have access to low-level affordances whilst the object remains in view. However, left hand responses were affected by the object size only briefly after onset of the object. It was suggested that this evidence might reflect a greater ability of the left hemisphere in the processing of visual information (e.g. a closed-loop system for preferred hand movements) which, in turn, results in the established right hand superiority in movement control. It would be particularly important to study whether the right hand superiority in access to continuous updates of action-relevant information is related to the established superiority of the right hand control system. One possible method of distinguishing between the effect of low-level affordances on movement planning and control would be to use a paradigm in which participants are asked to point a goal object whose size is compatible with precision or power grip. This methodology is possible because the error data of Experiment 7 showed that the right hand has an advantage when the viewed object is small and the left hand has an advantage when the viewed object is large regardless of whether the responding hand was holding the precision or power grip. Supposedly, the initiation of the pointing movement reflects the planning stage, while RTs of actual movement reflects the control stage. If the small objects are found to facilitate initiation (i.e., planning) and movement (i.e., control) of right hand responses and the large object are found to facilitate initiation but not movement of the left hand responses, it may be assumed that the manually asymmetrical time course effect of Experiment 7 (mapping 2) indeed reflects lateralized movement control and planning.

c) Both the high- and low-level characteristics of visual objects can guide planning of actions (e.g., Fagg & Arbib, 1998; Milner & Goodale, 1995; Tucker & Ellis, in preparation; 2004). Furthermore, Grezes et al. (2003) linked left hemispheric activation with affordance generation. Handy et al. (2003) also showed that recognition of action-relevant object characteristics (object affordances) is lateralized to the left hemsiphere. However, they discussed whether this lateralized recognition of object affordances may not completely depend on object-specific motor knowledge (e.g. the known size of the familiar object). An alternative is that lateralized recognition of motor affordance may occur for any object that conforms to a grasp-appropriate shape (e.g. low-level object characteristics), independent of whether or not that object has been previously associated with an idiosyncratic motor pattern. In addition, it has been suggested elsewhere that a visual object is processed in stages (e.g. the extraction of simple visual features of the object; construction of the object's shape; matching the object's shape to stored representations) (e.g. Humphrey, Price, & Riddoch, 1999; Farah, 2000). Several studies in which stimuli consist of, for example, familiar and novel objects have suggested that these stages may be partly lateralized (e.g. Vanni et al., 2003). Therefore, semantic attributes and visual attributes of the stimulus may be processed laterally for object recognition. Importantly, the results of Experiment 3 and 7 suggested that when the generation of the affordance effect does not require recognition of the prime object (cylinders), the object-orientation effect is more associated with right hand responses. In contrast, when the object needs to be recognized so that the object's orientation can guide actions (mugs and teapots), the object-orientation effect appears to be more associated with left hand responses. Therefore, these results suggest that the semantic and visual action-relevant object attributes may be processed laterally for action guidance. In other words, the high- and low-level object affordances may be recognized in different hemispheres. These lateralization issues in relation to levels of affordance, should be studied in detail so that the function of different regions of the visuomotor system in visually guided movements can be understood.

d) Tucker and Ellis (1998; 2001) did not report manual asymmetries in object affordance effects when the task required object categorization. Because the current thesis reported manual asymmetries in object affordances when the task does not require object categorization, the reasons for these contrary results should be investigated. For example, Wuyts et al. (1996) reported that performance of the dominant hand is less affected by allocation of attention to the hand performance than performance of the non-dominant hand, as mentioned earlier. Therefore, it may be reasoned that perhaps because the task, which was employed in the experiments in this thesis, required minimal allocation of endogenous attention to objects, the small objects were associated with facilitation of the precision responses of the right hand but not the left hand. In other words, it should be investigated whether the increased allocation of endogenous attention reduces manual asymmetries when it is allocated to the prime object, not only when it is allocated to actual manual performance.

e) These suggested studies (a-d) will use a right-handed population. It would be particularly important to examine the most interesting results, which these studies may reveal, with a left-handed population. For instance, Kimura and Archibald (1974), and Goodale (1988) have suggested right hand superiority in manual movements which require precision control of the hand, may be associated with lateralization of speech to the left hemisphere. Because the left-handers normally show less lateralized representation of speech, it would be interesting to investigate the lateralization of object affordances in relation to motor control and planning separately with left and right handed populations. Issues associated with lateralization of object affordances, lateralization of language processes, and handedness are discussed below in more detail.

6.4 Implications of the thesis on open questions in brain sciences

A large majority of people are right-handed and in most right-handers the left hemisphere plays a special role in language, as mentioned earlier. Speech is represented more bilaterally in left-handers. Many non-language disturbances that often follow the left hemisphere damage, such as apraxia (the inability to perform a purposeful familiar act), have been often attributed to verbal or symbolic impairment (see Kimura & Archibald, 1974 for review). However, Kimura and Archibald (1974) found that lesions of the left hemisphere impair the performance of complex motor sequences, regardless of whether the sequences are meaningful or not. These authors proposed that the left hemisphere has important functions in motor control, not shared by the right hemisphere. It was also suggested that speech disturbances and apraxia are simply different manifestations of impairment in the control of motor sequencing rather than related to symbolic or language function. Similarly, for example Goodale (1988) proposed that the left hemisphere is particularly important for the programming and integration of complex movements, for example, in speech and prehension. Therefore, Goodale (1988) and Kimura (1974) suggest a tight link between lateralized motor control and lateralized speech.

Interestingly, Grezes et al. (2003) showed a predominant left hemisphere involvement in the object affordance effect. In addition, the results of Experiment 7 suggested that the left hemisphere is predominatly involved in visually triggered precision grip programming. Finally, the results of Experiments 3 and 7 (mapping 2) suggested that the visual action-relevant object information is updated for longer for the right hand movement control than left hand movement control. It may be suggested that this superiority of the left hemisphere in access to visual updates and in the generation of visually guided precision grasp behaviour may be important for understanding the nature of the left hemisphere advantage in motor control processes proposed by Kimura and Archibald (1974) and Goodale (1988). The further research that was recommended above might show the importance of object affordances, and the control system that is related to these affordances, in the generation and development of speech and language.

The origin and nature of handedness is not yet fully understood. We do not know, for example, whether handedness is related to the development of bi-manual coordination or cognitive functions in the growing child. Additionally, it is not known whether handedness could be attributed to visual and/or motor feedback control of movements or to motor function of the specific hand. It is possible that by understanding the origin of one type of hand preference in human will contribute to our knowledge of the origin and nature of handedness in general. Therefore, it is tempting to propose that the recommended research aimed at explaining the visuomotor aspects of laterality in the control and planning of grasping (e.g., the superior access of the right hand control system to visual updates of the viewed object) may explain some important and complex questions about handedness.

Finally, neuropsychologists working with patients who have upper-limb movement deficits accompanying, for instance, unilateral stroke may benefit from the recommended research. For example, evidence for the left hemisphere (the right hand) superiority in (skilled) visually guided planning of grasp actions, which is one of the main aims of the recommended research, may be applied directly to the rehabilitation of these patients. In addition, systematic analyses of manual asymmetries provide critical information for quantifying and interpreting the deficits that were mentioned above. Furthermore, the recommended research might contribute to better prediction of consequences of unilateral brain damage. In the next section, we consider in more detail aspects of the relationship between lateralization of movement planning and control, handedness, and the evolution of language.

6.3.1 Hemispheric specialization in precision and power grasp and development of language

In the previous section, we suggested a tight relationship between laterality in control of precision movements, handedness, and lateralization of speech. This section aims to discuss how this relationship may have evolved. This section also aims to develop idea of this relationship further by proposing a close link between laterality of precision grip representation, which was found in Experiment 7, and the development of language.

When we speak as we breathe out to make speech sounds, we must precisely synchronize sound production with moments of the articulators, such as the tongue and lips (see Goodale, 1988). In addition, we must have simultaneous access to the brain structures that govern perception and knowledge of the world so that we can actually speak. Putting together all this precision movement control, perceptual, and cognitive processes requires large brain resources and complex programming. It has been argued that there is an evolutionary need for laterality of such processes, and this laterality may be tightly correlated with right-handedness (see Corballis, 2002 for review).

As stated above, majority of human population are right-handed and in most people language is lateralized in the left-hemisphere. Interestingly, a close relationship between handedness and hemispheric language dominance has been shown (e.g. Knecht, Dräger, Deppe, Bobe, Lohmann, Flöel, Ringelstein, & Henningsen, 2000). Knecht et al. (2000) demonstrated a consistent and almost linear relationship between the degree of handedness and the direction of language dominance. Furthermore, the gestural theory of language (see Corballis, 2003 for a review) suggests that right-handedness may have arisen during the evolution of language because of an association between manual gestures and the left-hemispheric lateralization of vocalization. According to this view, language evolved as a system of gestures based on movements of the hands, arms, and face. Although, the theory suggests that human language evolved from gestures of the hands and face, rather than from primate vocalization, it is commonly agreed that laterality of vocalization has evolved long before gestural communication had evolved. According to Corballis (2002), cerebral symmetry for vocalization has no evolutionary benefit because vocalization does not depend on the spatial layout of the environment. Therefore, he argued that little is lost, and perhaps much gained, by having it under asymmetrical control (Corballis, 2002). In fact, there is evidence for a left-sided bias of control of vocalization. This bias seems to be nearly universal. Corballis (2002) argued that gestures got linked to lateralized vocalization somewhere during the progression from ape to human when vocalization was added to the gestural repertoire and synchronized with it. Slowly these vocalizations became more and more synchronized with gestures. In the long run, the development of gestural communication improved all precision motor control, such as motor control of grasp and tongue. In turn the improvement in the precision motor control, progress of gestural communication, and their tighter synchronization with the lateralized vocalization led to lateralized speech.

A wide variety of observational data may be advanced to support the gestural theory of language. Great apes have been taught quite successfully to communicate using manual gestures. They have also been observed to use intentional gestures spontaneously in the wild and combine these gestures. Additionally, about two-third of chimpanzees show a preference for the right hand, even in gesturing (see Corballis, 2002 for review). The ability to combine gestures offers at least the potential for protolanguage. Additionally, the gestures we use when we speak are precisely synchronized with the speech (McNeill, 1985). In fact, it has been found that gesturing can facilitate word finding (Butterworth & Hadar, 1989) suggesting that gestures are an integral part of the language process itself. In addition, even Darwin (1872) observed that precise hand and finger movements are often accompanied by tongue-thrusts and twistings, as when one tries to thread a needle. This tool-tongue connection occurs not only among human beings, but among chimpanzees fishing for termites.

Corballis (2002) credited Hewes for developing the modern form of the gestural theory of language. Interestingly for the purposes of the current thesis, Hewes (1973) suggested that "*...human association of right-handedness and left-hemisphere dominance for both language skills and precise manual manipulations could well be the outcome of a long selective pressure for the clear separation of the precision grip from the power grip, combined with manual-gesture language exhibiting a similar (and related) asymmetry*" (pp.9). In other words, Hewes assumes that lateralization of the precision and a power grip precedes the development of speech in some fundamental way or is at least combined significantly with the evolution of language. Grasping is one of the most distinctive bodily characteristic that primates share. Most importantly, apes developed a precision grip (the use of index-thumb grip) which allowed them to perform, for example, ant dipping, nut cracking and leaf sponging. The long term effect of precision grip development could be seen in the development of tool use later in evolution. In fact, according to Hewes (1973) the emergence of tool use was one of the triggering landmarks in the evolution of language. Furthermore, the two hands typically have complementary roles, and in about two-thirds of the animals observed, it was the right hand that has been assumed to have the role requiring the more precise manipulations (see Corballis, 2002 for review). As mentioned earlier, the precision grip has developed in primates for manipulation of small objects whereas the power grip has developed for holding and grasping larger objects with high stability. It may be evolutionarily efficient, in manipulation movements, that one hand has evolved to hold an object while the other is performing the precision manipulation. The key point is that due to this long selective pressure for the clear separation of the precision grip from the power grip, the precision grip has lateralized to the same hemisphere (perhaps by chance) to which vocalization has lateralized in the earlier stages of evolution.

However, in the long run, precision motor control has developed, and somewhere during the evolutionary stages in which primates have used purely gestures in communication the precision motor control (including gestures and precision grip) has synchronized with vocalization which in turn led to laterally represented speech. The following scenario may offer a simplification for the evolution of language: left hemisphere (LH) specialization (by chance) for manipulation movements and precision grips led to LH specialization for gesture, which in turn led to LH specialization for language.

In sum, it is tempting to argue that lateralization of precision and power grips may have interesting evolutionary origins related to the development of language. Furthermore, superior access of the right hand control system to continuous visual updates may reveal some fundamental aspects in the nature of this control system for language. It is particularly important that these issues are studied so that the interaction between vision, action, cognition and language can be understood.

6.5 Conclusion

The experimental work of the thesis revealed several interesting findings, which clarified some aspects of object-guided movements. In addition to clarifying attentional aspects in object affordances, which formed the main theme of the thesis, the thesis made a few suggestions to improve the understanding of where (e.g., laterality effects) and how (e.g., the automatic generation of the response code in affordances) different kinds of action plans are formed. This final section offers a summary of the six most important proposals that this thesis made.

1) An object-related action plan can be formed to task-irrelevant object (at least) when the object is displayed at the foci of attention. Therefore, it may be concluded that the abrupt onset of a (at least focally) presented object, which has action-related attributes, captures the viewers exogenous attention to a degree, which is sufficient for constructing an object-

related action plan. This suggests that the actor does not have to attend to the object endogenously in order that the object affordance can be observed (*Experiments 1, 3, 5, 7, & 9*).

2) The motor activation related to an action plan for the left hand (formed by a task-irrelevant object) diminishes rapidly after the abrupt onset of the viewed object, if the action plan is facilitated by low-level (e.g., the orientation of principal axis of elongation) affordance. However, the right hand control system seems to have better (longer) access to visual updates of object representation. (*Experiments 3 & 7*).

3) If attention is focused endogenously to a competing item during the abrupt onset of the prime object, neural resources that are needed for the construction of the object affordance at the exogenous level of attention are reserved for the competing item. This suggests that an endogenously attended object always has priority over the peripheral object in competing for resources for the visual guidance of actions even when the peripheral object holds more affordances information than the attended object (*Experiments 2, 4, & 8*).

4) The object affordance effect consist of the same two stages as the Simon effect. First, the response code is formed by the action-relevant object attribute and then the identity of the target is analysed to perform the correct response. If the required response matches the automatically activated response code, the required response is facilitated (*Experiment 5*).

5) Object orientation is capable of guiding responses in the absence of an attention shift. This suggests that both micro-affordance effects, the object-orientation effect and the object-size effect, operate at the object-based level, and consequently mechanisms that compute grasping underlies both effects (*Experiment 6*).

6) The two hemispheres are specialized differentially in visually guided precision and power grasp. Small objects facilitate predominantly right hand-precision grip responses whereas large objects facilitate predominantly left hand-power grip responses (*Experiment 7*).

APPENDIX 1 (ANOVA and mean tables for Experiments 1-9)

Table 7.1.1 Experiment 1: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	330.380	1	330.380	1.419	.248
ORIENTAT * MAPPING	Sphericity Assumed	1165.185	1	1165.185	5.004	.037
Error(ORIENTAT)	Sphericity Assumed	4423.940	19	232.839		
SOA	Sphericity Assumed	2089.159	1	2089.159	5.903	.025
SOA * MAPPING	Sphericity Assumed	712.622	1	712.622	2.013	.172
Error(SOA)	Sphericity Assumed	6724.899	19	353.942		
RESPONSE	Sphericity Assumed	20686.397	1	20686.397	9.286	.007
RESPONSE * MAPPING	Sphericity Assumed	10158.819	1	10158.819	4.560	.046
Error(RESPONSE)	Sphericity Assumed	42327.688	19	2227.773		
ORIENTAT * SOA	Sphericity Assumed	43.696	1	43.696	.100	.756
ORIENTAT * SOA * MAPPING	Sphericity Assumed	813.760	1	813.760	1.855	.189
Error(ORIENTAT*SOA)	Sphericity Assumed	8333.206	19	438.590		
ORIENTAT * RESPONSE	Sphericity Assumed	881.926	1	881.926	5.407	.031
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	10.129	1	10.129	.062	.806
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	3099.316	19	163.122		
SOA * RESPONSE	Sphericity Assumed	3.663	1	3.663	.014	.906
SOA * RESPONSE * MAPPING	Sphericity Assumed	35.403	1	35.403	.139	.714
Error(SOA*RESPONSE)	Sphericity Assumed	4856.756	19	255.619		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	276.318	1	276.318	1.532	.231
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	137.711	1	137.711	.763	.393
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	3427.938	19	180.418		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	39587246.632	1	39587246.632	609.566	.000
MAPPING	42287.072	1	42287.072	.651	.430
Error	1233922.313	19	64943.280		

Table 7.1.2 Experiment 1: Repeated measures ANOVA for mean correct responses

(in SOA 300 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	66.887	1	66.887	.478	.498
ORIENTAT * MAPPING	Sphericity Assumed	15.727	1	15.727	.112	.741
Error(ORIENTAT)	Sphericity Assumed	2660.617	19	140.032		
RESPONSE	Sphericity Assumed	10620.295	1	10620.295	9.750	.006
RESPONSE * MAPPING	Sphericity Assumed	5696.825	1	5696.825	5.230	.034
Error(RESPONSE)	Sphericity Assumed	20694.914	19	1089.206		
ORIENTAT * RESPONSE	Sphericity Assumed	1072.774	1	1072.774	7.243	.014
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	111.269	1	111.269	.751	.397
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	2814.023	19	148.106		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	19507084.805	1	19507084.805	611.528	.000
MAPPING	26989.356	1	26989.356	.846	.369
Error	606079.328	19	31898.912		

Table 7.1.3 Experiment 1: Repeated measures ANOVA for mean correct responses

(in SOA 1100 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	307.189	1	307.189	.578	.456
ORIENTAT * MAPPING	Sphericity Assumed	1963.218	1	1963.218	3.694	.070
Error(ORIENTAT)	Sphericity Assumed	10096.529	19	531.396		
RESPONSE	Sphericity Assumed	10069.765	1	10069.765	7.223	.015
RESPONSE * MAPPING	Sphericity Assumed	4497.397	1	4497.397	3.226	.088
Error(RESPONSE)	Sphericity Assumed	26489.530	19	1394.186		
ORIENTAT * RESPONSE	Sphericity Assumed	85.470	1	85.470	.437	.516
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	36.571	1	36.571	.187	.670
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	3713.231	19	195.433		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	20082250.985	1	20082250.985	601.295	.000
MAPPING	16010.338	1	16010.338	.479	.497
Error	634567.885	19	33398.310		

Table 7.1.4 Overall experimental means for correct responses of Experiment 1

MAPPING * ORIENTAT * SOA * RESPONSE

						95% Confidence Interval	
MAPPING	ORIENTAT	SOA	RESPONS	Mean	Std. Error	Lower Bound	Upper Bound
1.00	1	1	1	481.118	29.229	419.941	542.294
			2	446.965	25.619	393.344	500.587
		2	1	495.228	28.866	434.812	555.644
			2	461.995	24.150	411.448	512.542
	2	1	1	486.889	29.693	424.741	549.037
			2	443.035	25.155	390.384	495.686
		2	1	492.718	30.389	429.113	556.323
			2	452.804	29.818	390.395	515.213
2.00	1	1	1	497.348	30.655	433.186	561.510
			2	500.783	26.869	444.545	557.022
		2	1	499.861	30.274	436.496	563.226
			2	493.288	25.329	440.274	546.302
	2	1	1	509.461	31.142	444.279	574.643
			2	493.976	26.383	438.756	549.197
		2	1	514.069	31.872	447.360	580.778
			2	506.098	31.273	440.643	571.554

Table 7.1.5 Experiment 1: Repeated measures ANOVA for mean correct responses (in SOA 300 ms) (for objects whose handle lies along the principal axis of the object)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	128.687	1	128.687	.505	.486
ORIENTAT * MAPPING	Sphericity Assumed	31.563	1	31.563	.124	.729
Error(ORIENTAT)	Sphericity Assumed	4839.310	19	254.701		
RESPONSE	Sphericity Assumed	9328.890	1	9328.890	6.491	.020
RESPONSE * MAPPING	Sphericity Assumed	1899.946	1	1899.946	1.322	.264
Error(RESPONSE)	Sphericity Assumed	27305.038	19	1437.107		
ORIENTAT * RESPONSE	Sphericity Assumed	2965.440	1	2965.440	8.313	.010
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	9.441	1	9.441	.026	.872
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	6778.035	19	356.739		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	19426147.477	1	19426147.477	619.338	.000
MAPPING	28442.788	1	28442.788	.907	.353
Error	595953.627	19	31365.980		

Table 7.1.6 Experiment 1: Repeated measures ANOVA for mean correct responses (in SOA 1100 ms) (for objects whose handle lies along the principal axis of the object)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	92.838	1	92.838	.141	.712
ORIENTAT * MAPPING	Sphericity Assumed	5034.595	1	5034.595	7.621	.012
Error(ORIENTAT)	Sphericity Assumed	12551.995	19	660.631		
RESPONSE	Sphericity Assumed	6495.667	1	6495.667	4.128	.056
RESPONSE * MAPPING	Sphericity Assumed	3213.691	1	3213.691	2.042	.169
Error(RESPONSE)	Sphericity Assumed	29899.060	19	1573.635		
ORIENTAT * RESPONSE	Sphericity Assumed	49.924	1	49.924	.115	.738
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1699.984	1	1699.984	3.922	.062
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	8235.669	19	433.456		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	19943997.281	1	19943997.281	608.598	.000
MAPPING	12737.798	1	12737.798	.389	.540
Error	622637.477	19	32770.394		

Table 7.1.7 Experiment 1: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	.000	1	.000	.000	.997
	Greenhouse-Geisser	.000	1.000	.000	.000	.997
	Huynh-Feldt	.000	1.000	.000	.000	.997
	Lower-bound	.000	1.000	.000	.000	.997
ORIENTAT * MAPPING	Sphericity Assumed	26.389	1	26.389	3.140	.092
	Greenhouse-Geisser	26.389	1.000	26.389	3.140	.092
	Huynh-Feldt	26.389	1.000	26.389	3.140	.092
	Lower-bound	26.389	1.000	26.389	3.140	.092
Error(ORIENTAT)	Sphericity Assumed	159.656	19	8.403		
	Greenhouse-Geisser	159.656	19.000	8.403		
	Huynh-Feldt	159.656	19.000	8.403		
	Lower-bound	159.656	19.000	8.403		
	Sphericity Assumed	.094	1	.094	.015	.905

	Greenhouse-Geisser	.094	1.000	.094	.015	.905
	Huynh-Feldt	.094	1.000	.094	.015	.905
	Lower-bound	.094	1.000	.094	.015	.905
SOA * MAPPING	Sphericity Assumed	1.086	1	1.086	.170	.684
	Greenhouse-Geisser	1.086	1.000	1.086	.170	.684
	Huynh-Feldt	1.086	1.000	1.086	.170	.684
	Lower-bound	1.086	1.000	1.086	.170	.684
Error(SOA)	Sphericity Assumed	121.070	19	6.372		
	Greenhouse-Geisser	121.070	19.000	6.372		
	Huynh-Feldt	121.070	19.000	6.372		
	Lower-bound	121.070	19.000	6.372		
RESPONSE	Sphericity Assumed	.018	1	.018	.001	.977
	Greenhouse-Geisser	.018	1.000	.018	.001	.977
	Huynh-Feldt	.018	1.000	.018	.001	.977
	Lower-bound	.018	1.000	.018	.001	.977
RESPONSE * MAPPING	Sphericity Assumed	6.566	1	6.566	.315	.581
	Greenhouse-Geisser	6.566	1.000	6.566	.315	.581
	Huynh-Feldt	6.566	1.000	6.566	.315	.581
	Lower-bound	6.566	1.000	6.566	.315	.581
Error(RESPONSE)	Sphericity Assumed	396.146	19	20.850		
	Greenhouse-Geisser	396.146	19.000	20.850		
	Huynh-Feldt	396.146	19.000	20.850		
	Lower-bound	396.146	19.000	20.850		
ORIENTAT * SOA	Sphericity Assumed	.000	1	.000	.000	.997
	Greenhouse-Geisser	.000	1.000	.000	.000	.997
	Huynh-Feldt	.000	1.000	.000	.000	.997
	Lower-bound	.000	1.000	.000	.000	.997
ORIENTAT * SOA * MAPPING	Sphericity Assumed	.066	1	.066	.007	.934
	Greenhouse-Geisser	.066	1.000	.066	.007	.934
	Huynh-Feldt	.066	1.000	.066	.007	.934
	Lower-bound	.066	1.000	.066	.007	.934
Error(ORIENTAT*SOA)	Sphericity Assumed	176.323	19	9.280		
	Greenhouse-Geisser	176.323	19.000	9.280		
	Huynh-Feldt	176.323	19.000	9.280		
	Lower-bound	176.323	19.000	9.280		
ORIENTAT * RESPONSE	Sphericity Assumed	.018	1	.018	.003	.959
	Greenhouse-Geisser	.018	1.000	.018	.003	.959
	Huynh-Feldt	.018	1.000	.018	.003	.959
	Lower-bound	.018	1.000	.018	.003	.959
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	8.021	1	8.021	1.203	.286
	Greenhouse-Geisser	8.021	1.000	8.021	1.203	.286
	Huynh-Feldt	8.021	1.000	8.021	1.203	.286
	Lower-bound	8.021	1.000	8.021	1.203	.286
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	126.701	19	6.668		
	Greenhouse-Geisser	126.701	19.000	6.668		
	Huynh-Feldt	126.701	19.000	6.668		
	Lower-bound	126.701	19.000	6.668		
SOA * RESPONSE	Sphericity Assumed	16.270	1	16.270	1.383	.254
	Greenhouse-Geisser	16.270	1.000	16.270	1.383	.254
	Huynh-Feldt	16.270	1.000	16.270	1.383	.254

	Lower-bound	16.270	1.000	16.270	1.383	.254
SOA * RESPONSE * MAPPING	Sphericity Assumed	2.580	1	2.580	.219	.645
	Greenhouse-Geisser	2.580	1.000	2.580	.219	.645
	Huynh-Feldt	2.580	1.000	2.580	.219	.645
	Lower-bound	2.580	1.000	2.580	.219	.645
Error(SOA*RESPONSE)	Sphericity Assumed	223.545	19	11.766		
	Greenhouse-Geisser	223.545	19.000	11.766		
	Huynh-Feldt	223.545	19.000	11.766		
	Lower-bound	223.545	19.000	11.766		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	3.074	1	3.074	1.273	.273
	Greenhouse-Geisser	3.074	1.000	3.074	1.273	.273
	Huynh-Feldt	3.074	1.000	3.074	1.273	.273
	Lower-bound	3.074	1.000	3.074	1.273	.273
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	.891	1	.891	.369	.551
	Greenhouse-Geisser	.891	1.000	.891	.369	.551
	Huynh-Feldt	.891	1.000	.891	.369	.551
	Lower-bound	.891	1.000	.891	.369	.551
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	45.868	19	2.414		
	Greenhouse-Geisser	45.868	19.000	2.414		
	Huynh-Feldt	45.868	19.000	2.414		
	Lower-bound	45.868	19.000	2.414		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	4265.411	1	4265.411	78.054	.000
MAPPING	1.721	1	1.721	.031	.861
Error	1038.292	19	54.647		

Table 7.1.8 Overall experimental means for incorrect responses of Experiment 1

MAPPING * ORIENTAT * SOA * RESPONSE

MAPPING	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	1	1	1	4.242	1.157	1.821	6.664
			2	6.364	1.064	4.136	8.591
		2	1	5.606	1.253	2.983	8.229
			2	5.152	1.259	2.516	7.787
	2	1	1	4.242	1.036	2.073	6.412
			2	4.697	1.070	2.458	6.936
		2	1	4.848	1.499	1.712	7.985
			2	4.394	.923	2.461	6.326
2.00	1	1	1	5.000	1.214	2.460	7.540
			2	4.667	1.116	2.330	7.003
		2	1	5.333	1.314	2.583	8.084
			2	4.000	1.321	1.236	6.764
	2	1	1	5.500	1.087	3.225	7.775
			2	5.833	1.122	3.485	8.182
		2	1	5.500	1.572	2.210	8.790

			2	5.333	.968	3.306	7.360

Table 7.2.1 Experiment 2: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	.200	1	.200	.001	.972
ORIENTAT * MAPPING	Sphericity Assumed	.103	1	.103	.001	.980
Error(ORIENTAT)	Sphericity Assumed	3156.804	20	157.840		
RESPONSE	Sphericity Assumed	1607.075	1	1607.075	1.520	.232
RESPONSE * MAPPING	Sphericity Assumed	116.327	1	116.327	.110	.744
Error(RESPONSE)	Sphericity Assumed	21150.357	20	1057.518		
ORIENTAT * RESPONSE	Sphericity Assumed	3.783	1	3.783	.038	.848
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	6.731	1	6.731	.067	.798
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	2001.254	20	100.063		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	20472922.421	1	20472922.421	823.382	.000
MAPPING	789.320	1	789.320	.032	.860
Error	497288.565	20	24864.428		

Table 7.2.2 Experiment 2: Repeated measures ANOVA for mean correct responses (for objects whose handle lies along the principal axis of the object)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	3.536	1	3.536	.021	.885
ORIENTAT * MAPPING	Sphericity Assumed	35.931	1	35.931	.218	.645
Error(ORIENTAT)	Sphericity Assumed	3290.264	20	164.513		
RESPONSE	Sphericity Assumed	2190.681	1	2190.681	1.355	.258
RESPONSE * MAPPING	Sphericity Assumed	545.927	1	545.927	.338	.568
Error(RESPONSE)	Sphericity Assumed	32342.697	20	1617.135		
ORIENTAT * RESPONSE	Sphericity Assumed	11.438	1	11.438	.036	.851
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	776.769	1	776.769	2.476	.131
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	6275.160	20	313.758		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	20241875.747	1	20241875.747	849.968	.000
MAPPING	175.569	1	175.569	.007	.932
Error	476297.371	20	23814.869		

Table 7.2.3 Experiment 2: Repeated measures ANOVA for mean correct responses Of Experiment 1 (SOA 300 ms) and Experiment 2 (omnibus ANOVA)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	36.408	1	36.408	.256	.616
ORIENTAT * EXPERIME	Sphericity Assumed	29.254	1	29.254	.206	.653
Error(ORIENTAT)	Sphericity Assumed	5833.250	41	142.274		
RESPONSE	Sphericity Assumed	10896.413	1	10896.413	9.374	.004
RESPONSE * EXPERIME	Sphericity Assumed	2338.255	1	2338.255	2.012	.164
Error(RESPONSE)	Sphericity Assumed	47658.422	41	1162.401		
ORIENTAT * RESPONSE	Sphericity Assumed	597.995	1	597.995	4.970	.031
ORIENTAT * RESPONSE * EXPERIME	Sphericity Assumed	472.430	1	472.430	3.926	.054
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	4933.278	41	120.324		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	39932078.506	1	39932078.506	1447.394	.000
EXPERIME	23.690	1	23.690	.001	.977
Error	1131146.568	41	27588.941		

Table 7.2.4 Overall experimental means for correct responses of Experiment 2

MAPPING * ORIENTAT * RESPONSE

MAPPING	ORIENTAT	RESPONSE	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	1	1	484.750	25.300	431.975	537.525
		2	473.766	24.425	422.816	524.715
	2	1	484.776	25.743	431.076	538.475
		2	474.068	21.922	428.338	519.797
2.00	1	1	487.956	25.300	435.181	540.731
		2	482.676	24.425	431.727	533.626
	2	1	488.951	25.743	435.251	542.651
		2	481.736	21.922	436.006	527.465

Table 7.2.5 Experiment 2: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	1.547	1	1.547	.418	.525
	Greenhouse-Geisser	1.547	1.000	1.547	.418	.525
	Huynh-Feldt	1.547	1.000	1.547	.418	.525
	Lower-bound	1.547	1.000	1.547	.418	.525
ORIENTAT * MAPPING	Sphericity Assumed	1.547	1	1.547	.418	.525
	Greenhouse-Geisser	1.547	1.000	1.547	.418	.525
	Huynh-Feldt	1.547	1.000	1.547	.418	.525
	Lower-bound	1.547	1.000	1.547	.418	.525
Error(ORIENTAT)	Sphericity Assumed	73.990	20	3.699		
	Greenhouse-Geisser	73.990	20.000	3.699		
	Huynh-Feldt	73.990	20.000	3.699		
	Lower-bound	73.990	20.000	3.699		
RESPONSE	Sphericity Assumed	121.338	1	121.338	20.600	.000
	Greenhouse-Geisser	121.338	1.000	121.338	20.600	.000
	Huynh-Feldt	121.338	1.000	121.338	20.600	.000
	Lower-bound	121.338	1.000	121.338	20.600	.000
RESPONSE * MAPPING	Sphericity Assumed	45.581	1	45.581	7.738	.012
	Greenhouse-Geisser	45.581	1.000	45.581	7.738	.012
	Huynh-Feldt	45.581	1.000	45.581	7.738	.012
	Lower-bound	45.581	1.000	45.581	7.738	.012
Error(RESPONSE)	Sphericity Assumed	117.803	20	5.890		
	Greenhouse-Geisser	117.803	20.000	5.890		
	Huynh-Feldt	117.803	20.000	5.890		
	Lower-bound	117.803	20.000	5.890		
ORIENTAT * RESPONSE	Sphericity Assumed	.505	1	.505	.138	.715
	Greenhouse-Geisser	.505	1.000	.505	.138	.715
	Huynh-Feldt	.505	1.000	.505	.138	.715
	Lower-bound	.505	1.000	.505	.138	.715
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	4.545	1	4.545	1.238	.279
	Greenhouse-Geisser	4.545	1.000	4.545	1.238	.279
	Huynh-Feldt	4.545	1.000	4.545	1.238	.279
	Lower-bound	4.545	1.000	4.545	1.238	.279
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	73.422	20	3.671		
	Greenhouse-Geisser	73.422	20.000	3.671		
	Huynh-Feldt	73.422	20.000	3.671		
	Lower-bound	73.422	20.000	3.671		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	3757.102	1	3757.102	86.734	.000
MAPPING	109.880	1	109.880	2.537	.127
Error	866.351	20	43.318		

Table 7.2.6 Overall experimental means for incorrect responses of Experiment 2

MAPPING * ORIENTAT * RESPONSE

MAPPING	ORIENTAT	RESPONSE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	1	1	5.606	1.018	3.483	7.729
		2	9.697	1.206	7.180	12.214
	2	1	5.909	1.042	3.736	8.082
		2	9.394	1.252	6.783	12.005
2.00	1	1	5.000	1.018	2.877	7.123
		2	5.303	1.206	2.786	7.820
	2	1	4.924	1.042	2.751	7.097
		2	6.439	1.252	3.828	9.050

Table 7.3.1 Experiment 3: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	4714.676	2	2357.338	1.657	.201
CATEGORY * MAPPING	Sphericity Assumed	870.710	2	435.355	.306	.738
Error(CATEGORY)	Sphericity Assumed	71118.800	50	1422.376		
	Lower-bound	.084	1.000	.084	.000	.987
ORIENTAT * MAPPING	Sphericity Assumed	1.543	1	1.543	.005	.946
Error(ORIENTAT)	Sphericity Assumed	8252.424	25	330.097		
SOA	Sphericity Assumed	32609.621	1	32609.621	25.753	.000
SOA * MAPPING	Sphericity Assumed	66.313	1	66.313	.052	.821
Error(SOA)	Sphericity Assumed	31656.290	25	1266.252		
RESPONSE	Sphericity Assumed	24535.041	1	24535.041	22.507	.000
RESPONSE * MAPPING	Sphericity Assumed	627.414	1	627.414	.576	.455
Error(RESPONSE)	Sphericity Assumed	27252.992	25	1090.120		
CATEGORY * ORIENTAT	Sphericity Assumed	3270.758	2	1635.379	10.274	.000
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	10.036	2	5.018	.032	.969
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	7958.603	50	159.172		
CATEGORY * SOA	Sphericity Assumed	1097.063	2	548.532	2.326	.108
CATEGORY * SOA * MAPPING	Sphericity Assumed	539.998	2	269.999	1.145	.327
Error(CATEGORY*SOA)	Sphericity Assumed	11793.367	50	235.867		
ORIENTAT * SOA	Sphericity Assumed	60.795	1	60.795	.266	.610
ORIENTAT * SOA * MAPPING	Sphericity Assumed	830.699	1	830.699	3.639	.068
Error(ORIENTAT*SOA)	Sphericity Assumed	5707.079	25	228.283		
CATEGORY * ORIENTAT * SOA	Sphericity Assumed	832.917	2	416.459	1.656	.201
CATEGORY * ORIENTAT * SOA * MAPPING	Sphericity Assumed	184.758	2	92.379	.367	.694
Error(CATEGORY*ORIENTAT*SOA)	Sphericity Assumed	12572.234	50	251.445		

CATEGORY * RESPONSE	Sphericity Assumed	1636.617	2	818.308	2.007	.145
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	929.042	2	464.521	1.139	.328
Error(CATEGORY*RESPONSE)	Sphericity Assumed	20387.777	50	407.756		
ORIENTAT * RESPONSE	Sphericity Assumed	4460.348	1	4460.348	28.835	.000
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	455.486	1	455.486	2.945	.099
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	3867.111	25	154.684		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	446.747	2	223.374	.886	.419
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	490.123	2	245.062	.972	.385
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	12609.227	50	252.185		
SOA * RESPONSE	Sphericity Assumed	1128.349	1	1128.349	2.524	.125
SOA * RESPONSE * MAPPING	Sphericity Assumed	343.237	1	343.237	.768	.389
Error(SOA*RESPONSE)	Sphericity Assumed	11177.921	25	447.117		
CATEGORY * SOA * RESPONSE	Sphericity Assumed	53.482	2	26.741	.128	.880
CATEGORY * SOA * RESPONSE * MAPPING	Sphericity Assumed	311.131	2	155.565	.743	.481
Error(CATEGORY*SOA*RESPONSE)	Sphericity Assumed	10462.198	50	209.244		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	1279.431	1	1279.431	6.143	.020
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	446.930	1	446.930	2.146	.155
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	5207.104	25	208.284		
CATEGORY * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	982.393	2	491.197	2.166	.125
CATEGORY * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	183.972	2	91.986	.406	.669
Error(CATEGORY*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	11337.857	50	226.757		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	95437705.658	1	95437705.658	1181.845	.000
MAPPING	75051.190	1	75051.190	.929	.344
Error	2018829.265	25	80753.171		

Table 7.3.2 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 300 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	2138.926	2	1069.463	1.182	.315
CATEGORY * MAPPING	Sphericity Assumed	1298.388	2	649.194	.717	.493
Error(CATEGORY)	Sphericity Assumed	45255.875	50	905.118		
ORIENTAT	Sphericity Assumed	32.699	1	32.699	.130	.721
ORIENTAT * MAPPING	Sphericity Assumed	451.926	1	451.926	1.797	.192
Error(ORIENTAT)	Sphericity Assumed	6286.254	25	251.450		
RESPONSE	Sphericity Assumed	7570.127	1	7570.127	9.427	.005
RESPONSE * MAPPING	Sphericity Assumed	949.385	1	949.385	1.182	.287
Error(RESPONSE)	Sphericity Assumed	20075.390	25	803.016		
CATEGORY * ORIENTAT	Sphericity Assumed	436.964	2	218.482	1.010	.371
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	59.590	2	29.795	.138	.872
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	10814.893	50	216.298		
CATEGORY * RESPONSE	Sphericity Assumed	1010.397	2	505.198	1.320	.276
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	890.701	2	445.351	1.163	.321
Error(CATEGORY*RESPONSE)	Sphericity Assumed	19139.391	50	382.788		
ORIENTAT * RESPONSE	Sphericity Assumed	5258.761	1	5258.761	29.647	.000
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	902.396	1	902.396	5.087	.033
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	4434.546	25	177.382		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	693.714	2	346.857	1.820	.173
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	50.927	2	25.463	.134	.875
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	9528.099	50	190.562		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	49499296.928	1	49499296.928	1261.776	.000
MAPPING	39789.639	1	39789.639	1.014	.324
Error	980746.739	25	39229.870		

Table 7.3.3 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 300 ms/category 1)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	19.923	1	19.923	.121	.730
ORIENTAT * MAPPING	Sphericity Assumed	36.298	1	36.298	.221	.642
Error(ORIENTAT)	Sphericity Assumed	4102.293	25	164.092		
RESPONSE	Sphericity Assumed	1979.658	1	1979.658	7.760	.010
RESPONSE * MAPPING	Sphericity Assumed	14.082	1	14.082	.055	.816
Error(RESPONSE)	Sphericity Assumed	6377.995	25	255.120		
ORIENTAT * RESPONSE	Sphericity Assumed	1525.911	1	1525.911	5.784	.024
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	276.107	1	276.107	1.047	.316
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	6595.326	25	263.813		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	16595194.699	1	16595194.699	1158.147	.000
MAPPING	14109.364	1	14109.364	.985	.331
Error	358227.273	25	14329.091		

Table 7.3.4 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 300 ms/category 2)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	144.635	1	144.635	1.053	.315
ORIENTAT * MAPPING	Sphericity Assumed	215.641	1	215.641	1.570	.222
Error(ORIENTAT)	Sphericity Assumed	3434.223	25	137.369		
RESPONSE	Sphericity Assumed	5628.481	1	5628.481	6.128	.020
RESPONSE * MAPPING	Sphericity Assumed	349.532	1	349.532	.381	.543
Error(RESPONSE)	Sphericity Assumed	22960.954	25	918.438		
ORIENTAT * RESPONSE	Sphericity Assumed	3811.257	1	3811.257	24.580	.000
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	161.300	1	161.300	1.040	.318
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	3876.438	25	155.058		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	16200951.645	1	16200951.645	1364.556	.000
MAPPING	7756.604	1	7756.604	.653	.427
Error	296817.298	25	11872.692		

Table 7.3.5 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 300 ms/category 3)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	305.104	1	305.104	.797	.380
ORIENTAT * MAPPING	Sphericity Assumed	259.577	1	259.577	.678	.418
Error(ORIENTAT)	Sphericity Assumed	9564.632	25	382.585		
RESPONSE	Sphericity Assumed	972.385	1	972.385	2.462	.129
RESPONSE * MAPPING	Sphericity Assumed	1476.473	1	1476.473	3.738	.065
Error(RESPONSE)	Sphericity Assumed	9875.832	25	395.033		
ORIENTAT * RESPONSE	Sphericity Assumed	615.307	1	615.307	4.407	.046
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	515.915	1	515.915	3.695	.066
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	3490.881	25	139.635		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	16705289.509	1	16705289.509	1125.821	.000
MAPPING	19222.059	1	19222.059	1.295	.266
Error	370958.043	25	14838.322		

Table 7.3.6 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 300 ms/category 3/left hand)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	893.487	1	893.487	4.396	.046
ORIENTAT * MAPPING	Sphericity Assumed	21.796	1	21.796	.107	.746
Error(ORIENTAT)	Sphericity Assumed	5080.954	25	203.238		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	8480582.807	1	8480582.807	1055.892	.000
MAPPING	15676.634	1	15676.634	1.952	.175
Error	200791.947	25	8031.678		

Table 7.3.7 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 300 ms/category 3/right hand)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	26.924	1	26.924	.084	.774
ORIENTAT * MAPPING	Sphericity Assumed	753.696	1	753.696	2.363	.137
Error(ORIENTAT)	Sphericity Assumed	7974.559	25	318.982		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	8225679.088	1	8225679.088	1142.189	.000
MAPPING	5021.898	1	5021.898	.697	.412
Error	180041.928	25	7201.677		

Table 7.3.8 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	3672.813	2	1836.407	2.438	.098
CATEGORY * MAPPING	Sphericity Assumed	112.320	2	56.160	.075	.928
Error(CATEGORY)	Sphericity Assumed	37656.292	50	753.126		
ORIENTAT	Sphericity Assumed	28.181	1	28.181	.092	.764
ORIENTAT * MAPPING	Sphericity Assumed	380.316	1	380.316	1.239	.276
Error(ORIENTAT)	Sphericity Assumed	7673.249	25	306.930		
RESPONSE	Sphericity Assumed	18093.263	1	18093.263	24.643	.000
RESPONSE * MAPPING	Sphericity Assumed	21.265	1	21.265	.029	.866
Error(RESPONSE)	Sphericity Assumed	18355.523	25	734.221		
CATEGORY * ORIENTAT	Sphericity Assumed	3666.711	2	1833.356	9.435	.000
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	135.204	2	67.602	.348	.708
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	9715.943	50	194.319		
CATEGORY * RESPONSE	Sphericity Assumed	679.702	2	339.851	1.451	.244
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	349.472	2	174.736	.746	.479
Error(CATEGORY*RESPONSE)	Sphericity Assumed	11710.584	50	234.212		
ORIENTAT * RESPONSE	Sphericity Assumed	481.018	1	481.018	2.592	.120
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	.020	1	.020	.000	.992
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	4639.668	25	185.587		
CATEGORY * ORIENTAT *	Sphericity Assumed	735.426	2	367.713	1.275	.288

RESPONSE						
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	623.169	2	311.584	1.080	.347
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	14418.985	50	288.380		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	45971018.351	1	45971018.351	1074.351	.000
MAPPING	35327.864	1	35327.864	.826	.372
Error	1069738.815	25	42789.553		

Table 7.3.9 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms/category 1)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	181.581	1	181.581	.703	.410
ORIENTAT * MAPPING	Sphericity Assumed	3.288	1	3.288	.013	.911
Error(ORIENTAT)	Sphericity Assumed	6455.006	25	258.200		
RESPONSE	Sphericity Assumed	6289.949	1	6289.949	15.051	.001
RESPONSE * MAPPING	Sphericity Assumed	1.280	1	1.280	.003	.956
Error(RESPONSE)	Sphericity Assumed	10447.576	25	417.903		
ORIENTAT * RESPONSE	Sphericity Assumed	43.640	1	43.640	.176	.679
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	154.947	1	154.947	.624	.437
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	6208.030	25	248.321		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	15684729.171	1	15684729.171	934.491	.000
MAPPING	13623.225	1	13623.225	.812	.376
Error	419606.370	25	16784.255		

Table 7.3.10 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms/category 2)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	2671.401	1	2671.401	12.658	.002
ORIENTAT * MAPPING	Sphericity Assumed	282.527	1	282.527	1.339	.258
Error(ORIENTAT)	Sphericity	5276.281	25	211.051		

	Assumed					
RESPONSE	Sphericity Assumed	9065.927	1	9065.927	20.190	.000
RESPONSE * MAPPING	Sphericity Assumed	94.558	1	94.558	.211	.650
Error(RESPONSE)	Sphericity Assumed	11225.930	25	449.037		
ORIENTAT * RESPONSE	Sphericity Assumed	165.105	1	165.105	.588	.450
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	57.384	1	57.384	.204	.655
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	7019.366	25	280.775		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	15019522.359	1	15019522.359	1128.325	.000
MAPPING	10409.394	1	10409.394	.782	.385
Error	332783.708	25	13311.348		

Table 7.3.11 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms/category 2/left hand)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	754.128	1	754.128	2.542	.123
ORIENTAT * MAPPING	Sphericity Assumed	42.627	1	42.627	.144	.708
Error(ORIENTAT)	Sphericity Assumed	7415.314	25	296.613		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	7883300.779	1	7883300.779	955.547	.000
MAPPING	4259.862	1	4259.862	.516	.479
Error	206250.906	25	8250.036		

Table 7.3.12 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms/category 2/right hand)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	2082.378	1	2082.378	10.667	.003
ORIENTAT * MAPPING	Sphericity Assumed	297.285	1	297.285	1.523	.229
Error(ORIENTAT)	Sphericity Assumed	4880.333	25	195.213		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	7145287.507	1	7145287.507	1296.703	.000
MAPPING	6244.090	1	6244.090	1.133	.297
Error	137758.732	25	5510.349		

Table 7.3.13 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms/category 3)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	841.910	1	841.910	3.720	.065
ORIENTAT * MAPPING	Sphericity Assumed	229.704	1	229.704	1.015	.323
Error(ORIENTAT)	Sphericity Assumed	5657.906	25	226.316		
RESPONSE	Sphericity Assumed	3417.089	1	3417.089	10.179	.004
RESPONSE * MAPPING	Sphericity Assumed	274.899	1	274.899	.819	.374
Error(RESPONSE)	Sphericity Assumed	8392.601	25	335.704		
ORIENTAT * RESPONSE	Sphericity Assumed	1007.699	1	1007.699	4.320	.048
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	410.858	1	410.858	1.761	.196
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	5831.256	25	233.250		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	15270439.634	1	15270439.634	1075.368	.000
MAPPING	11407.564	1	11407.564	.803	.379
Error	355005.029	25	14200.201		

Table 7.3.14 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms/category 3/left hand)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	1845.886	1	1845.886	7.408	.012
ORIENTAT * MAPPING	Sphericity Assumed	627.488	1	627.488	2.518	.125
Error(ORIENTAT)	Sphericity Assumed	6229.375	25	249.175		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	7865358.769	1	7865358.769	981.534	.000
MAPPING	7612.088	1	7612.088	.950	.339
Error	200333.326	25	8013.333		

Table 7.3.15 Experiment 3: Repeated measures ANOVA for mean correct responses (SOA 600 ms/category 3/right hand)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
ORIENTAT	Sphericity Assumed	3.723	1	3.723	.018	.895
ORIENTAT * MAPPING	Sphericity Assumed	13.075	1	13.075	.062	.805
Error(ORIENTAT)	Sphericity Assumed	5259.787	25	210.391		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	7408497.954	1	7408497.954	1135.825	.000
MAPPING	4070.375	1	4070.375	.624	.437
Error	163064.304	25	6522.572		

Table 7.3.16 Overall experimental means for correct responses of Experiment 3

MAPPING * CATEGORY * ORIENTAT * SOA * RESPONSE

MAPPING	CATEGORY	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1.00	1	1	1	1	404.452	16.480	370.510	438.394
				2	400.929	16.962	365.996	435.862
			2	1	398.650	19.713	358.050	439.250
				2	384.284	17.321	348.610	419.958
		2	1	1	410.795	17.958	373.811	447.779
				2	398.626	16.523	364.597	432.656
			2	1	402.021	19.532	361.795	442.247
				2	385.405	17.091	350.206	420.603
	2	1	1	1	400.103	16.358	366.412	433.794
				2	391.497	15.155	360.286	422.709
			2	1	395.861	19.078	356.569	435.154
				2	383.331	14.951	352.538	414.123
		2	1	1	410.058	16.792	375.475	444.641
				2	382.566	15.073	351.522	413.611
			2	1	386.604	17.131	351.323	421.885
				2	366.207	14.675	335.983	396.430
	3	1	1	1	410.180	16.549	376.097	444.263
				2	397.178	16.614	362.961	431.395
			2	1	391.351	17.022	356.294	426.408
				2	379.110	16.623	344.875	413.345
		2	1	1	417.050	18.963	377.995	456.105
				2	403.241	17.392	367.421	439.061
			2	1	396.230	18.597	357.930	434.530
				2	379.570	15.544	347.556	411.583
2.00	1	1	1	1	380.260	15.881	347.553	412.967
				2	381.691	16.345	348.029	415.354
			2	1	378.002	18.996	338.879	417.125
				2	359.277	16.691	324.901	393.653

		2	1	1	390.682	17.304	355.043	426.321
				2	370.668	15.922	337.876	403.459
			2	1	377.277	18.821	338.514	416.040
				2	365.891	16.469	331.973	399.809
	2	1	1	1	379.923	15.763	347.458	412.389
				2	383.411	14.603	353.334	413.487
			2	1	376.307	18.384	338.444	414.171
				2	357.114	14.407	327.441	386.786
		2	1	1	389.114	16.181	355.790	422.439
				2	363.932	14.525	334.017	393.847
			2	1	370.606	16.507	336.609	404.604
				2	349.381	14.141	320.257	378.506
	3	1	1	1	374.808	15.947	341.965	407.651
				2	385.354	16.010	352.382	418.327
			2	1	360.767	16.403	326.985	394.549
				2	362.719	16.018	329.730	395.709
		2	1	1	384.221	18.273	346.586	421.855
				2	376.464	16.760	341.947	410.981
			2	1	379.290	17.920	342.383	416.197
				2	361.209	14.978	330.360	392.057

Table 7.3.17 Experiment 3: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	41.222	2	20.611	.728	.488
CATEGORY * MAPPING	Sphericity Assumed	175.944	2	87.972	3.107	.053
Error(CATEGORY)	Sphericity Assumed	1415.877	50	28.318		
ORIENTAT	Sphericity Assumed	.449	1	.449	.037	.848
ORIENTAT * MAPPING	Sphericity Assumed	9.708	1	9.708	.809	.377
Error(ORIENTAT)	Sphericity Assumed	300.092	25	12.004		
SOA	Sphericity Assumed	207.761	1	207.761	4.410	.046
SOA * MAPPING	Sphericity Assumed	8.996	1	8.996	.191	.666
Error(SOA)	Sphericity Assumed	1177.656	25	47.106		
RESPONSE	Sphericity Assumed	3.921	1	3.921	.055	.817
RESPONSE * MAPPING	Sphericity Assumed	102.686	1	102.686	1.431	.243
Error(RESPONSE)	Sphericity Assumed	1793.842	25	71.754		
CATEGORY * ORIENTAT	Sphericity Assumed	82.337	2	41.168	1.743	.185
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	2.244	2	1.122	.048	.954
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	1180.781	50	23.616		
CATEGORY * SOA	Sphericity Assumed	71.216	2	35.608	1.842	.169
CATEGORY * SOA * MAPPING	Sphericity Assumed	1.000	2	.500	.026	.974
Error(CATEGORY*SOA)	Sphericity Assumed	966.747	50	19.335		
ORIENTAT * SOA	Sphericity Assumed	4.037	1	4.037	.247	.624
ORIENTAT * SOA * MAPPING	Sphericity Assumed	1.568	1	1.568	.096	.760

Error(ORIENTAT*SOA)	Sphericity Assumed	409.158	25	16.366		
CATEGORY * ORIENTAT * SOA	Sphericity Assumed	64.432	2	32.216	1.231	.301
CATEGORY * ORIENTAT * SOA * MAPPING	Sphericity Assumed	64.586	2	32.293	1.234	.300
Error(CATEGORY*ORIENTAT*SOA)	Sphericity Assumed	1308.253	50	26.165		
CATEGORY * RESPONSE	Sphericity Assumed	54.432	2	27.216	1.678	.197
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	6.129	2	3.065	.189	.828
Error(CATEGORY*RESPONSE)	Sphericity Assumed	811.000	50	16.220		
ORIENTAT * RESPONSE	Sphericity Assumed	71.310	1	71.310	2.117	.158
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	26.865	1	26.865	.797	.380
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	842.193	25	33.688		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	10.341	2	5.170	.208	.813
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	90.433	2	45.217	1.822	.172
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	1240.739	50	24.815		
SOA * RESPONSE	Sphericity Assumed	1.642	1	1.642	.068	.797
SOA * RESPONSE * MAPPING	Sphericity Assumed	7.814	1	7.814	.323	.575
Error(SOA*RESPONSE)	Sphericity Assumed	605.380	25	24.215		
CATEGORY * SOA * RESPONSE	Sphericity Assumed	3.485	2	1.743	.099	.905
CATEGORY * SOA * RESPONSE * MAPPING	Sphericity Assumed	55.183	2	27.591	1.575	.217
Error(CATEGORY*SOA*RESPONSE)	Sphericity Assumed	875.836	50	17.517		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	14.330	1	14.330	.902	.351
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	46.429	1	46.429	2.921	.100
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	397.321	25	15.893		
CATEGORY * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	36.384	2	18.192	.706	.499
CATEGORY * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	58.452	2	29.226	1.134	.330
Error(CATEGORY*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	1288.771	50	25.775		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	20868.540	1	20868.540	73.880	.000
MAPPING	.021	1	.021	.000	.993
Error	7061.630	25	282.465		

Table 7.3.18 Experiment 3: Repeated measures ANOVA for mean incorrect responses (SOA 300 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	65.996	2	32.998	1.341	.271
CATEGORY * MAPPING	Sphericity Assumed	78.033	2	39.017	1.585	.215
Error(CATEGORY)	Sphericity Assumed	1230.609	50	24.612		
ORIENTAT	Sphericity Assumed	.897	1	.897	.048	.829
ORIENTAT * MAPPING	Sphericity Assumed	9.539	1	9.539	.506	.483
Error(ORIENTAT)	Sphericity Assumed	471.016	25	18.841		
RESPONSE	Sphericity Assumed	.244	1	.244	.007	.936
RESPONSE * MAPPING	Sphericity Assumed	83.578	1	83.578	2.266	.145
Error(RESPONSE)	Sphericity Assumed	921.978	25	36.879		
CATEGORY * ORIENTAT	Sphericity Assumed	101.995	2	50.998	2.328	.108
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	44.279	2	22.140	1.010	.371
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	1095.536	50	21.911		
CATEGORY * RESPONSE	Sphericity Assumed	19.126	2	9.563	.632	.536
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	12.645	2	6.322	.418	.661
Error(CATEGORY*RESPONSE)	Sphericity Assumed	756.799	50	15.136		
ORIENTAT * RESPONSE	Sphericity Assumed	74.786	1	74.786	2.815	.106
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1.330	1	1.330	.050	.825
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	664.103	25	26.564		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	40.067	2	20.033	.884	.419
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	29.264	2	14.632	.646	.529
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	1133.082	50	22.662		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	8455.924	1	8455.924	56.523	.000
MAPPING	4.072	1	4.072	.027	.870
Error	3740.064	25	149.603		

Table 7.3.19 Experiment 3: Repeated measures ANOVA for mean incorrect responses (SOA 600 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	46.442	2	23.221	1.008	.372
CATEGORY * MAPPING	Sphericity Assumed	98.911	2	49.456	2.146	.128
Error(CATEGORY)	Sphericity Assumed	1152.015	50	23.040		
ORIENTAT	Sphericity Assumed	3.588	1	3.588	.377	.545
ORIENTAT * MAPPING	Sphericity Assumed	1.737	1	1.737	.182	.673
Error(ORIENTAT)	Sphericity Assumed	238.233	25	9.529		
RESPONSE	Sphericity Assumed	5.318	1	5.318	.090	.767
RESPONSE * MAPPING	Sphericity Assumed	26.923	1	26.923	.456	.506
Error(RESPONSE)	Sphericity Assumed	1477.244	25	59.090		
CATEGORY * ORIENTAT	Sphericity Assumed	44.773	2	22.387	.803	.454
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	22.551	2	11.276	.405	.669
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	1393.498	50	27.870		
CATEGORY * RESPONSE	Sphericity Assumed	38.791	2	19.395	1.043	.360
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	48.667	2	24.334	1.308	.279
Error(CATEGORY*RESPONSE)	Sphericity Assumed	930.037	50	18.601		
ORIENTAT * RESPONSE	Sphericity Assumed	10.853	1	10.853	.472	.499
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	71.964	1	71.964	3.127	.089
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	575.412	25	23.016		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	6.658	2	3.329	.119	.888
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	119.621	2	59.810	2.142	.128
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	1396.429	50	27.929		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	12620.377	1	12620.377	70.125	.000
MAPPING	4.945	1	4.945	.027	.870
Error	4499.222	25	179.969		

Table 7.3.20 Overall experimental means for incorrect responses of Experiment 3

MAPPING * CATEGORY * ORIENTAT * SOA * RESPONSE

MAPPING	CATEGORY	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval	
							Lower Bound	Upper Bound
1.00	1	1	1	1	3.462	1.056	1.288	5.635
				2	2.692	1.337	-.061	5.445
			2	1	5.000	1.610	1.683	8.317
				2	6.154	1.699	2.655	9.653
		2	1	1	5.769	1.376	2.935	8.604
				2	4.231	1.398	1.352	7.110
			2	1	6.538	1.887	2.653	10.424
				2	4.615	2.350	-.224	9.455
	2	1	1	1	6.923	1.723	3.375	10.471
				2	6.154	1.725	2.602	9.706
			2	1	8.462	1.779	4.798	12.125
				2	6.538	1.925	2.573	10.504
		2	1	1	7.308	2.433	2.297	12.318
				2	4.231	1.504	1.133	7.328
			2	1	6.154	1.748	2.553	9.755
				2	7.692	1.559	4.482	10.903
	3	1	1	1	5.769	2.032	1.584	9.955
				2	7.692	1.521	4.559	10.826
			2	1	6.154	1.276	3.526	8.782
				2	4.231	1.390	1.368	7.094
		2	1	1	5.000	1.492	1.928	8.072
				2	3.462	1.126	1.142	5.781
			2	1	5.385	1.377	2.549	8.220
				2	6.538	1.873	2.680	10.397
2.00	1	1	1	1	4.286	1.017	2.191	6.381
				2	5.000	1.288	2.347	7.653
			2	1	5.714	1.552	2.518	8.910
				2	6.786	1.637	3.414	10.157
		2	1	1	4.643	1.326	1.912	7.374
				2	5.714	1.347	2.940	8.489
			2	1	7.500	1.818	3.756	11.244
				2	8.571	2.264	3.908	13.235
	2	1	1	1	2.500	1.660	-.919	5.919
				2	6.071	1.662	2.649	9.494
			2	1	6.071	1.714	2.541	9.601
				2	7.143	1.855	3.321	10.964
		2	1	1	5.714	2.344	.886	10.543
				2	4.286	1.449	1.301	7.271
			2	1	7.143	1.685	3.673	10.613

				2	3.929	1.502	.835	7.022
	3	1	1	1	5.000	1.958	.967	9.033
				2	6.429	1.466	3.409	9.448
			2	1	3.571	1.230	1.039	6.104
				2	7.857	1.340	5.098	10.616
		2	1	1	4.643	1.437	1.682	7.603
				2	5.714	1.085	3.480	7.949
			2	1	5.714	1.327	2.982	8.446
				2	6.429	1.805	2.711	10.147

Table 7.4.1 Experiment 4: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	2874.989	2	1437.495	1.409	.255
CATEGORY * MAPPING	Sphericity Assumed	4464.857	2	2232.429	2.189	.124
Error(CATEGORY)	Sphericity Assumed	44882.895	44	1020.066		
ORIENTAT	Sphericity Assumed	341.527	1	341.527	2.299	.144
ORIENTAT * MAPPING	Sphericity Assumed	333.211	1	333.211	2.243	.148
Error(ORIENTAT)	Sphericity Assumed	3267.507	22	148.523		
SOA	Sphericity Assumed	23084.841	1	23084.841	45.553	.000
SOA * MAPPING	Sphericity Assumed	11.946	1	11.946	.024	.879
Error(SOA)	Sphericity Assumed	11148.893	22	506.768		
RESPONSE	Sphericity Assumed	34436.709	1	34436.709	18.504	.000
RESPONSE * MAPPING	Sphericity Assumed	13430.872	1	13430.872	7.217	.013
Error(RESPONSE)	Sphericity Assumed	40941.846	22	1860.993		
CATEGORY * ORIENTAT	Sphericity Assumed	51.404	2	25.702	.111	.895
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	917.697	2	458.849	1.986	.149
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	10163.765	44	230.995		
CATEGORY * SOA	Sphericity Assumed	44.650	2	22.325	.069	.934
CATEGORY * SOA * MAPPING	Sphericity Assumed	2.498	2	1.249	.004	.996
Error(CATEGORY*SOA)	Sphericity Assumed	14309.767	44	325.222		
ORIENTAT * SOA	Sphericity Assumed	34.806	1	34.806	.146	.706
ORIENTAT * SOA * MAPPING	Sphericity Assumed	155.957	1	155.957	.655	.427
Error(ORIENTAT*SOA)	Sphericity Assumed	5241.231	22	238.238		
CATEGORY * ORIENTAT * SOA	Sphericity Assumed	223.503	2	111.752	.525	.595
CATEGORY * ORIENTAT * SOA * MAPPING	Sphericity Assumed	78.013	2	39.006	.183	.833
Error(CATEGORY*ORIENTAT*SOA)	Sphericity Assumed	9360.788	44	212.745		
CATEGORY * RESPONSE	Sphericity Assumed	5156.396	2	2578.198	4.128	.023
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	439.411	2	219.705	.352	.705
Error(CATEGORY*RE	Sphericity Assumed	27480.210	44	624.550		

SPONSE)						
ORIENTAT * RESPONSE	Sphericity Assumed	220.775	1	220.775	.766	.391
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	123.086	1	123.086	.427	.520
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	6337.543	22	288.070		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	326.674	2	163.337	.334	.718
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	469.522	2	234.761	.480	.622
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	21516.971	44	489.022		
SOA * RESPONSE	Sphericity Assumed	2.130	1	2.130	.006	.941
SOA * RESPONSE * MAPPING	Sphericity Assumed	865.581	1	865.581	2.307	.143
Error(SOA*RESPONSE)	Sphericity Assumed	8253.647	22	375.166		
CATEGORY * SOA * RESPONSE	Sphericity Assumed	1205.289	2	602.645	1.818	.174
CATEGORY * SOA * RESPONSE * MAPPING	Sphericity Assumed	41.914	2	20.957	.063	.939
Error(CATEGORY*SOA*RESPONSE)	Sphericity Assumed	14582.878	44	331.429		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	26.367	1	26.367	.109	.744
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	10.400	1	10.400	.043	.838
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	5325.558	22	242.071		
CATEGORY * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	468.384	2	234.192	1.167	.321
CATEGORY * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	118.217	2	59.108	.294	.746
Error(CATEGORY*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	8833.579	44	200.763		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	76856542.139	1	76856542.139	872.873	.000
MAPPING	40757.882	1	40757.882	.463	.503
Error	1937100.860	22	88050.039		

Table 7.4.2 Experiment 4: Repeated measures ANOVA for mean correct responses (SOA 300 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	1119.407	2	559.703	.746	.480
CATEGORY * MAPPING	Sphericity Assumed	2339.281	2	1169.641	1.559	.222
Error(CATEGORY)	Sphericity Assumed	33009.280	44	750.211		
ORIENTAT	Sphericity Assumed	297.196	1	297.196	1.777	.196
ORIENTAT * MAPPING	Sphericity Assumed	472.545	1	472.545	2.825	.107
Error(ORIENTAT)	Sphericity Assumed	3679.787	22	167.263		
RESPONSE	Sphericity Assumed	16948.597	1	16948.597	18.639	.000
RESPONSE * MAPPING	Sphericity Assumed	3738.606	1	3738.606	4.111	.055
Error(RESPONSE)	Sphericity Assumed	20004.805	22	909.309		
CATEGORY * ORIENTAT	Sphericity Assumed	243.958	2	121.979	.875	.424
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	298.777	2	149.389	1.072	.351
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	6130.802	44	139.336		
CATEGORY * RESPONSE	Sphericity Assumed	2498.973	2	1249.486	4.234	.021
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	132.519	2	66.259	.225	.800
Error(CATEGORY*RESPONSE)	Sphericity Assumed	12984.936	44	295.112		
ORIENTAT * RESPONSE	Sphericity Assumed	47.274	1	47.274	.255	.619
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	102.521	1	102.521	.552	.465
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	4085.234	22	185.692		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	592.812	2	296.406	1.361	.267
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	150.602	2	75.301	.346	.710
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	9582.445	44	217.783		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	39771812.389	1	39771812.389	937.469	.000
MAPPING	21082.683	1	21082.683	.497	.488
Error	933342.985	22	42424.681		

Table 7.4.3 Experiment 4: Repeated measures ANOVA for mean correct responses (SOA 600 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	1800.233	2	900.117	1.513	.232
CATEGORY * MAPPING	Sphericity Assumed	2128.074	2	1064.037	1.788	.179
Error(CATEGORY)	Sphericity Assumed	26183.382	44	595.077		
ORIENTAT	Sphericity Assumed	79.138	1	79.138	.361	.554
ORIENTAT * MAPPING	Sphericity Assumed	16.622	1	16.622	.076	.786
Error(ORIENTAT)	Sphericity Assumed	4828.951	22	219.498		
RESPONSE	Sphericity Assumed	17490.242	1	17490.242	13.182	.001
RESPONSE * MAPPING	Sphericity Assumed	10557.846	1	10557.846	7.957	.010
Error(RESPONSE)	Sphericity Assumed	29190.688	22	1326.849		
CATEGORY * ORIENTAT	Sphericity Assumed	30.949	2	15.474	.051	.950
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	696.932	2	348.466	1.145	.328
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	13393.752	44	304.403		
CATEGORY * RESPONSE	Sphericity Assumed	3862.712	2	1931.356	2.922	.064
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	348.806	2	174.403	.264	.769
Error(CATEGORY*RESPONSE)	Sphericity Assumed	29078.152	44	660.867		
ORIENTAT * RESPONSE	Sphericity Assumed	199.868	1	199.868	.580	.454
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	30.965	1	30.965	.090	.767
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	7577.867	22	344.449		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	202.247	2	101.123	.214	.808
CATEGORY * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	437.137	2	218.569	.463	.632
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	20768.104	44	472.002		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	37107814.591	1	37107814.591	804.381	.000
MAPPING	19687.145	1	19687.145	.427	.520
Error	1014906.768	22	46132.126		

Table 7.4.4 Overall experimental means for correct responses of Experiment 4

MAPPING * CATEGORY * ORIENTAT * SOA * RESPONSE

MAPPING	CATEGORY	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval	
							Lower Bound	Upper Bound
1.00	1	1	1	1	366.313	17.426	330.174	402.451
				2	363.512	18.004	326.175	400.850
			2	1	355.405	19.192	315.604	395.207
				2	353.810	17.959	316.565	391.055
		2	1	1	363.693	17.058	328.317	399.068
				2	363.855	19.255	323.923	403.787
			2	1	352.428	17.545	316.043	388.813
				2	349.074	21.061	305.396	392.752
	2	1	1	1	365.155	18.738	326.295	404.014
				2	362.668	14.555	332.482	392.854
			2	1	349.310	16.858	314.348	384.272
				2	356.869	15.118	325.515	388.222
		2	1	1	375.576	16.262	341.850	409.302
				2	356.969	15.789	324.223	389.714
			2	1	351.422	15.895	318.457	384.386
				2	349.689	18.667	310.975	388.403
	3	1	1	1	366.110	20.920	322.724	409.495
				2	352.997	19.079	313.430	392.565
			2	1	349.921	21.510	305.312	394.529
				2	340.494	18.188	302.775	378.212
		2	1	1	365.910	19.648	325.163	406.656
				2	353.934	17.900	316.811	391.057
			2	1	356.049	27.104	299.839	412.258
				2	343.741	16.014	310.530	376.951
2.00	1	1	1	1	392.232	17.426	356.093	428.370
				2	377.460	18.004	340.123	414.798
			2	1	382.773	19.192	342.972	422.575
				2	360.197	17.959	322.952	397.442
		2	1	1	389.996	17.058	354.620	425.372
				2	377.475	19.255	337.543	417.408
			2	1	382.649	17.545	346.264	419.034
				2	362.079	21.061	318.401	405.756
	2	1	1	1	386.572	18.738	347.713	425.432
				2	365.035	14.555	334.849	395.220
			2	1	372.637	16.858	337.675	407.599
				2	349.442	15.118	318.088	380.796
		2	1	1	385.141	16.262	351.415	418.867
				2	360.256	15.789	327.510	393.001
			2	1	369.706	15.895	336.741	402.671
				2	351.303	18.667	312.589	390.017
	3	1	1	1	402.991	20.920	359.606	446.377
				2	370.506	19.079	330.939	410.074
			2	1	388.570	21.510	343.962	433.179
				2	354.287	18.188	316.568	392.005
		2	1	1	391.729	19.648	350.983	432.476
				2	362.638	17.900	325.516	399.761

			2	1	390.070	27.104	333.860	446.279
				2	342.927	16.014	309.716	376.137

Table 7.4.5 Experiment 4: Repeated measures ANOVA for mean correct responses Of Experiment 3 (SOA 300 ms) and Experiment 4 (SOA 300 ms) (omnibus ANOVA)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	2352.934	2	1176.467	1.408	.250
CATEGORY * EXPERIME	Sphericity Assumed	735.680	2	367.840	.440	.645
Error(CATEGORY)	Sphericity Assumed	81902.825	98	835.743		
ORIENTAT	Sphericity Assumed	83.880	1	83.880	.377	.542
ORIENTAT * EXPERIME	Sphericity Assumed	253.713	1	253.713	1.142	.291
Error(ORIENTAT)	Sphericity Assumed	10890.512	49	222.255		
RESPONSE	Sphericity Assumed	23613.958	1	23613.958	25.846	.000
RESPONSE * EXPERIME	Sphericity Assumed	1280.298	1	1280.298	1.401	.242
Error(RESPONSE)	Sphericity Assumed	44768.186	49	913.636		
CATEGORY * ORIENTAT	Sphericity Assumed	39.580	2	19.790	.112	.894
CATEGORY * ORIENTAT * EXPERIME	Sphericity Assumed	629.922	2	314.961	1.784	.173
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	17304.063	98	176.572		
CATEGORY * RESPONSE	Sphericity Assumed	1571.422	2	785.711	2.323	.103
CATEGORY * RESPONSE * EXPERIME	Sphericity Assumed	2045.212	2	1022.606	3.023	.053
Error(CATEGORY*RESPONSE)	Sphericity Assumed	33147.547	98	338.240		
ORIENTAT * RESPONSE	Sphericity Assumed	3085.482	1	3085.482	15.873	.000
ORIENTAT * RESPONSE * EXPERIME	Sphericity Assumed	2074.040	1	2074.040	10.670	.002
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	9524.697	49	194.382		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	1215.095	2	607.547	3.083	.050
CATEGORY * ORIENTAT * RESPONSE * EXPERIME	Sphericity Assumed	53.764	2	26.882	.136	.873
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	19312.072	98	197.062		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	88609296.700	1	88609296.700	2198.450	.000
EXPERIME	55677.400	1	55677.400	1.381	.246
Error	1974962.047	49	40305.348		

Table 7.4.6 Experiment 4: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	21.312	2	10.656	.399	.674
CATEGORY * MAPPING	Sphericity Assumed	56.275	2	28.138	1.053	.358
Error(CATEGORY)	Sphericity Assumed	1121.985	42	26.714		
ORIENTAT	Sphericity Assumed	.269	1	.269	.016	.899
ORIENTAT * MAPPING	Sphericity Assumed	7.515	1	7.515	.457	.506
Error(ORIENTAT)	Sphericity Assumed	345.202	21	16.438		
SOA	Sphericity Assumed	14.279	1	14.279	.748	.397
SOA * MAPPING	Sphericity Assumed	14.279	1	14.279	.748	.397
Error(SOA)	Sphericity Assumed	400.758	21	19.084		
RESPONSE	Sphericity Assumed	152.186	1	152.186	1.603	.219
RESPONSE * MAPPING	Sphericity Assumed	25.012	1	25.012	.263	.613
Error(RESPONSE)	Sphericity Assumed	1993.466	21	94.927		
CATEGORY * ORIENTAT	Sphericity Assumed	10.903	2	5.452	.441	.647
CATEGORY * ORIENTAT * MAPPING	Sphericity Assumed	50.939	2	25.470	2.058	.140
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	519.713	42	12.374		
CATEGORY * SOA	Sphericity Assumed	39.132	2	19.566	.945	.397
CATEGORY * SOA * MAPPING	Sphericity Assumed	20.111	2	10.055	.486	.619
Error(CATEGORY*SOA)	Sphericity Assumed	869.744	42	20.708		
ORIENTAT * SOA	Sphericity Assumed	.858	1	.858	.024	.878
ORIENTAT * SOA * MAPPING	Sphericity Assumed	9.916	1	9.916	.277	.604
Error(ORIENTAT*SOA)	Sphericity Assumed	750.410	21	35.734		
CATEGORY * ORIENTAT * SOA	Sphericity Assumed	50.046	2	25.023	1.279	.289
CATEGORY * ORIENTAT * SOA * MAPPING	Sphericity Assumed	49.140	2	24.570	1.256	.295
Error(CATEGORY*ORIENTAT*SOA)	Sphericity Assumed	821.512	42	19.560		
CATEGORY * RESPONSE	Sphericity Assumed	12.947	2	6.473	.542	.585
CATEGORY * RESPONSE * MAPPING	Sphericity Assumed	64.577	2	32.289	2.706	.078
Error(CATEGORY*RESPONSE)	Sphericity Assumed	501.184	42	11.933		
ORIENTAT * RESPONSE	Sphericity Assumed	.928	1	.928	.078	.783
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	5.276	1	5.276	.442	.514
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	250.884	21	11.947		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	89.967	2	44.983	2.389	.104
CATEGORY * ORIENTAT * RESPONSE *	Sphericity Assumed	8.989	2	4.494	.239	.789

MAPPING						
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	790.830	42	18.829		
SOA * RESPONSE	Sphericity Assumed	1.779	1	1.779	.070	.794
SOA * RESPONSE * MAPPING	Sphericity Assumed	12.648	1	12.648	.497	.488
Error(SOA*RESPONSE)	Sphericity Assumed	534.091	21	25.433		
CATEGORY * SOA * RESPONSE	Sphericity Assumed	7.640	2	3.820	.125	.883
CATEGORY * SOA * RESPONSE * MAPPING	Sphericity Assumed	6.009	2	3.005	.098	.907
Error(CATEGORY*SOA*RESPONSE)	Sphericity Assumed	1283.665	42	30.563		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	10.388	1	10.388	.393	.537
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	.605	1	.605	.023	.881
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	554.830	21	26.420		
CATEGORY * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	2.188	2	1.094	.048	.954
CATEGORY * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	11.427	2	5.714	.248	.781
Error(CATEGORY*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	967.377	42	23.033		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	10507.643	1	10507.643	48.916	.000
MAPPING	197.136	1	197.136	.918	.349
Error	4511.016	21	214.810		

Table 7.4.7 Overall experimental means for incorrect responses of Experiment 4

MAPPING * CATEGORY * ORIENTAT * SOA * RESPONSE

MAPPING	CATEGORY	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1.00	1	1	1	1	4.545	2.059	.264	8.827
				2	1.364	1.132	-.991	3.719
			2	1	5.455	1.672	1.978	8.931
				2	2.273	1.273	-.375	4.920
		2	1	1	3.182	1.051	.996	5.368
				2	2.727	1.709	-.826	6.281
			2	1	3.636	1.558	.396	6.877
				2	2.273	1.301	-.433	4.979
	2	1	1	1	5.000	1.868	1.115	8.885
				2	4.091	1.069	1.868	6.313
			2	1	5.000	1.944	.957	9.043
				2	5.000	2.462	-.120	10.120
		2	1	1	4.091	1.698	.560	7.622

				2	3.182	1.404	.262	6.101
			2	1	5.455	1.797	1.718	9.191
				2	2.727	1.771	-.956	6.410
	3	1	1	1	3.636	1.626	.255	7.018
				2	3.182	1.348	.378	5.986
			2	1	3.636	1.893	-.300	7.572
				2	3.182	2.034	-1.047	7.411
		2	1	1	4.091	2.071	-.216	8.398
				2	2.273	1.382	-.601	5.146
			2	1	6.364	2.077	2.045	10.682
				2	4.091	1.934	.069	8.112
2.00	1	1	1	1	6.250	1.971	2.151	10.349
				2	5.833	1.084	3.579	8.088
			2	1	4.583	1.601	1.255	7.912
				2	3.750	1.219	1.215	6.285
		2	1	1	4.167	1.007	2.073	6.260
				2	6.250	1.636	2.848	9.652
			2	1	3.750	1.492	.648	6.852
				2	5.417	1.246	2.826	8.007
	2	1	1	1	3.750	1.789	.030	7.470
				2	2.083	1.023	-.045	4.211
			2	1	5.417	1.861	1.546	9.287
				2	5.000	2.357	.098	9.902
		2	1	1	7.500	1.626	4.119	10.881
				2	4.167	1.344	1.371	6.962
			2	1	5.417	1.720	1.839	8.994
				2	3.750	1.696	.224	7.276
	3	1	1	1	6.250	1.557	3.012	9.488
				2	3.750	1.291	1.066	6.434
			2	1	5.417	1.812	1.648	9.185
				2	5.833	1.947	1.784	9.882
		2	1	1	5.000	1.983	.876	9.124
				2	4.583	1.323	1.832	7.335
			2	1	5.833	1.988	1.698	9.968
				2	5.417	1.851	1.566	9.267

Table 7.5.1 Experiment 5: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	307.579	1	307.579	.912	.349
Error(CATEGORY)	Sphericity Assumed	7756.251	23	337.228		
ORIENTAT	Sphericity Assumed	136.376	1	136.376	1.562	.224
Error(ORIENTAT)	Sphericity Assumed	2008.251	23	87.315		
SOA	Sphericity Assumed	2156.818	1	2156.818	7.600	.011
Error(SOA)	Sphericity Assumed	6526.899	23	283.778		
RESPONSE	Sphericity Assumed	3350.261	1	3350.261	4.525	.044
Error(RESPONSE)	Sphericity Assumed	17028.045	23	740.350		
CATEGORY * ORIENTAT	Sphericity Assumed	51.622	1	51.622	1.369	.254
Error(CATEGORY*OR	Sphericity Assumed	867.481	23	37.717		

IENTAT)						
CATEGORY * SOA	Sphericity Assumed	39.383	1	39.383	.645	.430
Error(CATEGORY*SOA)	Sphericity Assumed	1404.920	23	61.083		
ORIENTAT * SOA	Sphericity Assumed	.659	1	.659	.013	.911
Error(ORIENTAT*SOA)	Sphericity Assumed	1181.218	23	51.357		
CATEGORY * ORIENTAT * SOA	Sphericity Assumed	37.421	1	37.421	.788	.384
Error(CATEGORY*ORIENTAT*SOA)	Sphericity Assumed	1092.186	23	47.486		
CATEGORY * RESPONSE	Sphericity Assumed	70.544	1	70.544	.310	.583
Error(CATEGORY*RESPONSE)	Sphericity Assumed	5237.805	23	227.731		
ORIENTAT * RESPONSE	Sphericity Assumed	281.468	1	281.468	4.678	.041
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	1383.975	23	60.173		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	17.608	1	17.608	.410	.528
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	987.112	23	42.918		
SOA * RESPONSE	Sphericity Assumed	367.639	1	367.639	6.891	.015
Error(SOA*RESPONSE)	Sphericity Assumed	1227.068	23	53.351		
CATEGORY * SOA * RESPONSE	Sphericity Assumed	43.279	1	43.279	.800	.380
Error(CATEGORY*SOA*RESPONSE)	Sphericity Assumed	1244.782	23	54.121		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	78.708	1	78.708	.939	.343
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	1928.565	23	83.851		
CATEGORY * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	24.160	1	24.160	.288	.597
Error(CATEGORY*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	1930.130	23	83.919		

Table 7.5.2 Experiment 5: Repeated measures ANOVA for mean correct responses (SOA 300 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	283.542	1	283.542	1.630	.214
Error(CATEGORY)	Sphericity Assumed	3999.945	23	173.911		
ORIENTAT	Sphericity Assumed	59.038	1	59.038	.927	.346
Error(ORIENTAT)	Sphericity Assumed	1464.765	23	63.685		
RESPONSE	Sphericity Assumed	749.136	1	749.136	1.742	.200
Error(RESPONSE)	Sphericity Assumed	9889.780	23	429.990		
CATEGORY * ORIENTAT	Sphericity Assumed	.570	1	.570	.018	.895
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	741.414	23	32.235		
CATEGORY * RESPONSE	Sphericity Assumed	1.657	1	1.657	.011	.917
Error(CATEGORY*RESPONSE)	Sphericity Assumed	3441.842	23	149.645		

ORIENTAT * RESPONSE	Sphericity Assumed	328.929	1	328.929	5.384	.030
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	1405.189	23	61.095		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	.259	1	.259	.007	.935
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	883.914	23	38.431		

Table 7.5.3 Experiment 5: Repeated measures ANOVA for mean correct responses (SOA 450 ms)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	63.420	1	63.420	.283	.600
Error(CATEGORY)	Sphericity Assumed	5161.226	23	224.401		
ORIENTAT	Sphericity Assumed	77.997	1	77.997	1.040	.318
Error(ORIENTAT)	Sphericity Assumed	1724.704	23	74.987		
RESPONSE	Sphericity Assumed	2968.763	1	2968.763	8.162	.009
Error(RESPONSE)	Sphericity Assumed	8365.332	23	363.710		
CATEGORY * ORIENTAT	Sphericity Assumed	88.473	1	88.473	1.670	.209
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	1218.253	23	52.968		
CATEGORY * RESPONSE	Sphericity Assumed	112.166	1	112.166	.848	.367
Error(CATEGORY*RESPONSE)	Sphericity Assumed	3040.744	23	132.206		
ORIENTAT * RESPONSE	Sphericity Assumed	31.247	1	31.247	.377	.545
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	1907.351	23	82.928		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	41.510	1	41.510	.470	.500
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	2033.327	23	88.406		

Table 7.5.4 Overall experimental means for correct responses of Experiment 5

CATEGORY * ORIENTAT * SOA * RESPONSE

						95% Confidence Interval	
CATEGORY	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	Lower Bound	Upper Bound
1	1	1	1	308.308	4.366	299.276	317.340
			2	307.234	5.248	296.379	318.090
		2	1	305.079	5.700	293.288	316.869
			2	298.620	5.432	287.382	309.858
	2	1	1	309.999	5.172	299.300	320.698
			2	303.543	4.535	294.162	312.925
		2	1	305.038	5.137	294.412	315.665
			2	298.826	5.242	287.982	309.669
2	1	1	1	306.246	4.274	297.404	315.087
			2	304.654	4.365	295.625	313.683
		2	1	305.886	5.663	294.171	317.601
			2	298.229	5.188	287.498	308.961
	2	1	1	307.572	5.004	297.221	317.923

			2	300.891	4.374	291.843	309.940
		2	1	304.990	5.303	294.019	315.961
			2	293.860	4.996	283.524	304.196

Table 7.5.5 Experiment 5: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
CATEGORY	Sphericity Assumed	44.010	1	44.010	5.934	.023
Error(CATEGORY)	Sphericity Assumed	170.573	23	7.416		
ORIENTAT	Sphericity Assumed	250.260	1	250.260	8.926	.007
Error(ORIENTAT)	Sphericity Assumed	644.878	23	28.038		
SOA	Sphericity Assumed	.260	1	.260	.069	.795
Error(SOA)	Sphericity Assumed	86.545	23	3.763		
RESPONSE	Sphericity Assumed	31.510	1	31.510	3.002	.097
Error(RESPONSE)	Sphericity Assumed	241.406	23	10.496		
CATEGORY * ORIENTAT	Sphericity Assumed	27.807	1	27.807	3.325	.081
Error(CATEGORY*ORIENTAT)	Sphericity Assumed	192.332	23	8.362		
CATEGORY * SOA	Sphericity Assumed	.723	1	.723	.115	.737
Error(CATEGORY*SOA)	Sphericity Assumed	144.416	23	6.279		
ORIENTAT * SOA	Sphericity Assumed	.260	1	.260	.028	.869
Error(ORIENTAT*SOA)	Sphericity Assumed	214.323	23	9.318		
CATEGORY * ORIENTAT * SOA	Sphericity Assumed	.260	1	.260	.035	.854
Error(CATEGORY*ORIENTAT*SOA)	Sphericity Assumed	172.656	23	7.507		
CATEGORY * RESPONSE	Sphericity Assumed	24.334	1	24.334	3.331	.081
Error(CATEGORY*RESPONSE)	Sphericity Assumed	168.027	23	7.306		
ORIENTAT * RESPONSE	Sphericity Assumed	8.362	1	8.362	1.061	.314
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	181.221	23	7.879		
CATEGORY * ORIENTAT * RESPONSE	Sphericity Assumed	10.446	1	10.446	1.282	.269
Error(CATEGORY*ORIENTAT*RESPONSE)	Sphericity Assumed	187.471	23	8.151		
SOA * RESPONSE	Sphericity Assumed	10.446	1	10.446	4.025	.057
Error(SOA*RESPONSE)	Sphericity Assumed	59.693	23	2.595		
CATEGORY * SOA * RESPONSE	Sphericity Assumed	.260	1	.260	.034	.856
Error(CATEGORY*SOA*RESPONSE)	Sphericity Assumed	178.212	23	7.748		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	.260	1	.260	.026	.873
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	230.990	23	10.043		
CATEGORY * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	.723	1	.723	.086	.772
Error(CATEGORY*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	194.416	23	8.453		

Table 7.5.6 Overall experimental means for incorrect responses of Experiment 5

CATEGORY * ORIENTAT * SOA * RESPONSE

CATEGORY	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1	1	1	3.889	1.055	1.706	6.072
			2	4.167	.833	2.443	5.891
		2	1	3.611	.873	1.806	5.416
			2	4.722	1.021	2.609	6.835
	2	1	1	2.222	.556	1.073	3.371
			2	1.528	.491	.513	2.543
		2	1	2.222	.714	.745	3.699
			2	1.806	.491	.791	2.820
2	1	1	1	2.500	.610	1.238	3.762
			2	3.194	.709	1.728	4.661
		2	1	2.222	.685	.805	3.640
			2	3.611	.663	2.240	4.982
	2	1	1	1.528	.400	.700	2.356
			2	2.222	.591	1.000	3.444
		2	1	.972	.374	.198	1.746
			2	2.500	.673	1.108	3.892

Table 7.6.1 Experiment 6: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	12609.756	1	12609.756	10.447	.006
FIXATION * MAPPING	Sphericity Assumed	964.443	1	964.443	.799	.386
Error(FIXATION)	Sphericity Assumed	18105.471	15	1207.031		
TARGET	Sphericity Assumed	24593.440	3	8197.813	3.334	.028
TARGET * MAPPING	Sphericity Assumed	7277.994	3	2425.998	.987	.408
Error(TARGET)	Sphericity Assumed	110663.632	45	2459.192		
ORIENTAT	Sphericity Assumed	10.060	1	10.060	.004	.948
ORIENTAT * MAPPING	Sphericity Assumed	6604.675	1	6604.675	2.905	.109
Error(ORIENTAT)	Sphericity Assumed	34098.794	15	2273.253		
SOA	Sphericity Assumed	16504.749	1	16504.749	4.870	.043
SOA * MAPPING	Sphericity Assumed	4007.180	1	4007.180	1.182	.294
Error(SOA)	Sphericity Assumed	50840.914	15	3389.394		
RESPONSE	Sphericity Assumed	222932.700	1	222932.700	31.220	.000
RESPONSE * MAPPING	Sphericity Assumed	61422.889	1	61422.889	8.602	.010
Error(RESPONSE)	Sphericity Assumed	107109.497	15	7140.633		
FIXATION * TARGET	Sphericity Assumed	4827.632	3	1609.211	.842	.478
FIXATION * TARGET *	Sphericity Assumed	2030.459	3	676.820	.354	.786

MAPPING						
Error(FIXATION *TARGET)	Sphericity Assumed	86038.000	45	1911.956		
FIXATION * ORIENTAT	Sphericity Assumed	2385.748	1	2385.748	2.238	.155
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	2856.107	1	2856.107	2.679	.122
Error(FIXATION *ORIENTAT)	Sphericity Assumed	15989.570	15	1065.971		
TARGET * ORIENTAT	Sphericity Assumed	5120.919	3	1706.973	1.445	.242
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	3199.984	3	1066.661	.903	.447
Error(TARGET* ORIENTAT)	Sphericity Assumed	53140.942	45	1180.910		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	4525.903	3	1508.634	1.302	.285
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	7835.186	3	2611.729	2.254	.095
Error(FIXATION *TARGET*ORIENTAT)	Sphericity Assumed	52143.139	45	1158.736		
FIXATION * SOA	Sphericity Assumed	1018.217	1	1018.217	1.185	.293
FIXATION * SOA * MAPPING	Sphericity Assumed	629.407	1	629.407	.733	.405
Error(FIXATION *SOA)	Sphericity Assumed	12883.518	15	858.901		
TARGET * SOA	Sphericity Assumed	1904.161	3	634.720	.835	.482
TARGET * SOA * MAPPING	Sphericity Assumed	3952.081	3	1317.360	1.733	.174
Error(TARGET* SOA)	Sphericity Assumed	34199.794	45	759.995		
FIXATION * TARGET * SOA	Sphericity Assumed	1558.723	3	519.574	.541	.657
FIXATION * TARGET * SOA * MAPPING	Sphericity Assumed	1453.015	3	484.338	.504	.681
Error(FIXATION *TARGET*SOA)	Sphericity Assumed	43236.122	45	960.803		
ORIENTAT * SOA	Sphericity Assumed	13.388	1	13.388	.024	.879
ORIENTAT * SOA * MAPPING	Sphericity Assumed	1556.462	1	1556.462	2.766	.117
Error(ORIENTAT*SOA)	Sphericity Assumed	8440.440	15	562.696		
FIXATION * ORIENTAT * SOA	Sphericity Assumed	133.078	1	133.078	.047	.831
FIXATION * ORIENTAT * SOA * MAPPING	Sphericity Assumed	1121.904	1	1121.904	.397	.538
Error(FIXATION *ORIENTAT*SOA)	Sphericity Assumed	42422.840	15	2828.189		
TARGET * ORIENTAT * SOA	Sphericity Assumed	21722.804	3	7240.935	5.292	.003
TARGET * ORIENTAT * SOA *	Sphericity Assumed	1864.605	3	621.535	.454	.716

MAPPING						
Error(TARGET*ORIENTAT*SOA)	Sphericity Assumed	61573.776	45	1368.306		
FIXATION * TARGET * ORIENTAT * SOA	Sphericity Assumed	1045.510	3	348.503	.511	.676
FIXATION * TARGET * ORIENTAT * SOA * MAPPING	Sphericity Assumed	6137.456	3	2045.819	3.002	.040
Error(FIXATION*TARGET*ORIENTAT*SOA)	Sphericity Assumed	30663.396	45	681.409		
FIXATION * RESPONSE	Sphericity Assumed	1219.510	1	1219.510	1.639	.220
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	189.550	1	189.550	.255	.621
Error(FIXATION*RESPONSE)	Sphericity Assumed	11160.425	15	744.028		
TARGET * RESPONSE	Sphericity Assumed	62195.083	3	20731.694	7.871	.000
TARGET * RESPONSE * MAPPING	Sphericity Assumed	27830.410	3	9276.803	3.522	.022
Error(TARGET*RESPONSE)	Sphericity Assumed	118533.121	45	2634.069		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	2029.186	3	676.395	.667	.576
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	9589.350	3	3196.450	3.154	.034
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	45604.139	45	1013.425		
ORIENTAT * RESPONSE	Sphericity Assumed	748.580	1	748.580	1.200	.291
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1206.436	1	1206.436	1.935	.185
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	9354.161	15	623.611		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	1470.913	1	1470.913	.802	.385
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	395.641	1	395.641	.216	.649
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	27504.968	15	1833.665		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	1131.052	3	377.017	.520	.671
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	3022.652	3	1007.551	1.389	.258
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	32648.386	45	725.520		
FIXATION * TARGET *	Sphericity Assumed	2032.659	3	677.553	.564	.641

ORIENTAT * RESPONSE						
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	5621.053	3	1873.684	1.561	.212
Error(FIXATION *TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	54017.396	45	1200.387		
SOA * RESPONSE	Sphericity Assumed	35.887	1	35.887	.020	.889
SOA * RESPONSE * MAPPING	Sphericity Assumed	3.654	1	3.654	.002	.964
Error(SOA*RESPONSE)	Sphericity Assumed	26634.251	15	1775.617		
FIXATION * SOA * RESPONSE	Sphericity Assumed	716.833	1	716.833	.897	.359
FIXATION * SOA * RESPONSE * MAPPING	Sphericity Assumed	1855.470	1	1855.470	2.322	.148
Error(FIXATION *SOA*RESPONSE)	Sphericity Assumed	11985.563	15	799.038		
TARGET * SOA * RESPONSE	Sphericity Assumed	471.453	3	157.151	.139	.936
TARGET * SOA * RESPONSE * MAPPING	Sphericity Assumed	3659.420	3	1219.807	1.077	.368
Error(TARGET* SOA*RESPONSE)	Sphericity Assumed	50953.370	45	1132.297		
FIXATION * TARGET * SOA * RESPONSE	Sphericity Assumed	4383.941	3	1461.314	2.136	.109
FIXATION * TARGET * SOA * RESPONSE * MAPPING	Sphericity Assumed	70.794	3	23.598	.034	.991
Error(FIXATION *TARGET*SOA*RESPONSE)	Sphericity Assumed	30788.476	45	684.188		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	387.137	1	387.137	1.055	.321
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	810.088	1	810.088	2.207	.158
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	5505.017	15	367.001		
FIXATION * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	3487.562	1	3487.562	2.712	.120
FIXATION * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	2723.450	1	2723.450	2.118	.166
Error(FIXATION *ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	19288.123	15	1285.875		
TARGET * ORIENTAT *	Sphericity Assumed	4277.072	3	1425.691	1.180	.328

SOA * RESPONSE						
TARGET * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	3484.128	3	1161.376	.961	.419
Error(TARGET*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	54358.263	45	1207.961		
FIXATION * TARGET * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	14094.952	3	4698.317	3.280	.029
FIXATION * TARGET * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	861.354	3	287.118	.200	.896
Error(FIXATION*TARGET*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	64460.792	45	1432.462		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	408176419.192	1	408176419.192	1650.062	.000
MAPPING	540533.174	1	540533.174	2.185	.160
Error	3710555.278	15	247370.352		

Table 7.6.2 Experiment 6: Repeated measures ANOVA for mean correct responses (SOA 50 ms/lower visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	8366.558	1	8366.558	5.525	.033
FIXATION * MAPPING	Sphericity Assumed	761.977	1	761.977	.503	.489
Error(FIXATION)	Sphericity Assumed	22714.633	15	1514.309		
TARGET	Sphericity Assumed	1580.071	1	1580.071	1.292	.273
TARGET * MAPPING	Sphericity Assumed	840.024	1	840.024	.687	.420
Error(TARGET)	Sphericity Assumed	18342.766	15	1222.851		
ORIENTAT	Sphericity Assumed	3055.193	1	3055.193	1.938	.184
ORIENTAT * MAPPING	Sphericity Assumed	982.512	1	982.512	.623	.442
Error(ORIENTAT)	Sphericity Assumed	23642.651	15	1576.177		
RESPONSE	Sphericity Assumed	50536.333	1	50536.333	11.736	.004
RESPONSE * MAPPING	Sphericity Assumed	1244.580	1	1244.580	.289	.599
Error(RESPONSE)	Sphericity Assumed	64593.290	15	4306.219		
FIXATION * TARGET	Sphericity Assumed	1092.857	1	1092.857	.889	.361
FIXATION * TARGET * MAPPING	Sphericity Assumed	.948	1	.948	.001	.978

Error(FIXATION*TARGET)	Sphericity Assumed	18443.633	15	1229.576		
FIXATION * ORIENTAT	Sphericity Assumed	396.276	1	396.276	.235	.635
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	3620.768	1	3620.768	2.143	.164
Error(FIXATION*ORIENTAT)	Sphericity Assumed	25339.479	15	1689.299		
TARGET * ORIENTAT	Sphericity Assumed	6469.750	1	6469.750	6.137	.026
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	374.293	1	374.293	.355	.560
Error(TARGET*ORIENTAT)	Sphericity Assumed	15813.526	15	1054.235		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	1629.777	1	1629.777	2.345	.147
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	135.132	1	135.132	.194	.666
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	10425.546	15	695.036		
FIXATION * RESPONSE	Sphericity Assumed	569.108	1	569.108	.610	.447
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	2623.751	1	2623.751	2.813	.114
Error(FIXATION*RESPONSE)	Sphericity Assumed	13988.967	15	932.598		
TARGET * RESPONSE	Sphericity Assumed	25237.922	1	25237.922	13.393	.002
TARGET * RESPONSE * MAPPING	Sphericity Assumed	5.025	1	5.025	.003	.959
Error(TARGET*RESPONSE)	Sphericity Assumed	28265.639	15	1884.376		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	1052.303	1	1052.303	1.019	.329
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	170.222	1	170.222	.165	.690
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	15488.349	15	1032.557		
ORIENTAT * RESPONSE	Sphericity Assumed	35.801	1	35.801	.047	.832
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	666.778	1	666.778	.867	.367
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	11542.580	15	769.505		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	141.118	1	141.118	.084	.776
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	2222.289	1	2222.289	1.324	.268
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	25173.479	15	1678.232		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	149.592	1	149.592	.220	.645
TARGET *	Sphericity Assumed	6.816	1	6.816	.010	.921

ORIENTAT * RESPONSE * MAPPING						
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	10176.498	15	678.433		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	214.356	1	214.356	.336	.571
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	348.359	1	348.359	.546	.471
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	9574.290	15	638.286		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	104715600.619	1	104715600.619	1871.845	.000
MAPPING	210435.717	1	210435.717	3.762	.071
Error	839136.744	15	55942.450		

Table 7.6.3 Experiment 6: Repeated measures ANOVA for mean correct responses (SOA 50 ms/upper visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	2780.853	1	2780.853	4.103	.061
FIXATION * MAPPING	Sphericity Assumed	814.505	1	814.505	1.202	.290
Error(FIXATION)	Sphericity Assumed	10167.063	15	677.804		
TARGET	Sphericity Assumed	1648.932	1	1648.932	1.319	.269
TARGET * MAPPING	Sphericity Assumed	245.754	1	245.754	.197	.664
Error(TARGET)	Sphericity Assumed	18747.160	15	1249.811		
ORIENTAT	Sphericity Assumed	3109.299	1	3109.299	3.718	.073
ORIENTAT * MAPPING	Sphericity Assumed	7988.092	1	7988.092	9.553	.007
Error(ORIENTAT)	Sphericity Assumed	12542.749	15	836.183		
RESPONSE	Sphericity Assumed	58256.600	1	58256.600	22.122	.000
RESPONSE * MAPPING	Sphericity Assumed	45997.079	1	45997.079	17.466	.001
Error(RESPONSE)	Sphericity Assumed	39502.142	15	2633.476		
FIXATION * TARGET	Sphericity Assumed	118.435	1	118.435	.059	.811
FIXATION * TARGET * MAPPING	Sphericity Assumed	37.811	1	37.811	.019	.892
Error(FIXATION*TARGET)	Sphericity Assumed	29990.899	15	1999.393		
FIXATION * ORIENTAT	Sphericity Assumed	3273.540	1	3273.540	1.947	.183
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	6419.300	1	6419.300	3.818	.070
Error(FIXATION*ORIENTAT)	Sphericity Assumed	25217.105	15	1681.140		
TARGET * ORIENTAT	Sphericity Assumed	10979.895	1	10979.895	11.886	.004

TARGET * ORIENTAT * MAPPING	Sphericity Assumed	291.941	1	291.941	.316	.582
Error(TARGET*ORIENTAT)	Sphericity Assumed	13856.229	15	923.749		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	31.123	1	31.123	.039	.845
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	1234.285	1	1234.285	1.560	.231
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	11867.469	15	791.165		
FIXATION * RESPONSE	Sphericity Assumed	1024.239	1	1024.239	.976	.339
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	31.588	1	31.588	.030	.865
Error(FIXATION*RESPONSE)	Sphericity Assumed	15744.357	15	1049.624		
TARGET * RESPONSE	Sphericity Assumed	11183.124	1	11183.124	5.923	.028
TARGET * RESPONSE * MAPPING	Sphericity Assumed	51.176	1	51.176	.027	.871
Error(TARGET*RESPONSE)	Sphericity Assumed	28322.442	15	1888.163		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	1319.728	1	1319.728	1.608	.224
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	2866.246	1	2866.246	3.492	.081
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	12311.299	15	820.753		
ORIENTAT * RESPONSE	Sphericity Assumed	186.808	1	186.808	.162	.693
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1396.800	1	1396.800	1.210	.289
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	17309.096	15	1153.940		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	7315.167	1	7315.167	4.673	.047
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	621.817	1	621.817	.397	.538
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	23482.776	15	1565.518		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	652.699	1	652.699	1.094	.312
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	633.456	1	633.456	1.062	.319
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	8951.104	15	596.740		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	8.454	1	8.454	.010	.920
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1046.863	1	1046.863	1.292	.273
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	12151.058	15	810.071		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	101985421.131	1	101985421.131	2025.411	.000
MAPPING	115449.886	1	115449.886	2.293	.151
Error	755294.314	15	50352.954		

Table 7.6.4 Experiment 6: Repeated measures ANOVA for mean correct responses (SOA 700 ms/lower visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	6054.814	1	6054.814	5.320	.036
FIXATION * MAPPING	Sphericity Assumed	621.735	1	621.735	.546	.471
Error(FIXATION)	Sphericity Assumed	17071.998	15	1138.133		
TARGET	Sphericity Assumed	3704.618	1	3704.618	2.780	.116
TARGET * MAPPING	Sphericity Assumed	860.181	1	860.181	.646	.434
Error(TARGET)	Sphericity Assumed	19988.321	15	1332.555		
ORIENTAT	Sphericity Assumed	448.022	1	448.022	.504	.489
ORIENTAT * MAPPING	Sphericity Assumed	381.757	1	381.757	.429	.522
Error(ORIENTAT)	Sphericity Assumed	13334.914	15	888.994		
RESPONSE	Sphericity Assumed	53395.987	1	53395.987	14.429	.002
RESPONSE * MAPPING	Sphericity Assumed	2760.110	1	2760.110	.746	.401
Error(RESPONSE)	Sphericity Assumed	55510.152	15	3700.677		
FIXATION * TARGET	Sphericity Assumed	296.505	1	296.505	.307	.587
FIXATION * TARGET * MAPPING	Sphericity Assumed	17.690	1	17.690	.018	.894
Error(FIXATION*TARGET)	Sphericity Assumed	14468.797	15	964.586		
FIXATION * ORIENTAT	Sphericity Assumed	260.565	1	260.565	.218	.647
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	2352.762	1	2352.762	1.970	.181
Error(FIXATION*ORIENTAT)	Sphericity Assumed	17916.638	15	1194.443		
TARGET * ORIENTAT	Sphericity Assumed	1446.140	1	1446.140	1.056	.320
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	193.448	1	193.448	.141	.712
Error(TARGET*ORIENTAT)	Sphericity Assumed	20538.745	15	1369.250		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	186.720	1	186.720	.263	.616
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	1796.264	1	1796.264	2.526	.133
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	10666.707	15	711.114		
FIXATION * RESPONSE	Sphericity Assumed	194.003	1	194.003	.281	.604
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	167.792	1	167.792	.243	.629
Error(FIXATION*RESPONSE)	Sphericity Assumed	10344.774	15	689.652		
TARGET * RESPONSE	Sphericity Assumed	16898.258	1	16898.258	17.503	.001

TARGET * RESPONSE * MAPPING	Sphericity Assumed	1598.255	1	1598.255	1.655	.218
Error(TARGET*RESPONSE)	Sphericity Assumed	14481.506	15	965.434		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	979.427	1	979.427	2.829	.113
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	104.609	1	104.609	.302	.591
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	5192.488	15	346.166		
ORIENTAT * RESPONSE	Sphericity Assumed	2140.602	1	2140.602	1.922	.186
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	2239.200	1	2239.200	2.011	.177
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	16705.877	15	1113.725		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	4817.521	1	4817.521	1.567	.230
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	54.105	1	54.105	.018	.896
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	46127.364	15	3075.158		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	444.174	1	444.174	.588	.455
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1660.026	1	1660.026	2.199	.159
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	11324.564	15	754.971		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	43.794	1	43.794	.055	.818
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	34.966	1	34.966	.044	.837
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	12022.896	15	801.526		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	101570417.372	1	101570417.372	1301.183	.000
MAPPING	123634.045	1	123634.045	1.584	.227
Error	1170900.800	15	78060.053		

Table 7.6.5 Experiment 6: Repeated measures ANOVA for mean correct responses (SOA 700 ms/upper visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	6.610	1	6.610	.010	.922
FIXATION * MAPPING	Sphericity Assumed	359.751	1	359.751	.544	.472
Error(FIXATION)	Sphericity Assumed	9928.196	15	661.880		
TARGET	Sphericity Assumed	7225.184	1	7225.184	3.956	.065

TARGET * MAPPING	Sphericity Assumed	1718.503	1	1718.503	.941	.347
Error(TARGET)	Sphericity Assumed	27394.297	15	1826.286		
ORIENTAT	Sphericity Assumed	783.848	1	783.848	.566	.464
ORIENTAT * MAPPING	Sphericity Assumed	496.333	1	496.333	.358	.558
Error(ORIENTAT)	Sphericity Assumed	20780.922	15	1385.395		
RESPONSE	Sphericity Assumed	61044.750	1	61044.750	22.954	.000
RESPONSE * MAPPING	Sphericity Assumed	37398.986	1	37398.986	14.063	.002
Error(RESPONSE)	Sphericity Assumed	39891.356	15	2659.424		
FIXATION * TARGET	Sphericity Assumed	1297.697	1	1297.697	.519	.482
FIXATION * TARGET * MAPPING	Sphericity Assumed	2462.907	1	2462.907	.986	.337
Error(FIXATION*TARGET)	Sphericity Assumed	37477.890	15	2498.526		
FIXATION * ORIENTAT	Sphericity Assumed	1957.005	1	1957.005	.889	.361
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	1477.027	1	1477.027	.671	.426
Error(FIXATION*ORIENTAT)	Sphericity Assumed	33037.710	15	2202.514		
TARGET * ORIENTAT	Sphericity Assumed	575.024	1	575.024	.235	.635
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	2517.350	1	2517.350	1.028	.327
Error(TARGET*ORIENTAT)	Sphericity Assumed	36744.215	15	2449.614		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	355.234	1	355.234	.790	.388
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	915.116	1	915.116	2.034	.174
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	6748.290	15	449.886		
FIXATION * RESPONSE	Sphericity Assumed	2281.660	1	2281.660	2.584	.129
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	1785.984	1	1785.984	2.023	.175
Error(FIXATION*RESPONSE)	Sphericity Assumed	13243.922	15	882.928		
TARGET * RESPONSE	Sphericity Assumed	9082.149	1	9082.149	4.171	.059
TARGET * RESPONSE * MAPPING	Sphericity Assumed	3861.162	1	3861.162	1.773	.203
Error(TARGET*RESPONSE)	Sphericity Assumed	32663.713	15	2177.581		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	929.003	1	929.003	1.054	.321
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	3954.972	1	3954.972	4.486	.051
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	13224.448	15	881.630		
ORIENTAT * RESPONSE	Sphericity Assumed	.592	1	.592	.001	.971
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1684.974	1	1684.974	3.859	.068
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	6548.698	15	436.580		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	8120.076	1	8120.076	4.538	.050
FIXATION *	Sphericity Assumed	1572.248	1	1572.248	.879	.363

ORIENTAT * RESPONSE * MAPPING						
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	26837.670	15	1789.178		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	2933.574	1	2933.574	2.279	.152
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	235.256	1	235.256	.183	.675
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	19307.410	15	1287.161		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	425.599	1	425.599	.645	.435
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	3700.852	1	3700.852	5.606	.032
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	9901.746	15	660.116		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	99933823.614	1	99933823.614	1418.903	.000
MAPPING	102586.318	1	102586.318	1.457	.246
Error	1056455.216	15	70430.348		

Table 7.6.6 Overall experimental means for correct responses of Experiment 6

FIXATION * TARGET * ORIENTAT * SOA * RESPONSE

Measure: MEASURE_1

FIXATION	TARGET	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1	1	1	1	612.701	12.772	585.478	639.923
				2	606.095	13.967	576.325	635.865
			2	1	626.642	18.598	587.001	666.283
				2	604.302	14.491	573.416	635.188
		2	1	1	621.266	12.290	595.070	647.462
				2	625.529	20.419	582.007	669.051
			2	1	611.263	16.619	575.840	646.686
				2	598.058	14.859	566.386	629.729
	2	1	1	1	636.814	15.126	604.573	669.054
				2	615.592	12.844	588.216	642.969
			2	1	621.388	16.414	586.402	656.373
				2	595.400	11.396	571.109	619.691
		2	1	1	605.766	15.387	572.969	638.562
				2	595.090	12.414	568.630	621.549
			2	1	626.572	20.836	582.160	670.983
				2	596.675	16.001	562.570	630.780
	3	1	1	1	639.224	19.882	596.847	681.601
				2	576.570	16.958	540.424	612.715
			2	1	619.429	17.550	582.023	656.835
				2	595.864	25.977	540.495	651.233

		2	1	1	625.365	12.775	598.135	652.594
				2	587.083	14.172	556.877	617.290
			2	1	632.379	16.248	597.748	667.010
				2	568.563	13.861	539.020	598.106
	4	1	1	1	636.730	14.154	606.561	666.898
				2	590.174	15.751	556.602	623.747
			2	1	625.294	21.619	579.214	671.374
				2	582.487	18.810	542.395	622.579
		2	1	1	642.090	16.935	605.994	678.185
				2	593.346	19.457	551.873	634.818
			2	1	625.987	14.110	595.912	656.061
				2	585.289	17.756	547.444	623.135
2	1	1	1	1	628.959	21.644	582.827	675.091
				2	615.119	19.772	572.977	657.262
			2	1	621.444	18.498	582.017	660.871
				2	625.347	21.420	579.690	671.003
		2	1	1	648.940	16.913	612.891	684.988
				2	633.082	17.538	595.701	670.463
			2	1	628.562	24.465	576.417	680.708
				2	611.089	15.516	578.017	644.161
	2	1	1	1	626.114	13.407	597.536	654.691
				2	623.915	21.055	579.038	668.792
			2	1	621.927	20.550	578.125	665.729
				2	598.069	13.567	569.152	626.985
		2	1	1	627.684	18.332	588.610	666.758
				2	595.884	18.345	556.782	634.986
			2	1	616.399	17.805	578.447	654.350
				2	622.394	28.969	560.647	684.140
	3	1	1	1	620.280	10.153	598.638	641.921
				2	595.714	16.554	560.431	630.997
			2	1	619.054	15.849	585.273	652.836
				2	572.784	17.651	535.163	610.405
		2	1	1	643.163	19.432	601.744	684.582
				2	599.997	13.884	570.404	629.590
			2	1	620.426	18.325	581.369	659.484
				2	587.715	16.766	551.979	623.451
	4	1	1	1	650.440	15.789	616.786	684.094
				2	605.299	15.116	573.080	637.519
			2	1	625.228	14.452	594.424	656.033
				2	596.673	22.903	547.856	645.489
		2	1	1	640.485	19.536	598.846	682.124
				2	594.497	13.547	565.621	623.373
			2	1	644.994	26.389	588.746	701.241
				2	581.606	16.537	546.357	616.854

Table 7.6.7 Experiment 6: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	137.337	1	137.337	4.739	.046

FIXATION * MAPPING	Sphericity Assumed	2.042	1	2.042	.070	.794
Error(FIXATION)	Sphericity Assumed	434.722	15	28.981		
TARGET	Sphericity Assumed	1180.724	3	393.575	6.807	.001
TARGET * MAPPING	Sphericity Assumed	213.812	3	71.271	1.233	.309
Error(TARGET)	Sphericity Assumed	2601.997	45	57.822		
ORIENTAT	Sphericity Assumed	22.243	1	22.243	.501	.490
ORIENTAT * MAPPING	Sphericity Assumed	176.654	1	176.654	3.981	.065
Error(ORIENTAT)	Sphericity Assumed	665.625	15	44.375		
SOA	Sphericity Assumed	8.170	1	8.170	.144	.710
SOA * MAPPING	Sphericity Assumed	5.229	1	5.229	.092	.766
Error(SOA)	Sphericity Assumed	851.389	15	56.759		
RESPONSE	Sphericity Assumed	28.722	1	28.722	.332	.573
RESPONSE * MAPPING	Sphericity Assumed	13.281	1	13.281	.153	.701
Error(RESPONSE)	Sphericity Assumed	1299.219	15	86.615		
FIXATION * TARGET	Sphericity Assumed	202.134	3	67.378	1.946	.136
FIXATION * TARGET * MAPPING	Sphericity Assumed	90.370	3	30.123	.870	.464
Error(FIXATION*TARGET)	Sphericity Assumed	1558.160	45	34.626		
FIXATION * ORIENTAT	Sphericity Assumed	87.628	1	87.628	1.695	.213
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	113.363	1	113.363	2.192	.159
Error(FIXATION*ORIENTAT)	Sphericity Assumed	775.608	15	51.707		
TARGET * ORIENTAT	Sphericity Assumed	20.047	3	6.682	.229	.876
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	112.694	3	37.565	1.288	.290
Error(TARGET*ORIENTAT)	Sphericity Assumed	1312.674	45	29.171		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	56.378	3	18.793	.443	.723
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	33.584	3	11.195	.264	.851
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	1906.858	45	42.375		
FIXATION * SOA	Sphericity Assumed	77.252	1	77.252	6.005	.027
FIXATION * SOA * MAPPING	Sphericity Assumed	110.340	1	110.340	8.577	.010
Error(FIXATION*SOA)	Sphericity Assumed	192.969	15	12.865		
TARGET * SOA	Sphericity Assumed	128.380	3	42.793	.982	.410
TARGET * SOA * MAPPING	Sphericity Assumed	166.616	3	55.539	1.275	.294
Error(TARGET*SOA)	Sphericity Assumed	1960.590	45	43.569		
FIXATION * TARGET * SOA	Sphericity Assumed	122.942	3	40.981	.958	.421
FIXATION * TARGET * SOA * MAPPING	Sphericity Assumed	10.442	3	3.481	.081	.970
Error(FIXATION*TARGET*SOA)	Sphericity Assumed	1925.955	45	42.799		
ORIENTAT * SOA	Sphericity Assumed	1.476	1	1.476	.028	.870
ORIENTAT * SOA * MAPPING	Sphericity Assumed	27.211	1	27.211	.511	.486
Error(ORIENTAT*SOA)	Sphericity Assumed	798.524	15	53.235		
FIXATION * ORIENTAT * SOA	Sphericity Assumed	64.052	1	64.052	3.255	.091

FIXATION * ORIENTAT * SOA * MAPPING	Sphericity Assumed	55.229	1	55.229	2.807	.115
Error(FIXATION*ORIENTAT*SOA)	Sphericity Assumed	295.139	15	19.676		
TARGET * ORIENTAT * SOA	Sphericity Assumed	216.325	3	72.108	1.724	.176
TARGET * ORIENTAT * SOA * MAPPING	Sphericity Assumed	34.707	3	11.569	.277	.842
Error(TARGET*ORIENTAT*SOA)	Sphericity Assumed	1882.205	45	41.827		
FIXATION * TARGET * ORIENTAT * SOA	Sphericity Assumed	62.286	3	20.762	.737	.536
FIXATION * TARGET * ORIENTAT * SOA * MAPPING	Sphericity Assumed	194.638	3	64.879	2.302	.090
Error(FIXATION*TARGET*ORIENTAT*SOA)	Sphericity Assumed	1268.229	45	28.183		
FIXATION * RESPONSE	Sphericity Assumed	66.360	1	66.360	3.425	.084
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	.184	1	.184	.009	.924
Error(FIXATION*RESPONSE)	Sphericity Assumed	290.625	15	19.375		
TARGET * RESPONSE	Sphericity Assumed	2979.356	3	993.119	9.279	.000
TARGET * RESPONSE * MAPPING	Sphericity Assumed	559.503	3	186.501	1.743	.172
Error(TARGET*RESPONSE)	Sphericity Assumed	4816.233	45	107.027		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	64.471	3	21.490	.403	.751
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	10.059	3	3.353	.063	.979
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	2399.132	45	53.314		
ORIENTAT * RESPONSE	Sphericity Assumed	11.765	1	11.765	.642	.436
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	144.118	1	144.118	7.861	.013
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	275.000	15	18.333		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	38.649	1	38.649	2.910	.109
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	5.561	1	5.561	.419	.527
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	199.219	15	13.281		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	86.346	3	28.782	.799	.501
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	368.699	3	122.900	3.412	.025
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	1621.007	45	36.022		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	61.014	3	20.338	.797	.502
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	123.514	3	41.171	1.614	.199

Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	1148.177	45	25.515		
SOA * RESPONSE	Sphericity Assumed	184.334	1	184.334	5.181	.038
SOA * RESPONSE * MAPPING	Sphericity Assumed	.511	1	.511	.014	.906
Error(SOA*RESPONSE)	Sphericity Assumed	533.681	15	35.579		
FIXATION * SOA * RESPONSE	Sphericity Assumed	101.517	1	101.517	3.129	.097
FIXATION * SOA * RESPONSE * MAPPING	Sphericity Assumed	2.252	1	2.252	.069	.796
Error(FIXATION*SOA*RESPONSE)	Sphericity Assumed	486.719	15	32.448		
TARGET * SOA * RESPONSE	Sphericity Assumed	70.701	3	23.567	.367	.777
TARGET * SOA * RESPONSE * MAPPING	Sphericity Assumed	275.112	3	91.704	1.430	.247
Error(TARGET*SOA*RESPONSE)	Sphericity Assumed	2886.285	45	64.140		
FIXATION * TARGET * SOA * RESPONSE	Sphericity Assumed	76.312	3	25.437	.656	.584
FIXATION * TARGET * SOA * RESPONSE * MAPPING	Sphericity Assumed	69.695	3	23.232	.599	.619
Error(FIXATION*TARGET*SOA*RESPONSE)	Sphericity Assumed	1745.747	45	38.794		
ORIENTAT * SOA * RESPONSE	Sphericity Assumed	28.722	1	28.722	.874	.365
ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	13.281	1	13.281	.404	.535
Error(ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	492.969	15	32.865		
FIXATION * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	134.007	1	134.007	2.737	.119
FIXATION * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	41.360	1	41.360	.845	.373
Error(FIXATION*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	734.375	15	48.958		
TARGET * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	167.611	3	55.870	1.947	.136
TARGET * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	218.347	3	72.782	2.536	.069
Error(TARGET*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	1291.580	45	28.702		
FIXATION * TARGET * ORIENTAT * SOA * RESPONSE	Sphericity Assumed	52.808	3	17.603	.406	.749
FIXATION * TARGET * ORIENTAT * SOA * RESPONSE * MAPPING	Sphericity Assumed	71.926	3	23.975	.553	.649
Error(FIXATION*TARGET*ORIENTAT*SOA*RESPONSE)	Sphericity Assumed	1950.868	45	43.353		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	16895.226	1	16895.226	70.426	.000
MAPPING	6.255	1	6.255	.026	.874
Error	3598.524	15	239.902		

Table 7.6.8 Experiment 6: Repeated measures ANOVA for mean incorrect responses (SOA 50 ms/lower visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	208.354	1	208.354	4.177	.059
FIXATION * MAPPING	Sphericity Assumed	76.001	1	76.001	1.524	.236
Error(FIXATION)	Sphericity Assumed	748.264	15	49.884		
TARGET	Sphericity Assumed	8.170	1	8.170	.213	.651
TARGET * MAPPING	Sphericity Assumed	314.052	1	314.052	8.173	.012
Error(TARGET)	Sphericity Assumed	576.389	15	38.426		
ORIENTAT	Sphericity Assumed	11.765	1	11.765	.328	.575
ORIENTAT * MAPPING	Sphericity Assumed	47.059	1	47.059	1.313	.270
Error(ORIENTAT)	Sphericity Assumed	537.500	15	35.833		
RESPONSE	Sphericity Assumed	97.243	1	97.243	1.315	.269
RESPONSE * MAPPING	Sphericity Assumed	176.654	1	176.654	2.389	.143
Error(RESPONSE)	Sphericity Assumed	1109.375	15	73.958		
FIXATION * TARGET	Sphericity Assumed	.082	1	.082	.002	.969
FIXATION * TARGET * MAPPING	Sphericity Assumed	29.493	1	29.493	.561	.466
Error(FIXATION*TARGET)	Sphericity Assumed	788.889	15	52.593		
FIXATION * ORIENTAT	Sphericity Assumed	64.052	1	64.052	2.734	.119
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	5.229	1	5.229	.223	.643
Error(FIXATION*ORIENTAT)	Sphericity Assumed	351.389	15	23.426		
TARGET * ORIENTAT	Sphericity Assumed	22.243	1	22.243	.596	.452
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	66.360	1	66.360	1.779	.202
Error(TARGET*ORIENTAT)	Sphericity Assumed	559.375	15	37.292		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	17.177	1	17.177	.575	.460
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	2.471	1	2.471	.083	.778
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	448.264	15	29.884		
FIXATION * RESPONSE	Sphericity Assumed	3.452	1	3.452	.081	.780
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	.511	1	.511	.012	.914
Error(FIXATION*RESPONSE)	Sphericity Assumed	639.931	15	42.662		
TARGET *	Sphericity Assumed	1061.765	1	1061.765	13.700	.002

RESPONSE						
TARGET * RESPONSE * MAPPING	Sphericity Assumed	73.529	1	73.529	.949	.345
Error(TARGET*RESPONSE)	Sphericity Assumed	1162.500	15	77.500		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	.327	1	.327	.006	.940
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	.327	1	.327	.006	.940
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	843.056	15	56.204		
ORIENTAT * RESPONSE	Sphericity Assumed	88.971	1	88.971	5.338	.035
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	36.029	1	36.029	2.162	.162
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	250.000	15	16.667		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	83.660	1	83.660	3.489	.081
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	1.307	1	1.307	.055	.819
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	359.722	15	23.981		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	45.118	1	45.118	1.293	.273
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	465.707	1	465.707	13.350	.002
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	523.264	15	34.884		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	.511	1	.511	.010	.923
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	3.452	1	3.452	.066	.801
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	789.931	15	52.662		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	6520.118	1	6520.118	83.359	.000
MAPPING	17.177	1	17.177	.220	.646
Error	1173.264	15	78.218		

Table 7.6.9 Experiment 6: Repeated measures ANOVA for mean incorrect responses (SOA 50 ms/upper visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	36.892	1	36.892	1.767	.204
FIXATION * MAPPING	Sphericity Assumed	.128	1	.128	.006	.939
Error(FIXATION)	Sphericity Assumed	313.108	15	20.874		

TARGET	Sphericity Assumed	11.280	1	11.280	.384	.545
TARGET * MAPPING	Sphericity Assumed	21.574	1	21.574	.735	.405
Error(TARGET)	Sphericity Assumed	440.191	15	29.346		
ORIENTAT	Sphericity Assumed	.005	1	.005	.000	.990
ORIENTAT * MAPPING	Sphericity Assumed	1.476	1	1.476	.044	.836
Error(ORIENTAT)	Sphericity Assumed	498.524	15	33.235		
RESPONSE	Sphericity Assumed	82.358	1	82.358	1.597	.226
RESPONSE * MAPPING	Sphericity Assumed	107.358	1	107.358	2.082	.170
Error(RESPONSE)	Sphericity Assumed	773.524	15	51.568		
FIXATION * TARGET	Sphericity Assumed	13.281	1	13.281	.941	.347
FIXATION * TARGET * MAPPING	Sphericity Assumed	.046	1	.046	.003	.955
Error(FIXATION*TARGET)	Sphericity Assumed	211.719	15	14.115		
FIXATION * ORIENTAT	Sphericity Assumed	87.628	1	87.628	2.501	.135
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	30.275	1	30.275	.864	.367
Error(FIXATION*ORIENTAT)	Sphericity Assumed	525.608	15	35.041		
TARGET * ORIENTAT	Sphericity Assumed	142.407	1	142.407	5.094	.039
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	8.584	1	8.584	.307	.588
Error(TARGET*ORIENTAT)	Sphericity Assumed	419.358	15	27.957		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	28.722	1	28.722	1.329	.267
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	77.252	1	77.252	3.574	.078
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	324.219	15	21.615		
FIXATION * RESPONSE	Sphericity Assumed	.005	1	.005	.000	.987
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	1.476	1	1.476	.081	.780
Error(FIXATION*RESPONSE)	Sphericity Assumed	273.524	15	18.235		
TARGET * RESPONSE	Sphericity Assumed	301.517	1	301.517	3.321	.088
TARGET * RESPONSE * MAPPING	Sphericity Assumed	50.046	1	50.046	.551	.469
Error(TARGET*RESPONSE)	Sphericity Assumed	1361.719	15	90.781		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	.046	1	.046	.002	.962
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	13.281	1	13.281	.695	.418
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	286.719	15	19.115		
ORIENTAT * RESPONSE	Sphericity Assumed	.414	1	.414	.016	.900
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	93.061	1	93.061	3.669	.075
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	380.469	15	25.365		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	74.760	1	74.760	2.844	.112

FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	8.584	1	8.584	.326	.576
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	394.358	15	26.291		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	1.843	1	1.843	.070	.794
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	6.255	1	6.255	.239	.632
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	392.274	15	26.152		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	10.340	1	10.340	.244	.629
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	50.046	1	50.046	1.179	.295
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	636.719	15	42.448		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	2713.649	1	2713.649	29.486	.000
MAPPING	.414	1	.414	.004	.947
Error	1380.469	15	92.031		

Table 7.6.10 Experiment 6: Repeated measures ANOVA for mean incorrect responses (SOA 700 ms/lower visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	57.373	1	57.373	1.218	.287
FIXATION * MAPPING	Sphericity Assumed	25.020	1	25.020	.531	.477
Error(FIXATION)	Sphericity Assumed	706.597	15	47.106		
TARGET	Sphericity Assumed	105.882	1	105.882	1.396	.256
TARGET * MAPPING	Sphericity Assumed	.000	1	.000	.000	1.000
Error(TARGET)	Sphericity Assumed	1137.500	15	75.833		
ORIENTAT	Sphericity Assumed	2.042	1	2.042	.023	.881
ORIENTAT * MAPPING	Sphericity Assumed	196.160	1	196.160	2.225	.156
Error(ORIENTAT)	Sphericity Assumed	1322.222	15	88.148		
RESPONSE	Sphericity Assumed	1.001	1	1.001	.010	.923
RESPONSE * MAPPING	Sphericity Assumed	192.177	1	192.177	1.862	.193
Error(RESPONSE)	Sphericity Assumed	1548.264	15	103.218		
FIXATION * TARGET	Sphericity Assumed	184.334	1	184.334	5.370	.035
FIXATION * TARGET * MAPPING	Sphericity Assumed	34.334	1	34.334	1.000	.333
Error(FIXATION*TARGET)	Sphericity Assumed	514.931	15	34.329		
FIXATION * ORIENTAT	Sphericity Assumed	2.471	1	2.471	.037	.850
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	270.118	1	270.118	4.059	.062

Error(FIXATION*ORIENTAT)	Sphericity Assumed	998.264	15	66.551		
TARGET * ORIENTAT	Sphericity Assumed	29.493	1	29.493	.561	.466
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	.082	1	.082	.002	.969
Error(TARGET*ORIENTAT)	Sphericity Assumed	788.889	15	52.593		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	45.118	1	45.118	.695	.417
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	1.001	1	1.001	.015	.903
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	973.264	15	64.884		
FIXATION * RESPONSE	Sphericity Assumed	229.493	1	229.493	5.185	.038
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	.082	1	.082	.002	.966
Error(FIXATION*RESPONSE)	Sphericity Assumed	663.889	15	44.259		
TARGET * RESPONSE	Sphericity Assumed	1589.890	1	1589.890	8.968	.009
TARGET * RESPONSE * MAPPING	Sphericity Assumed	134.007	1	134.007	.756	.398
Error(TARGET*RESPONSE)	Sphericity Assumed	2659.375	15	177.292		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	64.052	1	64.052	.651	.432
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	5.229	1	5.229	.053	.821
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	1476.389	15	98.426		
ORIENTAT * RESPONSE	Sphericity Assumed	1.654	1	1.654	.036	.852
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	81.066	1	81.066	1.777	.202
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	684.375	15	45.625		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	13.807	1	13.807	.308	.587
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	137.337	1	137.337	3.065	.100
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	672.222	15	44.815		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	57.373	1	57.373	1.263	.279
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	25.020	1	25.020	.551	.470
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	681.597	15	45.440		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	100.082	1	100.082	3.421	.084
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	23.611	1	23.611	.807	.383
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	438.889	15	29.259		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	6918.382	1	6918.382	28.628	.000
MAPPING	18.382	1	18.382	.076	.786
Error	3625.000	15	241.667		

Table 7.6.11 Experiment 6: Repeated measures ANOVA for mean incorrect responses (SOA 700 ms/upper visual field)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FIXATION	Sphericity Assumed	21.574	1	21.574	.735	.405
FIXATION * MAPPING	Sphericity Assumed	48.044	1	48.044	1.637	.220
Error(FIXATION)	Sphericity Assumed	440.191	15	29.346		
TARGET	Sphericity Assumed	3.722	1	3.722	.204	.658
TARGET * MAPPING	Sphericity Assumed	3.722	1	3.722	.204	.658
Error(TARGET)	Sphericity Assumed	274.219	15	18.281		
ORIENTAT	Sphericity Assumed	20.267	1	20.267	2.577	.129
ORIENTAT * MAPPING	Sphericity Assumed	20.267	1	20.267	2.577	.129
Error(ORIENTAT)	Sphericity Assumed	117.969	15	7.865		
RESPONSE	Sphericity Assumed	52.088	1	52.088	1.574	.229
RESPONSE * MAPPING	Sphericity Assumed	90.324	1	90.324	2.729	.119
Error(RESPONSE)	Sphericity Assumed	496.441	15	33.096		
FIXATION * TARGET	Sphericity Assumed	17.775	1	17.775	.687	.420
FIXATION * TARGET * MAPPING	Sphericity Assumed	.128	1	.128	.005	.945
Error(FIXATION*TARGET)	Sphericity Assumed	388.108	15	25.874		
FIXATION * ORIENTAT	Sphericity Assumed	8.584	1	8.584	.587	.455
FIXATION * ORIENTAT * MAPPING	Sphericity Assumed	2.701	1	2.701	.185	.673
Error(FIXATION*ORIENTAT)	Sphericity Assumed	219.358	15	14.624		
TARGET * ORIENTAT	Sphericity Assumed	31.868	1	31.868	1.151	.300
TARGET * ORIENTAT * MAPPING	Sphericity Assumed	11.280	1	11.280	.408	.533
Error(TARGET*ORIENTAT)	Sphericity Assumed	415.191	15	27.679		
FIXATION * TARGET * ORIENTAT	Sphericity Assumed	16.590	1	16.590	.614	.446
FIXATION * TARGET * ORIENTAT * MAPPING	Sphericity Assumed	7.767	1	7.767	.287	.600
Error(FIXATION*TARGET*ORIENTAT)	Sphericity Assumed	405.469	15	27.031		
FIXATION * RESPONSE	Sphericity Assumed	9.441	1	9.441	.409	.532
FIXATION * RESPONSE * MAPPING	Sphericity Assumed	.618	1	.618	.027	.872
Error(FIXATION*RESPONSE)	Sphericity Assumed	346.441	15	23.096		
TARGET * RESPONSE	Sphericity Assumed	77.252	1	77.252	2.732	.119

TARGET * RESPONSE * MAPPING	Sphericity Assumed	24.311	1	24.311	.860	.369
Error(TARGET*RESPONSE)	Sphericity Assumed	424.219	15	28.281		
FIXATION * TARGET * RESPONSE	Sphericity Assumed	1.843	1	1.843	.070	.794
FIXATION * TARGET * RESPONSE * MAPPING	Sphericity Assumed	60.667	1	60.667	2.320	.149
Error(FIXATION*TARGET*RESPONSE)	Sphericity Assumed	392.274	15	26.152		
ORIENTAT * RESPONSE	Sphericity Assumed	.414	1	.414	.017	.897
ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	.414	1	.414	.017	.897
Error(ORIENTAT*RESPONSE)	Sphericity Assumed	355.469	15	23.698		
FIXATION * ORIENTAT * RESPONSE	Sphericity Assumed	2.701	1	2.701	.127	.727
FIXATION * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	8.584	1	8.584	.403	.535
Error(FIXATION*ORIENTAT*RESPONSE)	Sphericity Assumed	319.358	15	21.291		
TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	98.657	1	98.657	3.582	.078
TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	36.892	1	36.892	1.340	.265
Error(TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	413.108	15	27.541		
FIXATION * TARGET * ORIENTAT * RESPONSE	Sphericity Assumed	.618	1	.618	.022	.884
FIXATION * TARGET * ORIENTAT * RESPONSE * MAPPING	Sphericity Assumed	9.441	1	9.441	.336	.571
Error(FIXATION*TARGET*ORIENTAT*RESPONSE)	Sphericity Assumed	421.441	15	28.096		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1931.296	1	1931.296	71.447	.000
MAPPING	16.590	1	16.590	.614	.446
Error	405.469	15	27.031		

Table 7.6.12 Overall experimental means for incorrect responses of Experiment 6

FIXATION * TARGET * ORIENTAT * SOA * RESPONSE

FIXATION	TARGET	ORIENTAT	SOA	RESPONSE	Mean	Std. Error	95% Confidence Interval	
							Lower Bound	Upper Bound
1	1	1	1	1	4.792	1.235	2.160	7.424
				2	7.014	1.462	3.898	10.130
			2	1	2.917	1.471	-.219	6.052
				2	7.500	2.661	1.827	13.173

		2	1	1	3.472	1.501	.274	6.671
				2	7.083	1.718	3.422	10.745
			2	1	5.556	2.070	1.143	9.968
				2	5.278	1.565	1.943	8.613
	2	1	1	1	3.403	1.416	.384	6.422
				2	3.542	1.521	.301	6.783
			2	1	1.736	.978	-.348	3.821
				2	2.292	1.064	.025	4.559
		2	1	1	3.472	1.501	.274	6.671
				2	5.417	2.624	-.177	11.010
			2	1	.556	.591	-.705	1.816
				2	3.472	1.501	.274	6.671
	3	1	1	1	7.014	1.710	3.369	10.659
				2	2.431	1.043	.208	4.653
			2	1	2.222	1.289	-.525	4.970
				2	2.917	1.471	-.219	6.052
		2	1	1	2.431	1.857	-1.528	6.389
				2	.556	.591	-.705	1.816
			2	1	4.028	1.210	1.448	6.607
				2	1.875	.859	.044	3.706
	4	1	1	1	8.264	1.591	4.873	11.655
				2	4.167	2.173	-.465	8.798
			2	1	9.167	1.984	4.938	13.395
				2	1.736	.978	-.348	3.821
		2	1	1	8.542	2.162	3.934	13.149
				2	2.917	1.174	.415	5.418
			2	1	7.847	3.609	.155	15.539
				2	4.097	1.549	.796	7.399
2	1	1	1	1	1.736	.978	-.348	3.821
				2	5.694	1.586	2.315	9.074
			2	1	1.875	.859	.044	3.706
				2	8.750	2.624	3.157	14.343
		2	1	1	3.403	1.416	.384	6.422
				2	4.653	1.549	1.351	7.954
			2	1	2.431	1.043	.208	4.653
				2	11.111	3.634	3.366	18.856
	2	1	1	1	1.111	.782	-.557	2.779
				2	2.500	1.537	-.775	5.775
			2	1	2.847	1.104	.494	5.200
				2	3.611	1.183	1.090	6.132
		2	1	1	3.472	1.210	.893	6.052
				2	4.028	1.501	.829	7.226
			2	1	1.181	.833	-.595	2.956
				2	4.722	1.289	1.975	7.470
	3	1	1	1	3.472	1.501	.274	6.671
				2	1.806	.970	-.261	3.872
			2	1	1.181	.833	-.595	2.956
				2	2.361	1.410	-.645	5.367
		2	1	1	5.347	1.549	2.046	8.649
				2	.625	.587	-.626	1.876

			2	1	4.097	1.785	.292	7.902
				2	3.611	1.183	1.090	6.132
	4	1	1	1	4.097	1.993	-.152	8.346
				2	1.806	1.314	-.996	4.607
			2	1	5.972	3.182	-.809	12.754
				2	1.806	.970	-.261	3.872
		2	1	1	9.722	2.527	4.337	15.108
				2	1.111	.782	-.557	2.779
			2	1	4.167	2.173	-.465	8.798
				2	.625	.587	-.626	1.876

Table 7.7.1 Experiment 7: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	4.298	1	4.298	.038	.846
SIZE * MAPPING	Sphericity Assumed	581.750	1	581.750	5.155	.029
Error(SIZE)	Sphericity Assumed	4513.771	40	112.844		
SOA	Sphericity Assumed	7907.478	2	3953.739	20.794	.000
SOA * MAPPING	Sphericity Assumed	35.124	2	17.562	.092	.912
Error(SOA)	Sphericity Assumed	15211.123	80	190.139		
GRIP	Sphericity Assumed	6113.636	1	6113.636	12.588	.001
GRIP * MAPPING	Sphericity Assumed	2984.642	1	2984.642	6.145	.017
Error(GRIP)	Sphericity Assumed	19426.756	40	485.669		
SIZE * SOA	Sphericity Assumed	1316.598	2	658.299	10.901	.000
SIZE * SOA * MAPPING	Sphericity Assumed	77.378	2	38.689	.641	.530
Error(SIZE*SOA)	Sphericity Assumed	4831.065	80	60.388		
SIZE * GRIP	Sphericity Assumed	1804.228	1	1804.228	23.209	.000
SIZE * GRIP * MAPPING	Sphericity Assumed	2156.261	1	2156.261	27.737	.000
Error(SIZE*GRIP)	Sphericity Assumed	3109.575	40	77.739		
SOA * GRIP	Sphericity Assumed	404.337	2	202.169	3.001	.055
SOA * GRIP * MAPPING	Sphericity Assumed	455.206	2	227.603	3.378	.039
Error(SOA*GRIP)	Sphericity Assumed	5390.031	80	67.375		
SIZE * SOA * GRIP	Sphericity Assumed	74.123	2	37.061	.711	.494
SIZE * SOA * GRIP * MAPPING	Sphericity Assumed	89.161	2	44.580	.855	.429
Error(SIZE*SOA*GRIP)	Sphericity Assumed	4170.384	80	52.130		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	39858639.256	1	39858639.256	2587.204	.000
MAPPING	22870.793	1	22870.793	1.485	.230
Error	616242.796	40	15406.070		

Table 7.7.2 Experiment 7: Repeated measures ANOVA for mean correct responses (mapping 1)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	343.026	1	343.026	4.519	.046
Error(SIZE)	Sphericity Assumed	1518.271	20	75.914		
SOA	Sphericity Assumed	3502.142	2	1751.071	8.826	.001
Error(SOA)	Sphericity Assumed	7935.721	40	198.393		
GRIP	Sphericity Assumed	8820.792	1	8820.792	18.272	.000
Error(GRIP)	Sphericity Assumed	9654.869	20	482.743		
SIZE * SOA	Sphericity Assumed	481.551	2	240.775	2.869	.069
Error(SIZE*SOA)	Sphericity Assumed	3357.350	40	83.934		
SIZE * GRIP	Sphericity Assumed	7.838	1	7.838	.189	.668
Error(SIZE*GRIP)	Sphericity Assumed	827.755	20	41.388		
SOA * GRIP	Sphericity Assumed	38.653	2	19.326	.282	.756
Error(SOA*GRIP)	Sphericity Assumed	2741.212	40	68.530		
SIZE * SOA * GRIP	Sphericity Assumed	13.362	2	6.681	.144	.866
Error(SIZE*SOA*GRIP)	Sphericity Assumed	1849.587	40	46.240		

Table 7.7.3 Experiment 7: Repeated measures ANOVA for mean correct responses (mapping 2)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	243.022	1	243.022	1.623	.217
Error(SIZE)	Sphericity Assumed	2995.499	20	149.775		
SOA	Sphericity Assumed	4440.460	2	2220.230	12.207	.000
Error(SOA)	Sphericity Assumed	7275.402	40	181.885		
GRIP	Sphericity Assumed	277.486	1	277.486	.568	.460
Error(GRIP)	Sphericity Assumed	9771.887	20	488.594		
SIZE * SOA	Sphericity Assumed	912.425	2	456.213	12.383	.000
Error(SIZE*SOA)	Sphericity Assumed	1473.715	40	36.843		
SIZE * GRIP	Sphericity Assumed	3952.651	1	3952.651	34.645	.000
Error(SIZE*GRIP)	Sphericity Assumed	2281.819	20	114.091		
SOA * GRIP	Sphericity Assumed	820.891	2	410.445	6.198	.005
Error(SOA*GRIP)	Sphericity Assumed	2648.819	40	66.220		
SIZE * SOA * GRIP	Sphericity Assumed	149.922	2	74.961	1.292	.286
Error(SIZE*SOA*GRIP)	Sphericity Assumed	2320.797	40	58.020		

Table 7.7.4 Experiment 7: Repeated measures ANOVA for mean correct responses (for right hand-precision grip responses)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	3077.930	1	3077.930	18.811	.000
Error(SIZE)	Sphericity Assumed	3272.406	20	163.620		
SOA	Sphericity Assumed	3985.074	2	1992.537	14.999	.000
Error(SOA)	Sphericity Assumed	5313.846	40	132.846		
SIZE * SOA	Sphericity Assumed	751.580	2	375.790	8.892	.001
Error(SIZE*SOA)	Sphericity Assumed	1690.532	40	42.263		

Tests of Within-Subjects Contrasts

Source	SIZE	SOA	Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Linear		3077.930	1	3077.930	18.811	.000
Error(SIZE)	Linear		3272.406	20	163.620		
SOA		Linear	3002.882	1	3002.882	12.983	.002
		Quadratic	982.192	1	982.192	28.560	.000
Error(SOA)		Linear	4626.029	20	231.301		
		Quadratic	687.817	20	34.391		
SIZE * SOA	Linear	Linear	688.104	1	688.104	23.388	.000
		Quadratic	63.476	1	63.476	1.152	.296
Error(SIZE* SOA)	Linear	Linear	588.425	20	29.421		
		Quadratic	1102.107	20	55.105		

Table 7.7.5 Experiment 7: Repeated measures ANOVA for mean correct responses (for left hand-power grip responses)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	1117.743	1	1117.743	11.150	.003
Error(SIZE)	Sphericity Assumed	2004.913	20	100.246		
SOA	Sphericity Assumed	1276.276	2	638.138	5.537	.008
Error(SOA)	Sphericity Assumed	4610.375	40	115.259		
SIZE * SOA	Sphericity Assumed	310.767	2	155.384	2.954	.064
Error(SIZE*SOA)	Sphericity Assumed	2103.980	40	52.599		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	SIZE	SOA	Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Linear		1117.743	1	1117.743	11.150	.003
Error(SIZE)	Linear		2004.913	20	100.246		
SOA		Linear	204.597	1	204.597	1.395	.251
		Quadratic	1071.679	1	1071.679	12.776	.002
Error(SOA)		Linear	2932.712	20	146.636		
		Quadratic	1677.663	20	83.883		
SIZE * SOA	Linear	Linear	270.765	1	270.765	4.300	.051
		Quadratic	40.002	1	40.002	.947	.342
Error(SIZE*SOA)	Linear	Linear	1259.241	20	62.962		

		Quadratic	844.739	20	42.237		

Table 7.7.6 Overall experimental means for correct responses of Experiment 7

MAPPING * SIZE * SOA * GRIP

MAPPING	SIZE	SOA	GRIP	Mean	Std. Error	95% Confidence Interval	
						Lower Bound	Upper Bound
1.00	1	1	1	287.827	8.349	270.954	304.700
			2	276.177	6.726	262.583	289.772
		2	1	279.325	8.269	262.613	296.036
			2	265.596	8.126	249.173	282.020
		3	1	278.077	8.389	261.122	295.031
			2	266.899	8.907	248.898	284.899
	2	1	1	282.377	8.573	265.050	299.704
			2	271.790	7.657	256.315	287.266
		2	1	274.938	8.133	258.502	291.375
			2	262.821	7.312	248.043	277.599
		3	1	279.855	8.945	261.778	297.933
			2	268.119	8.383	251.176	285.062
2.00	1	1	1	295.380	8.349	278.507	312.253
			2	294.905	6.726	281.311	308.499
		2	1	279.111	8.269	262.399	295.822
			2	286.558	8.126	270.134	302.981
		3	1	277.698	8.389	260.744	294.653
			2	288.193	8.907	270.192	306.194
	2	1	1	298.537	8.573	281.210	315.864
			2	286.154	7.657	270.679	301.630
		2	1	291.003	8.133	274.567	307.440
			2	279.007	7.312	264.229	293.786
		3	1	292.303	8.945	274.226	310.381
			2	286.624	8.383	269.681	303.567

Table 7.7.7 Experiment 7: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	6.124	1	6.124	.808	.374
SIZE * MAPPING	Sphericity Assumed	.551	1	.551	.073	.789
Error(SIZE)	Sphericity Assumed	303.253	40	7.581		
SOA	Sphericity Assumed	5.879	2	2.939	.300	.741
SOA * MAPPING	Sphericity Assumed	88.306	2	44.153	4.512	.014
Error(SOA)	Sphericity Assumed	782.873	80	9.786		
GRIP	Sphericity Assumed	266.755	1	266.755	21.769	.000
GRIP * MAPPING	Sphericity Assumed	93.144	1	93.144	7.601	.009
Error(GRIP)	Sphericity Assumed	490.153	40	12.254		
SIZE * SOA	Sphericity Assumed	3.062	2	1.531	.132	.877
SIZE * SOA * MAPPING	Sphericity Assumed	34.171	2	17.086	1.470	.236
Error(SIZE*SOA)	Sphericity Assumed	929.845	80	11.623		
SIZE * GRIP	Sphericity Assumed	3.001	1	3.001	.365	.549

SIZE * GRIP * MAPPING	Sphericity Assumed	129.581	1	129.581	15.750	.000
Error(SIZE*GRIP)	Sphericity Assumed	329.096	40	8.227		
SOA * GRIP	Sphericity Assumed	1.470	2	.735	.075	.928
SOA * GRIP * MAPPING	Sphericity Assumed	73.854	2	36.927	3.769	.027
Error(SOA*GRIP)	Sphericity Assumed	783.730	80	9.797		
SIZE * SOA * GRIP	Sphericity Assumed	18.494	2	9.247	1.043	.357
SIZE * SOA * GRIP * MAPPING	Sphericity Assumed	41.275	2	20.637	2.328	.104
Error(SIZE*SOA*GRIP)	Sphericity Assumed	709.264	80	8.866		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	3982.033	1	3982.033	76.667	.000
MAPPING	3.919	1	3.919	.075	.785
Error	2077.577	40	51.939		

Table 7.7.8 Experiment 7: Repeated measures ANOVA for mean incorrect responses (mapping 1)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	5.175	1	5.175	.801	.381
Error(SIZE)	Sphericity Assumed	129.213	20	6.461		
SOA	Sphericity Assumed	35.335	2	17.667	1.282	.289
Error(SOA)	Sphericity Assumed	551.085	40	13.777		
GRIP	Sphericity Assumed	337.577	1	337.577	17.736	.000
Error(GRIP)	Sphericity Assumed	380.658	20	19.033		
SIZE * SOA	Sphericity Assumed	8.512	2	4.256	.593	.558
Error(SIZE*SOA)	Sphericity Assumed	287.270	40	7.182		
SIZE * GRIP	Sphericity Assumed	46.572	1	46.572	5.394	.031
Error(SIZE*GRIP)	Sphericity Assumed	172.693	20	8.635		
SOA * GRIP	Sphericity Assumed	29.946	2	14.973	1.443	.248
Error(SOA*GRIP)	Sphericity Assumed	415.013	40	10.375		
SIZE * SOA * GRIP	Sphericity Assumed	50.154	2	25.077	2.287	.115
Error(SIZE*SOA*GRIP)	Sphericity Assumed	438.529	40	10.963		

Table 7.7.9 Experiment 7: Repeated measures ANOVA for mean incorrect responses (mapping 2)

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	1.500	1	1.500	.172	.682
Error(SIZE)	Sphericity Assumed	174.040	20	8.702		
SOA	Sphericity Assumed	58.850	2	29.425	5.078	.011
Error(SOA)	Sphericity Assumed	231.788	40	5.795		
GRIP	Sphericity Assumed	22.321	1	22.321	4.077	.057
Error(GRIP)	Sphericity Assumed	109.494	20	5.475		

SIZE * SOA	Sphericity Assumed	28.721	2	14.360	.894	.417
Error(SIZE*SOA)	Sphericity Assumed	642.575	40	16.064		
SIZE * GRIP	Sphericity Assumed	86.009	1	86.009	10.998	.003
Error(SIZE*GRIP)	Sphericity Assumed	156.403	20	7.820		
SOA * GRIP	Sphericity Assumed	45.378	2	22.689	2.461	.098
Error(SOA*GRIP)	Sphericity Assumed	368.717	40	9.218		
SIZE * SOA * GRIP	Sphericity Assumed	9.614	2	4.807	.710	.498
Error(SIZE*SOA*GRIP)	Sphericity Assumed	270.735	40	6.768		

Table 7.7.10 Overall experimental means for incorrect responses of Experiment 7

MAPPING * SIZE * SOA * GRIP

MAPPING	SIZE	SOA	GRIP	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	1	1	1	3.704	1.057	1.568	5.840
			2	1.984	.901	.164	3.804
		2	1	4.497	.819	2.843	6.152
			2	1.323	.649	.012	2.634
		3	1	5.688	.822	4.026	7.350
			2	1.058	.837	-.633	2.749
	2	1	1	3.968	.891	2.168	5.769
			2	1.455	.474	.497	2.413
		2	1	2.116	.907	.283	3.950
			2	2.116	.583	.937	3.295
		3	1	4.365	.854	2.639	6.091
			2	2.513	.565	1.371	3.655
2.00	1	1	1	2.910	1.057	.774	5.046
			2	2.778	.901	.958	4.598
		2	1	2.778	.819	1.123	4.432
			2	3.175	.649	1.864	4.486
		3	1	1.852	.822	.190	3.514
			2	3.307	.837	1.616	4.998
	2	1	1	3.307	.891	1.507	5.107
			2	1.323	.474	.364	2.281
		2	1	5.291	.907	3.457	7.125
			2	2.249	.583	1.070	3.428
		3	1	1.984	.854	.258	3.710
			2	1.720	.565	.578	2.862

Table 7.8.1 Experiment 8: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	15.705	1	15.705	.168	.686
Error(SIZE)	Sphericity Assumed	1772.172	19	93.272		
SOA	Sphericity Assumed	13841.482	2	6920.741	42.505	.000
Error(SOA)	Sphericity Assumed	6187.225	38	162.822		
GRIP	Sphericity Assumed	653.329	1	653.329	.801	.382
Error(GRIP)	Sphericity Assumed	15489.651	19	815.245		

SIZE * SOA	Sphericity Assumed	145.543	2	72.772	.526	.595
Error(SIZE*SOA)	Sphericity Assumed	5253.021	38	138.237		
SIZE * GRIP	Sphericity Assumed	200.527	1	200.527	2.553	.127
Error(SIZE*GRIP)	Sphericity Assumed	1492.513	19	78.553		
SOA * GRIP	Sphericity Assumed	65.626	2	32.813	.232	.794
Error(SOA*GRIP)	Sphericity Assumed	5380.918	38	141.603		
SIZE * SOA * GRIP	Sphericity Assumed	61.409	2	30.704	.606	.551
Error(SIZE*SOA*GRIP)	Sphericity Assumed	1925.461	38	50.670		

Table 7.8.2 Experiment 8: Repeated measures ANOVA for mean correct responses [omnibus ANOVA of Experiment 7 (mapping 2) and Experiment 8]

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	64.830	1	64.830	.530	.471
SIZE * EXPERIME	Sphericity Assumed	188.353	1	188.353	1.541	.222
Error(SIZE)	Sphericity Assumed	4767.672	39	122.248		
SOA	Sphericity Assumed	17060.609	2	8530.305	49.423	.000
SOA * EXPERIME	Sphericity Assumed	1450.625	2	725.313	4.202	.018
Error(SOA)	Sphericity Assumed	13462.627	78	172.598		
GRIP	Sphericity Assumed	895.646	1	895.646	1.383	.247
GRIP * EXPERIME	Sphericity Assumed	44.336	1	44.336	.068	.795
Error(GRIP)	Sphericity Assumed	25261.538	39	647.732		
SIZE * SOA	Sphericity Assumed	835.476	2	417.738	4.844	.010
SIZE * SOA * EXPERIME	Sphericity Assumed	203.788	2	101.894	1.182	.312
Error(SIZE*SOA)	Sphericity Assumed	6726.736	78	86.240		
SIZE * GRIP	Sphericity Assumed	2920.856	1	2920.856	30.181	.000
SIZE * GRIP * EXPERIME	Sphericity Assumed	1140.807	1	1140.807	11.788	.001
Error(SIZE*GRIP)	Sphericity Assumed	3774.333	39	96.778		
SOA * GRIP	Sphericity Assumed	613.370	2	306.685	2.979	.057
SOA * GRIP * EXPERIME	Sphericity Assumed	254.726	2	127.363	1.237	.296
Error(SOA*GRIP)	Sphericity Assumed	8029.738	78	102.945		
SIZE * SOA * GRIP	Sphericity Assumed	197.500	2	98.750	1.814	.170
SIZE * SOA * GRIP * EXPERIME	Sphericity Assumed	11.672	2	5.836	.107	.898
Error(SIZE*SOA*GRIP)	Sphericity Assumed	4246.257	78	54.439		

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	42491252.548	1	42491252.548	2339.245	.000
EXPERIME	17756.608	1	17756.608	.978	.329
Error	708415.962	39	18164.512		

Table 7.8.3 Overall experimental means for correct responses of Experiment 8

SIZE * SOA * GRIP

SIZE	SOA	GRIP	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1	1	312.984	10.341	291.340	334.629
		2	309.944	11.960	284.911	334.978
	2	1	294.739	11.307	271.072	318.406
		2	293.634	11.358	269.861	317.407
	3	1	295.176	9.920	274.414	315.939
		2	294.906	9.617	274.778	315.034
2	1	1	312.028	11.053	288.893	335.163
		2	307.523	11.574	283.299	331.747
	2	1	296.376	10.751	273.874	318.878
		2	288.926	10.777	266.370	311.483
	3	1	298.445	11.078	275.259	321.631
		2	295.016	11.560	270.820	319.211

Table 7.8.4 Experiment 8: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	.322	1	.322	.046	.833
Error(SIZE)	Sphericity Assumed	118.634	17	6.978		
SOA	Sphericity Assumed	19.504	2	9.752	2.507	.096
Error(SOA)	Sphericity Assumed	132.245	34	3.890		
GRIP	Sphericity Assumed	8.038	1	8.038	1.889	.187
Error(GRIP)	Sphericity Assumed	72.338	17	4.255		
SIZE * SOA	Sphericity Assumed	2.786	2	1.393	.324	.726
Error(SIZE*SOA)	Sphericity Assumed	146.391	34	4.306		
SIZE * GRIP	Sphericity Assumed	.893	1	.893	.164	.690
Error(SIZE*GRIP)	Sphericity Assumed	92.343	17	5.432		
SOA * GRIP	Sphericity Assumed	9.216	2	4.608	.674	.516
Error(SOA*GRIP)	Sphericity Assumed	232.553	34	6.840		
SIZE * SOA * GRIP	Sphericity Assumed	.500	2	.250	.063	.939
Error(SIZE*SOA*GRIP)	Sphericity Assumed	135.817	34	3.995		

Table 7.8.5 Overall experimental means for incorrect responses of Experiment 8

SIZE * SOA * GRIP

SIZE	SOA	GRIP	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1	1	2.623	.614	1.328	3.919
		2	1.698	.750	.116	3.279
	2	1	1.543	.461	.570	2.517
		2	1.852	.502	.792	2.911
	3	1	1.543	.513	.460	2.626
		2	1.389	.605	.113	2.665
2	1	1	2.623	.654	1.244	4.003

		2	1.698	.457	.734	2.661
	2	1	1.389	.405	.535	2.243
		2	1.235	.604	-.039	2.508
	3	1	1.852	.674	.430	3.273
		2	1.389	.463	.412	2.366

Table 7.9.1 Experiment 9: Repeated measures ANOVA for mean correct responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	163.395	1	163.395	.684	.418
Error(SIZE)	Sphericity Assumed	4537.496	19	238.816		
SOA	Sphericity Assumed	25602.466	2	12801.233	38.077	.000
Error(SOA)	Sphericity Assumed	12775.198	38	336.189		
GRIP	Sphericity Assumed	326.304	1	326.304	.386	.542
Error(GRIP)	Sphericity Assumed	16072.514	19	845.922		
SIZE * SOA	Sphericity Assumed	38.078	2	19.039	.229	.797
Error(SIZE*SOA)	Sphericity Assumed	3161.788	38	83.205		
SIZE * GRIP	Sphericity Assumed	197.773	1	197.773	1.634	.216
Error(SIZE*GRIP)	Sphericity Assumed	2299.089	19	121.005		
SOA * GRIP	Sphericity Assumed	150.488	2	75.244	.513	.603
Error(SOA*GRIP)	Sphericity Assumed	5569.211	38	146.558		
SIZE * SOA * GRIP	Sphericity Assumed	242.128	2	121.064	1.113	.339
Error(SIZE*SOA*GRIP)	Sphericity Assumed	4132.108	38	108.740		

Table 7.9.2 Overall experimental means for correct responses of Experiment 9

SIZE * SOA * GRIP

					95% Confidence Interval	
SIZE	SOA	GRIP	Mean	Std. Error	Lower Bound	Upper Bound
1	1	1	318.523	10.005	297.582	339.464
		2	323.417	10.246	301.971	344.864
	2	1	295.853	9.382	276.215	315.491
		2	300.908	10.085	279.800	322.017
	3	1	300.522	9.825	279.958	321.086
		2	303.015	9.775	282.556	323.474
2	1	1	325.888	10.785	303.314	348.461
		2	321.578	10.309	300.002	343.155
	2	1	298.003	10.021	277.028	318.977
		2	301.254	10.637	278.990	323.518
	3	1	301.405	9.276	281.990	320.819
		2	304.012	10.070	282.935	325.090

Table 7.9.3 Experiment 9: Repeated measures ANOVA for mean incorrect responses

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
SIZE	Sphericity Assumed	.804	1	.804	.083	.776
Error(SIZE)	Sphericity Assumed	183.738	19	9.670		

SOA	Sphericity Assumed	19.740	2	9.870	1.310	.282
Error(SOA)	Sphericity Assumed	286.330	38	7.535		
GRIP	Sphericity Assumed	20.094	1	20.094	1.259	.276
Error(GRIP)	Sphericity Assumed	303.337	19	15.965		
SIZE * SOA	Sphericity Assumed	26.299	2	13.149	1.664	.203
Error(SIZE*SOA)	Sphericity Assumed	300.347	38	7.904		
SIZE * GRIP	Sphericity Assumed	35.012	1	35.012	3.741	.068
Error(SIZE*GRIP)	Sphericity Assumed	177.823	19	9.359		
SOA * GRIP	Sphericity Assumed	1.222	2	.611	.212	.810
Error(SOA*GRIP)	Sphericity Assumed	109.375	38	2.878		
SIZE * SOA * GRIP	Sphericity Assumed	3.665	2	1.833	.134	.875
Error(SIZE*SOA*GRIP)	Sphericity Assumed	518.454	38	13.644		

Table 7.9.4 Overall experimental means for incorrect responses of Experiment 9

SIZE * SOA * GRIP

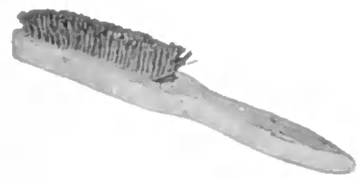
SIZE	SOA	GRIP	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	1	1	1.944	.537	.821	3.068
		2	2.500	.899	.618	4.382
	2	1	2.639	1.056	.428	4.850
		2	2.500	.985	.438	4.562
	3	1	1.944	.574	.744	3.145
		2	2.083	.852	.300	3.867
2	1	1	2.083	.694	.630	3.537
		2	.694	.276	.117	1.272
	2	1	2.778	.855	.988	4.567
		2	1.806	.734	.269	3.342
	3	1	3.611	1.194	1.112	6.110
		2	1.944	.498	.903	2.986

APPENDIX 2: THE PRIME STIMULI USED FOR EXPERIMENTS 1-9

Figure 9.1 Catalogue of prime objects used in Experiments 1-9 (objects were presented also as a mirror image in the left orientation)

1.

2.



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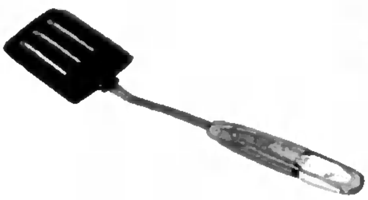

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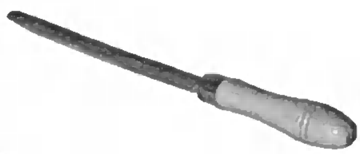
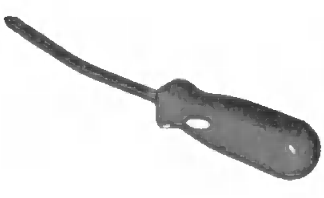
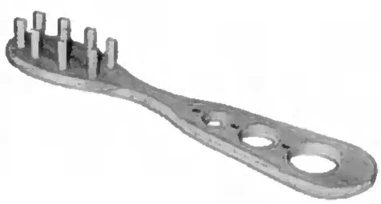


5.

6.



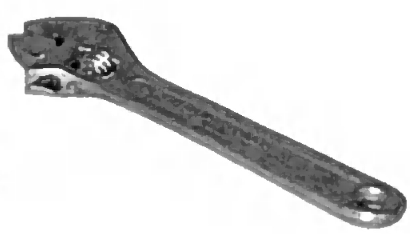
7.



8.

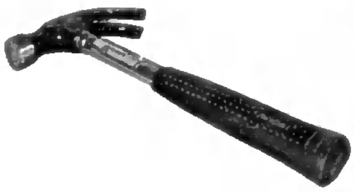
9.

10.



11.

12.



13.

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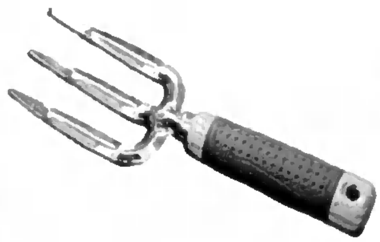
16.



17.

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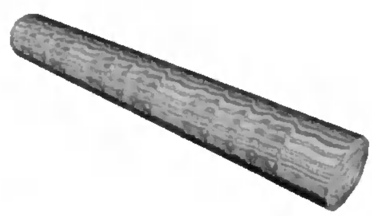

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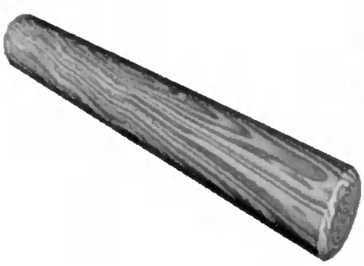

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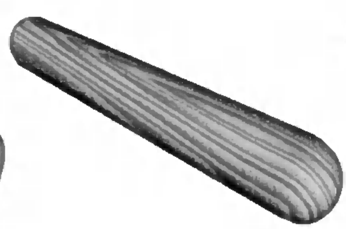

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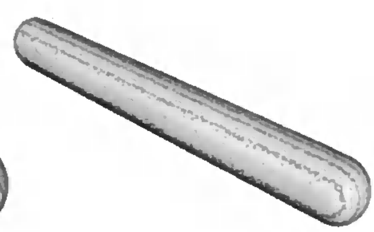

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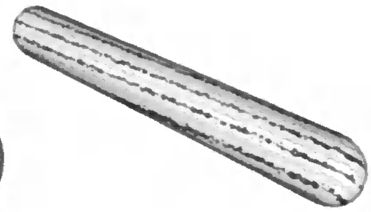

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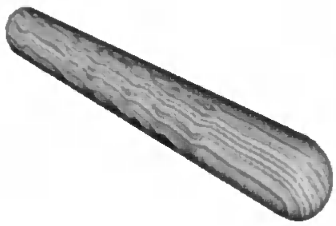

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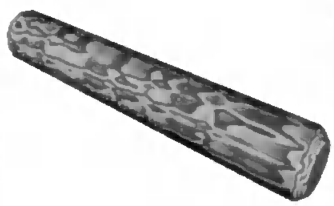

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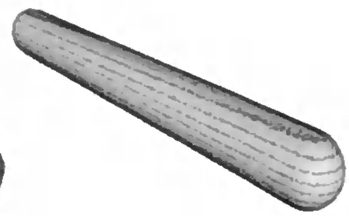

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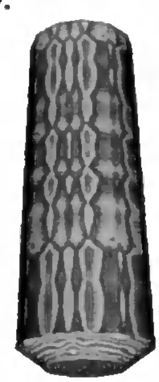
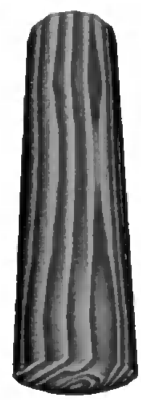


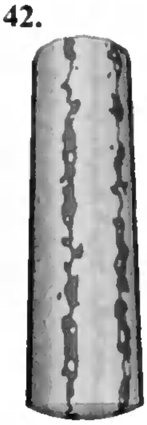
42.

43.

44.



45.



46.

47.

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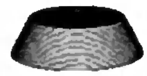
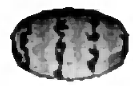
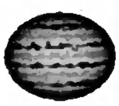
50.

51. 52. 53. 54. 55.

56. 57. 58. 59. 60. 61.

62. 63. 64.

Experiments 1-2 (stimuli 1-20)
Experiments 3-4 (stimuli 2-4, 8, 11, 13, 15, 17-18, 20, 21-30, 31-40)
Experiment 5 (stimuli 21-39, 31-40)
Experiment 6 (stimuli 2-4, 8, 11, 13, 15, 17-18, 20)
Experiments 7-9 (stimuli 41-64)

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