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Perception and Action Weighting in Memory Representations

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Declaration

I confirm that this thesis contains original work solely completed by the author Clare Kirtley, under the supervision of Dr. Ben Tatler. This work has not been previously accepted for a higher degree. All references cited in this work have been consulted by the author (unless otherwise stated).

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Abstract

The research reported in the present explored the interaction between perception and action, focusing on how this might occur under memory conditions. This was done in line with the proposals of grounded cognition and situated action, in which action and perception are tightly linked, and able to influence one another in order to aid the performance of a task. Following this idea of a bi-directional loop between the two processes, studies were conducted which focused on each side of this relationship, in conditions where memory would be necessary. The first experiments investigated how the perception of objects and the memory of those perceived objects could influence the production of actions. Later studies examined how the preparation and performance of actions could affect the perception of a scene, and subsequent recall of the objects presented. Throughout these studies, object properties (e.g., shape, colour, position) were used as a means to either manipulate or measure the effect of the tasks.

The findings of the studies suggested that weighting an off-line memory representation by means of the task setting was possible, but that this was not an automatic occurrence. Based on the results obtained, it seemed that there were conditions which would affect whether memories could be tailored to the current demands of the tasks, and that these conditions were linked to the realism of the situation. Factors such as the task complexity, the potential for object interaction and the immersive environment were all suggested as possible contributors to the construction and use of weighted representations.

Overall, the studies conducted suggest that memory can play a role in guiding action, as on-line perception does, so long as the situation makes it clear that this is necessary. If such weightings are useful, then the memory will be constructed accordingly. However, if the situation is such that there is no clear task, then the memory representations will remain unaffected and unprepared for one specific action, or not be used to aid action. Memory can be seen as serving action, but our memory systems are flexible, allowing us to cope with the demands and restrictions of particular situations.

Executive Summary

Within the present thesis, six chapters present experiments designed to investigate how perception and action might interact in order to influence on-line performance and off-line memory representations. The following presents a brief summary of the studies and the reason they were conducted.

Chapter 2 presents the findings of an investigation of perception on action. Participants were required to attend to a particular object feature, that could be action-relevant (e.g., shape) or visually-relevant (e.g., colour). They then produced an action in response to this feature cue, which could be compatible or incompatible with the target object. This was done to determine if, by attending to an action-associated feature, participants' might be primed to act with such an object, shown by faster responses when their gestures were object-compatible.

This first study allows us to test one side of the perception-action link under both visual and memory condition in order to provide evidence that a memory representation can be formed in order to aid action.

Chapter 3 is the first of a series of experiments which investigate the other side of the perception-action link, examining how action can affect the perception of a scene. Participants were required to form an action gesture (e.g., a type of grasp) while they viewed a scene presenting several different objects. Following this, they were given a memory test which asked them to recall the features of the objects. This was done to determine if, by preparing an action, participants' would be primed to attend to objects compatible with that action, and thus show improved recall of such objects.

Chapter 3 allows us to test how the simple preparation of action might influence perception, even without actual interaction. It also allows us to investigate how this might affect the memory representation, a previously neglected area. By requiring participants' to form the action postures at encoding, we can investigate whether any influence on memory is acquired during the construction of the representation.

Chapter 4 replicates the experiment presented in Chapter 3, but changes the stage at which the prepared action was present. Thus, rather than forming the grasps during encoding, as in Chapter 3, they were now formed during the retrieval stage, when participants were recalling the object features.

This study allows us to investigate further how a memory representation might be weighted by the preparation of action. By manipulating the poses at the retrieval stage, we can determine if the weighting of the representation occurs when the memories are accessed for recall.

Chapter 5 replicates the paradigm used in Chapters 3 and 4, but again changes when the action postures are present. For this study, participants' were asked to perform the postures throughout the encoding and retrieval stages of the study.

This study allows us to investigate whether effects seen in Chapters 3 and 4 are simply additive, and will remain in the eye-movement and memory findings without being affected by the continued presence of the action. Alternatively, by maintaining the posture throughout encoding and retrieval, it may be that differences arise in either the construction of the representation, or later access to the information held there.

Chapter 6 replicates the paradigm used in Chapter 3 once again, but this time the objects are physically present in the room with the participant. As in Chapter 3, participants perform the action postures while encoding the object information.

This study allows us to determine if new or stronger effects can be seen in the memory measures that may be due to the use of a more realistic setting. For example, by having participants examine objects that are present in the same environment as they are; this may strengthen their ideas of interacting with the objects, resulting in more pronounced effects.

Chapter 7 increases the realism of the environment further by locating the study in the context of an every-day task. Participants were required to carry out either a tea-making or a sandwich-making task, prior to a memory test which asked them to recall the features of the objects present in the environment. The study also differentiated between interaction with objects in order to use them for a task, and interaction with objects in order to move them out of the way.

This study allows us to determine if the task setting under which objects are interacted with can affect the way in which information about the objects is extracted and stored. It also uses a strongly realistic setting compared to the earlier studies, allowing us to investigate if the realism of the task is also an important factor in the effects on perception and memory.

Chapter One- Literature Review

1.1 Grounded Cognition and the Perception-Action Link

The traditional view of cognition proposed a modular structure to the construction and arrangement of the processes which make up the cognitive system. According to this view, each module involved in cognition is held apart from the others. Thus, there is a central mechanism which receives input from the low-level perceptual processes. This input is then manipulated into the form of abstract, amodal symbols, before being output via the equally low-level motor processes. While the initial representations are formed with perceptual systems, transduction into amodal symbols is considered necessary for the central cognitive processes. For example, while the initial perception of coloured objects would involve activation of the neural populations in the visual cortex that respond to colours, the amodal representation of these colours in semantic memory would involve an entirely separate neural system. Similarly, motor processes begin as amodal symbols in the cognitive system, and must be translated into the correct patterns of excitation to move effector muscles and allow the action to be carried out. Figure 1.1 presents an illustration of this early approach,

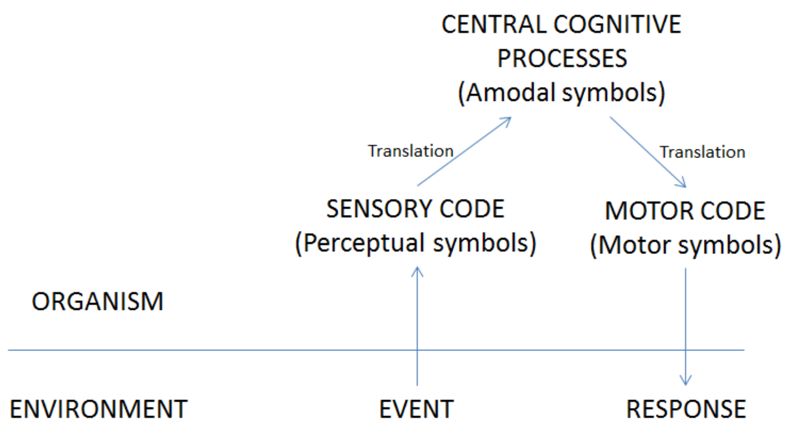


Figure 1.1 Diagram of the traditional cognitive approach, requiring translation between perceptual and amodal symbols

However, more recent research has begun to suggest that the traditional approach to cognition may not adequately account for the way that perception appears to operate. In particular, the idea of amodal symbols is problematic, with the steps necessary to allow for these symbols to be part of the system being strongly criticised. Problems have been noted for both the process of translating perceptual experiences into an amodal form (the transduction problem; Barsalou, 1999), and how these symbols are then converted back into perceptual outputs (the symbol grounding problem; Harnad, 1990).

Despite the fact that the transduction of incoming information into the abstract symbols is a key component of classical cognition, there is no strong account of how this would occur. Furthermore, even with the advent of powerful neural imaging technologies, there is no evidence from these methods to suggest that any such process is occurring (Barsalou, 1999). Similarly, without grounding amodal symbols in a perceptual base, it would not be possible for meaning to be assigned to the symbols. This has been likened to the task of trying to learn Chinese as a first language, using only a Chinese/Chinese dictionary (Harnad, 1990). Each symbol would link to another (its definition), but without any way for the reader to ever discover what the meaning was, and so interpret the symbol strings. The classical cognitive structure is faced with the same problem, and there is no explanation as to how the amodal symbols can ever be linked to anything other than another amodal symbol, and so allow for translation into a perceptual understanding. While it has been suggested that the symbols acquire meaning by being linked to the external world via the perceptual channels (e.g., Fodor, 1980), Harnad states that this simply underestimates the scale of such a task, and the overall complexity of the problem.

The alternative to the traditional approach is that of embodied or grounded cognition. While there are several different accounts of grounded cognition (see Wilson, 2002, for six of them), they are united in their proposal that there are no amodal symbols representing knowledge. Instead, the cognitive processes are grounded in the body, and thus closely linked to sensorimotor processes. Barsalou (2008) suggests three broad groups of grounded cognition accounts: those that focus on the part the body plays in cognition, particularly the findings that show bodily states can influence cognitions; those that focus on simulation in cognition, the idea that bodily states during an experience are recorded in their particular modal representation, and then reactivated at a later time when the experience needs to be retrieved and those which focus on how action is situated, and how both perception and action are central to cognition, rather than being simply input and output systems. It is the ideas put forward in the third of these areas that is of most important for the work in this thesis; however, all three views have something to offer to the ideas that will be discussed here.

According to the traditional view of cognition, action processes are separate not only from the central semantic knowledge store, but from the initial perception of stimuli that triggers the action. The translation processes that are proposed to occur are necessary to allow the perceptual and motor systems to communicate. Thus, if we have to detect and pick up a red mug, the perception of the correctly coloured object would activate the neural areas in the visual system responsible for colour, which would then be transduced into amodal symbols that represent the concept of the mug. These symbols must then be mapped back onto the real world, to inform the motor system on the actions needed to achieve the goal of picking up the right mug. In contrast, the situated action theories of grounded cognition take the view that perception and cognition evolved in order to facilitate action. That is, our primary aim was to interact with the environment around us and the perception and use of this external information was solely in order to serve this aim. An early expression of these ideas is shown in Gibson's (1979) ecological approach to perception and action. It was considered that there were no internal representations, but all information was derived directly from the environment. Objects in the environment possess 'affordances', which indicate how the observer may use the object in their actions. When an item is perceived, and the affordance used to determine the action, the information in the environment specifies how this action may be carried out. More recent anti-representational accounts have been proposed, such as Wilson and Golonka's (2013) replacement style embodied cognition, which, in the same fashion as Gibson's ecological approach, does away with any central representation system. It is proposed that as long as an organism can sense the world around them and allow this to guide behaviour, there is no need for internal representations to be constructed.

As an alternative to the ecological approach, cognitive views on perception and action allow a role for off-line cognitive processes, such as memory and stored knowledge. An important and defining aspect of such theories is that they emphasise the fact that information derived from the environment can be stored in memory, and that this stored information can interact with new incoming perceptions. Rather than explain action as resulting from direct perception of the environment, the role of intention and planning in completing the tasks is considered. Such views are in many ways more flexible, and better able to cope with 'representation-hungry' problems (Clark, 1997). These are tasks which seemingly cannot be completed without some form of internal representation, such as planning, recalling or reasoning about items that may be distant in time or space. As a result, the actor is no longer restrained to act on only what they see, but what they recall, and what they know from previous experience. The cognitive approach has largely overtaken the ecological theory as a basis for the more specific accounts of grounded cognition.

Despite their differences, in both the ecological and the cognitive approaches, perception and cognition are seen as supporting action, having first developed to provide the information we need to achieve our active goals. However, as Bridgeman and Tseng (2011) point out, perception should not be considered a passive process in this system. Our perceptions allow us to find the information we need in order to carry out the actions we require, such as determining whether the current environment contains the items we need, finding the locations of required objects or working out the appropriate grip to act with the target object. Perception is an active process that we engage in, rather than a passive response to the environment and our own actions. This information can then be interpreted in terms of how we can act on it. Thus, perception and action are seen as being closely linked, with each informing the other throughout our experiences. Theories which allow action and perception a more equal role began with examples such as the ideo-motor principle, and the common coding approach, both of which form the basis for the more recent theory linking action and perception, the Theory of Event Coding.

1.1.1 The ideo-motor principle. The basis of the ideo-motor principle was first formed in the 19th century, in order to address the problem of how the thought of an action could lead to the execution of that action. Some authors suggested that such a link would be similar to a reflex action, and therefore not truly intentional. Furthermore, the researchers concentrated on very specific circumstances where thought seemed to produce action, limiting the applicability of the idea, and as a result, the term ‘ideo-motor’ itself. Laycock, (1840; cited in Stock and Stock, 2004) examined behaviour initiated by ideas in the context of medical patients suffering from hydrophobia, after he noted that the physical phobic response could be triggered when the patient only thought of water. Due to examining the link only in the context of patients, Laycock did not move beyond considering this a cerebral reflex, not under the patient’s voluntary control. Carpenter (1852; cited in Stock and Stock, 2004) used the ideo-motor principle in order to scientifically explain various parapsychological phenomena of the time, such as séances in which a participant was hypnotised and convinced they were unable to move parts of their body. Carpenter suggested that, in the absence of the participant's conscious will, ideas and emotions had direct access to the motor outputs, resulting in the apparent paralysis. Like Laycock, he considered this to be another form of a reflex action, occurring when the participant was in some way impaired.

Other researchers (e.g., Herbart, 1825; cited in Stock and Stock, 2004) conceptualised the ideo-motor principle as a part of action control, and held that such connections were formed in the earliest stages of development. Initially, an infant would produce involuntary movements, which would lead to a particular sensation being experienced by the infant. Over time, repetition of the movement would mean that perceptual consequence of the action would become integrated with the action itself, and so if the particular outcome was required, then the correct action could be made to produce it. Thus, the activation of the response would have come under intentional control (James, 1890). More recently, various studies have shown evidence for the integration of an action and its consequences. Elsner and Hommel (2001) found that if participants repeatedly paired a tone with a left or right key response in an initial learning stage, then presenting the same tone as a cue facilitated the production of the response if it maintained the previously learnt mapping between the key pressed and the tone pitch. The presence of the tone increased the frequency with which the paired key was chosen in a free choice task. Figure 1.2 shows a diagram of the principle in which communication is possible between perception (sensory codes) and action (motor codes).

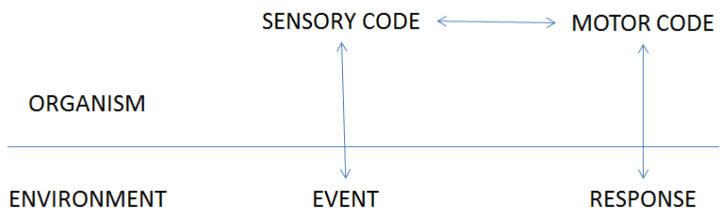


Figure 1.2 Diagram of the ideo-motor principle of cognition, incorporating bi-directional communication between perceptual events and motor responses

1.1.2 The common-coding principle. The common-coding approach (Prinz, 1997) similarly proposes that action and perception can interact directly, as in the ideo-motor principle. However, it goes further by suggesting that action and perception are linked by a common representational domain, and are essentially functionally equivalent. In the traditional view of cognition, the sensory codes for perceptual experiences and the motor codes that affect the action execution are separate, as they code for patterns of excitation in different sense organs and muscles, respectively. Thus, in order for communication to occur between the two codes, there must be a process of translation between them. However, Prinz (1997) drew on the earlier ideas from the ideo-motor principle that suggests there is no fundamental difference between the representational contents of perception and action codes. If actions can be represented in the terms of their perceptual consequences, then our representations of the events we perceive and the actions we perform should not essentially differ. Prinz (1997) applied these ideas to the functional mechanisms of perception and action, suggesting that there are event codes and action codes which form the basis of perception and action. The codes are commensurate, and share the same representational domain. Based on this proposal, the codes within the domain will overlap with each other to some extent, depending on the level of similarity between the external event (the stimulus) and the resulting response (the action). The classic example is that of affordance studies, which examine stimulus-response compatibility effects (e.g., Kornblum, Hasbroucq and Osman, 1990), where, for example, the location of the stimulus and the location of the response required are the same (i.e. stimulus on the right side, response button on the right side). Situations can therefore arise in which there is a greater or lesser degree of overlap between the stimulus and response, and this degree of similarity can have an influence on either the perception of the stimulus, or the production of the response. Such effects are strong evidence that it is possible for the supposedly separate perceptual and action processes to interact with each other, without the need for translation between them. Figure 1.3 presents a diagram of the common-coding principle.

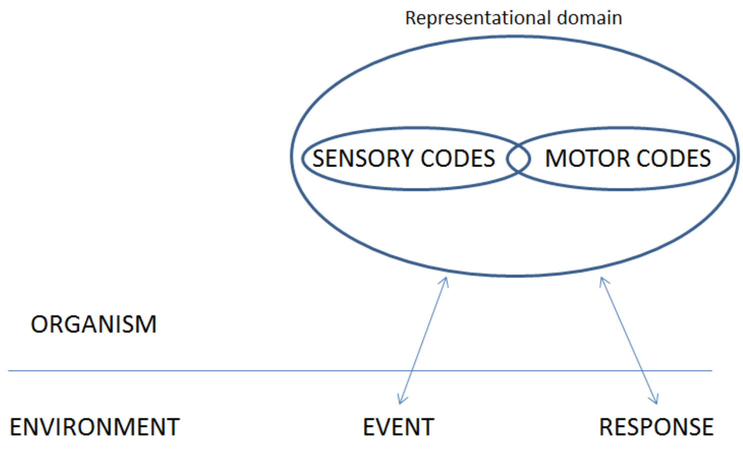


Figure 1.3 Diagram of the common-coding principle of cognition, incorporating a common representational domain in which both perceptual and motor codes are held

1.1.3 The Theory of Event Coding. Hommel, Müsseler, Aschersleben and Prinz (2001) proposed the Theory of Event Coding (TEC) on the basis of the ideo-motor principle, and common-coding theories. Following Prinz (1997), the TEC claims that perception and action features are stored in a common representational framework, and so may be considered to be functionally equivalent. Action involves the anticipation of the perceptual outcome of that action, and over time, the outcome will become integrated with the action in question (following the ideo-motor principle). Perception is similarly active, employed to seek out the relevant information to inform the anticipated action. Thus, perceiving and acting with an object will activate the same associated codes for that object, and so perception and action are seen as being bi-directionally linked, with perception able to influence action, and action able to influence perception. This theoretical basis is still very much a combination of the two earlier theories, but the TEC goes further by providing a more detailed account of the contents of the representations, and the procedures by which they may be manipulated.

Within the representational domain, an object stimulus will be represented using feature codes for each of its individual properties (e.g., colour, shape), which are supported by different neural populations. As a result, the complete representation of a single object is actually distributed across the cortex (e.g., DeYoe and VanEssen, 1988; Zeki, 1990). Similarly, action plans are coded in terms of action features (e.g., direction, force and distance, Georgopoulos, 1990), supported by different neural populations. The perception or planning of an event will lead to activation of the relevant feature codes, which must then be integrated into an event code, from which the theory takes its name. Figure 1.4 presents a diagram of the TEC, in which an event file is formed from the activation of both perceptual and motor codes. Figure 1.5 shows a diagram representing the integration of relevant featural and motor codes into an event file within the common representational domain.

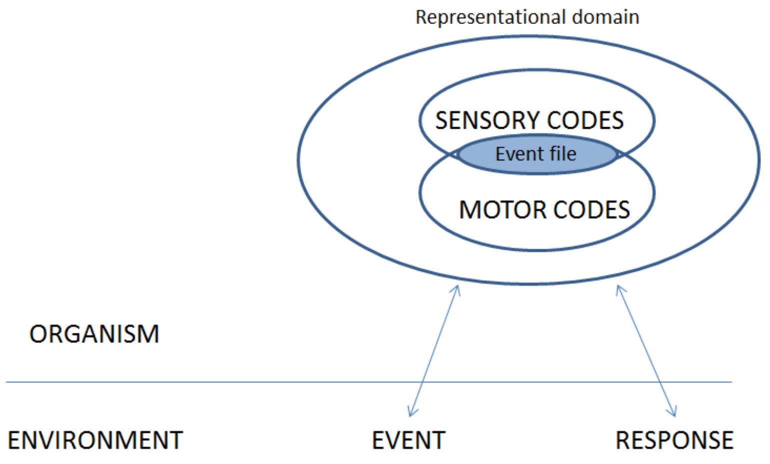


Figure 1.4 Diagram of the TEC, incorporating the formation of event files

This integration is necessary to ensure that the features from the same stimulus are grouped together, and is similar to the ideas of feature binding proposed for visual memory (e.g., Kahneman, Treisman and Gibbs, 1992)**,** where the feature codes must be temporarily synchronised. Indeed, Stoet and Hommel (1999) explored the characteristics of binding in action features; participants prepared a response before performing an intervening task prior to actually executing the original response. Any overlap between the prepared response, and the action required for the intervening task slowed the performance of the intervening task. This was suggested to support the idea that the action code for the prepared task had been bound into the first event code, and so was unavailable for code of the second action, similar to previous studies which had shown such binding problems for visual features of stimuli.

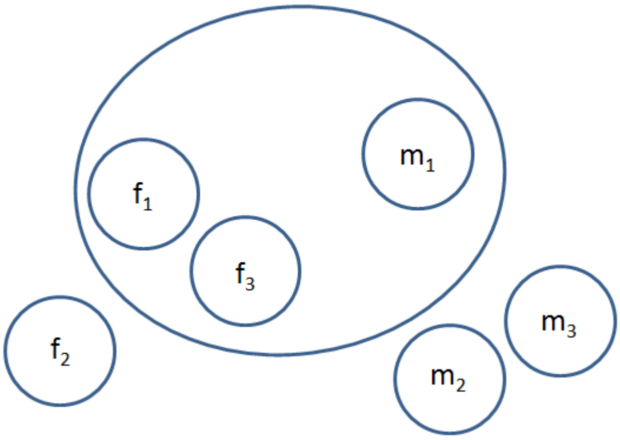


Figure 1.5 Representation of the formation of an event file: relevant featural codes (f_1, f_2) are bound within a file alongside the relevant motor code (m_1) for the event

The TEC suggests that the activated codes should overlap in time in order for them to be bound into the same event file (Hommel, 2004), but that the order in which the codes are activated is not important. Thus, a stimulus can precede or follow an action, and will still be integrated as one event, provided they fall into the same integration window (Hommel, 2009). This allows for the incorporation of the main ideo-motor proposal: that action-effect experiences can be integrated, and then reversed to allow for the later intentional re-activation of the effect. Evidence has been found to support this idea. Dutzi and Hommel (2009) showed that repeated perception of a tone stimulus increased the probability that participants would produce the action response that had been used to produce that tone in a previous trial, thus suggesting that the there is an automatic binding between even arbitrarily paired stimuli and responses, which can be reactivated via either part of the event code. The preparation of actions or stimuli prior to a task should also lead to activation and binding of the relevant codes, without the presence of the stimulus or the execution of the response (Hommel, 2009). Indeed, in the spirit of the ideo-motor principle, even thinking or mentally running through a task should be enough to activate and form weak bindings between the required codes, which will be strengthened by the actual performance of the action.

Another important proposal from the TEC is the idea of intentional weighting, or the influence of the task on the construction of the event files. Depending on the task and goals of the actor, different features will be more or less relevant to the completion of the task. According to the TEC, by preparing for a task, the features considered to be task-relevant will be primed prior to the task, meaning they have a higher level of activation in relation to task-irrelevant features (Hommel, 2009). The priming of these task-relevant properties takes place in a top-down fashion. While initially, any stimuli will activate or reactivate the associated codes, the weighting process ensures that information from feature dimensions that are known to be relevant to the task are primed, facilitating the processing of the information. Some of the previous studies investigating the binding processes in event files noted an influence of task relevance; for example, Dutzi and Hommel's (2009) study found that the integration of action responses with the tone stimulus was affected by whether the response was part of the current attentional set, and therefore was task-relevant. Similarly, Hommel (2007) noted that changing the relevance of stimulus features affected their integration with particular action responses, indicating that both sides of the action-perception loop can be affected by the nature of the task. Furthermore, the task relevance of a feature did not affect the initial binding of stimuli and responses, but did affect their retrieval of the information at a later test phase (Hommel, Memelink, Zmigrod and Colzato, *in press*). Thus, event files may contain a wide range of feature and response information, but it is the current task restrictions that affect what parts of the code will be most easily retrieved, regardless of the task at the initial formation of the file.

Hommel et al. (2001) suggested that weighting in perception is attentional, whereas weighting action selection is intentional, as perceptual weighting is proposed to affect the way the attentional processes operate, directing attention towards those features relevant for the task. The perceptual weighting processes have more recently been suggested to be no different from those weighting action selection, as both of them are the result of an intention to act or perceive, thus the term 'intentional weighting' is used for both processes (Memelink and Hommel, 2013). Intentional weighting is therefore a general principle underlying the action-perception link, allowing for the situation to influence the event code that is constructed. The intentional weighting is assumed to occur during off-line preparation for attentional or action selection, and thus influence the on-line execution of these processes.

The TEC not only allows for perception and action to be closely linked, in accordance with grounded cognition, but also gives consideration to the role that the actors' intentions, goals and previous experiences have on their performance. While many of the initial studies into the claims of the TEC were conducted using more restricted stimulus-response paradigms, there are now many studies showing evidence for these ideas when dealing with more realistic objects. (e.g., Symes, Tucker, Vainio, Ellis and Ottoboni, 2008). Furthermore, the idea that there should be influences of action on perception and perception on action provides a structure with which to consider this evidence. Studies into object affordances provide further insight into perception influencing action, while the influence of action on perception has been shown using various visual search paradigms as a starting point. Within both areas, studies have been conducted examining what conditions are required for effect of either perception or action to be seen in performance. In the following section, these areas are examined more closely, to further clarify how perception and action work together to affect both aspects of behaviour.

1.2 Action Influencing Perception: Intentional Weighting

Evidence that our actions can influence the way in which we perceive the world is found in a wide range of studies. Initially, there are studies which show that even the potential for action can influence the deployment of attention towards objects. While there may not be any strong intention for action here, such studies demonstrate how the perceptual system is made for serving action. The addition of an intention to act adds further weight to this side of the action-perception link, showing how the same stimuli may be processed differently under different task conditions. Finally, using recordings of eye movements, it can be shown how the requirements of a task continue to direct perception throughout the actions themselves.

1.2.1 The influence of a potential for action on attention. Given that action is the end goal of perception, it seems reasonable that attention might be attuned to action, including the possibilities that objects offer for actions. This can be linked to the proposals of the ideo-motor principle, and the TEC (Hommel et al., 2001), whereby the thought of an action is proposed to lead to the re-activation of the representation of the external stimuli (and vice versa) even if such effects are relatively weak.

Evidence for this idea comes from neurological studies of patients suffering from neglect or extinction, conditions in which patients fail to detect objects that are located in the visual field contralateral to the lesion they have suffered. This work demonstrated that, even in the absence of a specific task, the possible action relationships between objects could influence the way in which these objects were viewed. Riddoch, Humphreys, Edwards, Baker and Willson (2003) found that grouping objects into pairs, in which the two objects were depicted either about to act together (corkscrew about to open bottle) or in positions in which action would not be possible (bottle above corkscrew) led to patients being able to detect both items only in the action-possible condition. When action was not possible in the displayed configuration, patients exhibited the usual visual neglect for the contralesional object. Thus, the positioning of the objects in a way that suggested action might have led to patients encoding both items as a perceptual unit, leading to both items being selected and attended to. This effect was not maintained if the object pair was associated in terms of semantics (e.g., a hammer and a mallet) but not in terms of being frequently used together (as a hammer and nail are). Furthermore, Humphreys, Riddoch and Fortt (2006) found that the familiarity of locations (i.e. typically a hammer is above a nail) did not account for the reduction of neglect: non-action related items that have familiar location arrangements (e.g., the sun above a tree) did not lead to the same effect. Riddoch, Humphreys, Hickman, Clift, Daly and Colin (2006) also established whether the location of the object pair needed to afford action (for example, if the objects were used together, but were shown simply standing side by side, as they might be seen in everyday life), and if the objects acting together needed to be familiar to the patients. While identification was best when the two objects were frequently depicted together (e.g., a bottle pouring into a glass), it was still improved when the objects *could* be used together (e.g., a bottle pouring into a bucket) compared to two objects that were not related in action (e.g., a bottle and a beach ball). Identification was also better if the objects were pictured in the process of interacting, rather than only side by side. Thus, the active interaction of the objects was important, as was the familiarity of the action, but if the two objects could act together in a plausible way, then this could lead to attention facilitation towards both objects. Action possibilities, or the affordances, seem to influence the perception of items.

Another more recent set of studies has shown that neurologically normal participants are influenced by certain physical attributes and skills, such as size or sporting ability. These are still able to influence the way in which people perceive the environment. All such studies demonstrate that the participant appears to interpret the world not solely based on how it actually is, but in terms of their ability (either inherent or learnt) to interact with it. For example, participants’ body size was found to affect their perception of the width of doorways, with those with broader shoulders (who would find it more difficult to pass through narrow spaces) perceiving doorways to be narrower than those with narrower shoulders (Stefanucci and Geuss, 2009). Taylor, Witt and Sugovic (2010) also found that such differences in perception could be acquired over time, due to increased expertise in a particular area. In their study, parkour experts judged walls to be shorter, in comparison to novices' judgements. Thus, it appears that as a skill develops, the influence it has on perception will develop too.

As well as ability, other studies have shown that energetic potential will influence perception. Bhalla and Profitt (1999) found that participants who wore a heavy backpack judged hills to be steeper than unburdened participants, while chronic pain sufferers, for whom walking was a greater effort, judged hallways to be longer than control participants (Witt et al., 2009). Such influences of ability on perception are proposed to have an adaptive advantage. Witt (2011) suggests that perceiving the environment in the terms of one's ability to act with it will help shape the planning of future activities. If the observer has less ability, and so perceives the obstacle or distance as greater, they are less likely to attempt to act, and so prevent themselves from risking failure and/or injury.

This action-specific approach shares some common ground with the TEC, as both propose that action can have some influence on the way in which the environment, and objects within it can be perceived. However, the mechanisms by which these are achieved differ. While the TEC suggests that planning of an action will influence perception, the action-specific account focuses on the action capabilities of the observer, and holds that this is the factor which will influence perception. In a comparison of these accounts, it was found that the TEC is a better account of the observed behaviour. When participants were given a gun-shaped object to respond to stimuli, then they perceived more incidences of other people holding guns, although these were incorrect perceptions. When participants were instead asked to hold a shoe, and respond with that item, then they similarly showed an increase in the incorrect detection of shoes being held in the presented stimuli (Witt and Brockmole, 2012). This is problematic for the action-specific account, as holding a shoe does not change the action capabilities of the holder in the same way that holding a gun does. However, the planned action with either object influenced perception for the specific object held, suggesting a particular weighting in favour of the specific item, which was unrelated to the action capabilities it provided to the holder. While there may be action-specific effects in the earlier stages of visual perception of objects and their properties (particularly the spatial properties; Witt and Brockmole, 2012), it seems that the TEC can better account for higher level processes, such as object recognition. However, while the precise domain of influence for these action specific effects has yet to be determined, these studies again show that even without a specific preparation for action there is an influence on our general perception of the world. Importantly, they extend the previous findings of Riddoch and colleagues beyond initial studies on neurological patients.

1.2.1.1 The influence of proximal hands on attention. There is also a growing area of research examining the influence of having the hands close to the area in which a task is being performed. In the typical paradigm investigating this, the participants are not required to perform any gesture with the hands, merely to hold them close to the display screen or work area. Like the studies reviewed above, there is therefore no direct task to be performed. However, the paradigm of using the hands to change behaviours is a rapidly growing and fairly distinct area of research, and so is considered separately here. It is proposed that the presence of the hands near items leads to an anticipation of action, as objects near the hands are items that we might be about to act with (Abrams, Davoli, Du, Knapp and Paull, 2008). Alternatively, it may be that items near the hands represent potential obstacles, which need to be avoided, and so require the extra attention to assess how much of an obstacle they are and the best way to deal with them (Graziano and Cooke, 2006). In either case, the presence of the hands may influence the visual processing of the environment, in order to facilitate upcoming actions, whether avoidance or manipulation. Thus, these studies represent another means by which the potential for action can affect an observer's perception of a scene. Specifically, it is suggested that attention should be biased towards these proximal items in order to prepare us for the possibility of acting with them.

The first studies on the influence of the hands used standard attention paradigms and search tasks, comparing performance when the hands were positioned close to the screen, and when they were at a distance. Several studies showed that the presence of the hands did indeed affect the distribution of attention, as shown by performance on the tasks. For example, Reed, Grubb and Steele (2006) found participants were faster to detect stimuli near the outstretched hand, indicating a biasing of attention to the items near the hands. Abrams et al. (2008) later showed that attention is not only biased to items near the hands, but actually leads to altered processing of these items. Using visual search, spatial cuing and rapid serial visual presentation tasks, Abrams et al. (2008) showed that placing the hands next to the screen led to slower disengagement from these locations. This was so for both spatial attention, shown in the first two tasks, and attention over time, shown by the use of the RSVP paradigm.

Neurological evidence provides further support for the influence of the hands on processing. Indeed, it was originally suggested that peripersonal space, that is, the space near the body, might be coded differently compared to areas further away (Graziano, 2001). Makin, Holmes and Zohary (2007) showed this in humans, with specific brain regions responding to the objects near the hands. A later study found that activation was present in the parietal and premotor areas when objects were presented within 100cm of the hands (Brozzoli, Gentile, Petkova and Ehrsson, 2011). Interestingly, these two areas deal differently with the hands; while the parietal area is concerned with the position of the hands when static, the premotor area responds to the movements of the hands through space. It is suggested that the two areas work together, contributing to the effect of the nearby hands depending on whether or not the hand is in motion (Brozzoli et.al, 2011).

It could be argued that the influence of the hands is not necessarily functional, as the participants were not considering acting with objects when they placed their hands near the displays. However, there are several studies that indicate the proximity of the hands can influence perception in favour of action. Davoli, Du, Montana, Garverick and Abrams (2010) demonstrated that while placing the hands near visual display led to increased spatial processing, semantic processing was reduced, shown by slower responses in tasks such as judging the sensibleness of sentences. While perhaps more indirect, this suggests a trade-off favouring more detailed spatial processing of objects at the expense of higher level processes that are less related to action. Further evidence for the hands having a functional effect has focused on the conditions necessary for the influence to emerge, and so also identified conditions under which the effect is absent. Participants were found to produce more accurate pointing behaviour when a target was projected onto the palm of their hand, but not when it was projected onto the back (Brown, Morrissey and Goodale, 2009). Similarly, when both the hands enclosed a particular space, there was enhanced processing of items between them in comparison to items outside the enclosed space (Davoli and Brockmole, 2012). Both these studies indicate that the effect of the hands is only directed towards items on the palm side, which is the side more commonly associated with acting with objects. In comparison, the back of the hands do not allow for any particularly complicated manipulation of objects close by (beyond, perhaps, pushing them away). Thus, it is only when the hands are posed in such a way to encourage the typical interaction style associated with the hands that this action-relevant influence on perception will be observed. Recently, studies have examined the involvement of the magno-cellular and parvo-cellular pathway in the near-hands effect. Gozli, West and Pratt (2012) suggested that objects near the hands are processed using the action based M-pathway, rather than the perception based P-pathway. Their study showed that the presence of the hands near objects improved temporal processing (requiring the M-pathway) over spatial processing (in which the P-pathway is most involved). The importance of the potential for action was further demonstrated in a study where the action ability was manipulated, either by the position of the hands (palms-in vs. palms-out/ proximal vs. distal positioning) or the position of the object (easily grasped vs. not easily grasped) (Chan, Peterson, Barense and Pratt, 2013). For each condition, the object or posture manipulation proposed to enhance the potential for action (hands proximal, palms-in, object graspable) improved the detection of stimuli presented as a low spatial frequency image, strongly suggesting the hand posture is closely linked to the preparation for action, and acts via recruitment of the M-pathway. Thus, there is a small but varied set of studies that all suggest that the presence of the hands has a functional influence, affecting processing of relevant objects in favour of action.

1.2.2 The influence of action preparation on attention. The previously considered studies indicate an influence from the mere potential for action, while the participants do not yet have a specific intention to act with the objects. Despite this, the studies demonstrate that the suggestion of action, whether by the placement of objects in certain arrangements, the current ability of an observer to act in an environment, or the placement of the hands in a position that allows for the possibility of interaction is enough to influence the processes of perception in such a way that behaviour is noticeably changed. However, the TEC (Hommel et al., 2001) stresses the importance of the actor's goal state, or intention in the context of the task. The following studies provide evidence for the influence that preparing for an action has on perception. These come largely from visual search tasks, in which the intention of the participant towards the displayed objects is manipulated, to determine if this will affect their search for the target.

Craighero, Fadiga, Rizzolatti and Umiltà (1999) found some of the earliest support for this, demonstrating that when participants prepared a grasping movement towards a bar, they were faster in producing this response when the cue stimulus was congruent with the grasp they had planned. Craighero et al. (1999) considered this to indicate faster processing of the matching items, with the preparation of the grasp increasing the readiness of the motor system to execute the action, and facilitating processing of objects with properties that matched the grip. Craighero et al.'s (1999) study suggested that processing single objects could be influenced by action preparation. Subsequently, Bekkering and Neggers (2002) demonstrated that in the more crowded environment of a visual search task, action preparation could facilitate detecting a particular target. Participants were instructed to find a target defined by its colour or its orientation (e.g., a red target, or a target angled at 45°) in order to interact with it (by grasping) or to point towards it. Participants were more accurate in locating the object, as measured by their first saccades to it, when the object was defined by its orientation, and the task was to find and then grasp it. Again, planning an action did affect the visual processing of the scene, but the type of action, coupled with the property of the target in question also had an effect. The orientation of an object is clearly important to the way in which it will be grasped, but is less relevant if the object will only be pointed at. Similarly, the colour of the target is not relevant to forming either action. By preparing the action, processing of object features is facilitated, but only if the feature is relevant to the action. Bekkering and Neggers (2002) interpreted this in terms of visual attention as a selection-for-action mechanism, with action constraining attention to the relevant items within the scene. This is consistent with the TEC's idea of weighting an event file in favour of the task-relevant features, and thus influencing subsequent attention to objects.

Later work by Fagioli, Hommel and Schubotz (2007) looked at how different actions (pointing vs. grasping) influenced the perception of items that were defined by different properties. Again, the action prepared only facilitated the search for targets defined by a property that was relevant to the execution of the action (location and orientation, respectively). Fagioli et al. (2007) showed that the biasing of attention by action towards object features might occur not only for the individual features, but the overall feature dimension. In their study, the overall feature dimensions of location and size were facilitated; not only the specific sizes or locations that directly matched the prepared gesture. That is, while the participant might be specifically cued by an item orientated at 90°, in the intervening oddity detection task, detection of the odd target would be enhanced if it stood out because it was at any angle different to the other items in the display, not only the orientation dimension used to cue. Thus, the intention to act seems to prime visual attention to process any information that is part of the relevant feature dimension.

Further studies have confirmed and expanded on these findings, using adaptations of Fagioli et al.'s (2007) paradigm. Wykowska, Schubö and Hommel (2009) compared the influence of action preparation with other methods of biasing attention to targets, such as pre-defining the target to make it specifically relevant to the task, or presenting it repeatedly. The influence of the action weighting (the prepared action affecting perception of a feature dimension) was only present if the task had defined the feature as relevant. Wykowska et al. (2009) proposed that action induced weighting will only occur if the actions are relevant to the task, but not if the actions are made relevant by more bottom-up signals, such as a higher saliency. This further confirms the importance of intention and goals during the task for whether such action induced influences occur, and indicates that action preparation may not be the only influence on weighting representations in object search. Repetition of particular stimuli did have a priming effect, but only emerged in the absence of action-induced effects, suggesting that this priming occurs via a separate mechanism, apart from the top-down influence of task. Finally, it was demonstrated that the action effects could still emerge even if the stimuli that were to be interacted with didn't bear any resemblance to the perceived stimuli that the search task was performed on (Wykowska, Hommel and Schubö, 2011). Their study used different stimulus sets for the items to be pointed/grasped at (to provide the action preparation cue) and those in the display that would be examined during the search task Despite the fact that the two stimulus sets did not share any specific object forms, the initial action preparation still influenced performance in the search task, so that preparation of pointing enhanced detections of luminosity oddballs, while preparation of grasping affected detection of orientation oddities. Action influences are therefore not dependent on the low-level perceptual similarities, but may result from higher level perception-action representations, and the associations between particular actions and properties.

While the standard paradigm for investigating the influence of action preparation tends to be the visual search task, other methods have been employed. Symes et al. (2008) used a change detection task in their experiment, again using this to determine if the preparation of an action could bias attention towards certain items. In contrast to the previous studies, the actions employed for this investigation were more specific. Rather than two clearly different actions such as a grasp vs. a point, they used variations of grasps that were appropriate for different sized objects (power vs. precision). Again, the preparation of the grips increased the detection rate of changes to items that were size compatible with the grip. Symes et al. (2008) further made the point that the prepared grip types were not being directed to a region in space (and did not possess a spatial dimension). Thus, the preparation of the grasp was not biasing attention towards particular spatial locations, but instead to the relevant specific features of the objects that were presented (in this case, the size). This is further evidence that the action preparation is biasing particular associated object properties.

The set of studies described here demonstrate that the intention is an important part of the interactions between action and perception. Our previous experience in performing actions allows us to determine which aspects are the most relevant for our purposes, and so enhance their processing to facilitate our actions. However, while such studies introduce a little more realism by including specific goals related to the objects, they do not allow for any direct manipulation of the objects in question. Studies in real world settings deal with this problem, and eye movement studies in these contexts are particularly useful for examining perception and action interactions, as the movements of the eyes reflect an early perceptual response. Although the eye movements themselves are a motor response, it is one that occurs early, in order to direct the hands, or other motor effectors. Furthermore, unlike the hands, the eyes are not involved in acting with the objects, and so the eye movements are not conflated with the required manipulations of the task objects.

1.2.3 The influence of action execution on attention. As well as gathering information prior to action, information about the changing environment needs to be gathered during action. Studies of vision during real world tasks have supported this, showing clearly that the nature of the task influences where we look. Examples of such studies include Land, Mennie and Rusted (1999), using a tea making task; Hayhoe (2000) and Hayhoe, Srivastava, Mruczec and Pelz (2003) using sandwich making tasks, and Lee and Land (1994), recording eye movements during driving. In all such studies, the typical finding is that participants will direct their eyes to the places that provide them with the necessary information, whether this is the correct objects in the case of the tea and sandwich tasks, or to the tangent point on a winding road, which gives information about the bend curvature, and so informs steering behaviour (Land and Tatler, 2009). These fixations were made prior to any actions (grasping the fixated object, etc.), but only by a short time period of roughly 0.5s-1s, indicating a closely linked eye-hand strategy. The prioritisation of task-relevant objects is shown particularly clearly in Hayhoe et al.'s (2003) study, where the objects for the task were placed among irrelevant objects. While fixations were made more or less equally to both types of objects before the task began, after it started, fixations on irrelevant objects fell significantly, with more attention being paid to items that were necessary for the action. Perhaps even more importantly than the influence of task relevance, these and other real world tasks all show the common finding that vision is constantly in the service of action. As well as selecting the next item for use in the ongoing task, vision is involved in monitoring the actions currently being completed (see e.g., Ballard, Hayhoe, Li and Whitehead, 1992). Indeed, when participants were prevented from monitoring their actions, performance was slower (Ballard, Hayhoe and Pelz, 1995). In order to successfully complete tasks, not only do we need to select the correct items, we need to use them as the task demands. Vision is central to both these requirements, following the demands of action in order to allow for the end goal to be achieved.

If perception is for action, as is suggested by various authors, and embodied theories, then it should be influenced by the action requirements. The studies outlined here show very clearly that this is the case: even without a guiding task or intention, the potential for action is enough to change how attention is biased. At the other extreme, in the context of everyday tasks, we can see how eye-movements (a strong measure of perception) respond and follow the on-going demands of an action. Thus, one side of the action-perception link is supported here, but the other side, where perception can influence action, must also be considered, as this provides evidence for the idea that perception is not merely a passive response to the demands of a task, but, as Bridgeman and Tseng (2011) state, an active process itself, used to anticipate a potential upcoming action. In the following section, studies of affordance effects are examined, to provide evidence for the other side of the loop.

1.3 Perception Influencing Action: Attentional Weighting

Studies into the influence perception might have on action were conducted prior to the suggestions of the TEC, and so initially were not strictly linked into that framework. However, the findings and conclusions are compatible with much of the TEC's proposals, and provide the required evidence for the complimentary side of the action-perception link.

It is important to note that the object affordances considered in this area of the literature differ from the original meaning of the term, first used by Gibson (1979). Gibson's affordances arise from the direct perception of the world, informing the viewer as to how the objects could be acted with. A chair affords 'sit-ability', a mug 'grip-ability', and so forth, although the particular situation affects which affordance is most relevant; whether an object will be held or thrown, for example. Importantly, all this information is provided by on-line visual stimulation the object provides, with no internal representation required to store the various possibilities. In contrast, the affordances suggested by Tucker, Ellis and others result from the observer's internal representation of the object. Rather than rely solely on what the visual system provides from the external world, these representations are the result of learning about the objects, their visual properties, and their associated actions. Thus, over time, familiar objects will become more detailed as further information is added from experience, allowing the mental representation to be grounded in the observers' experience of the world. Indeed, Ellis and Tucker (2000) make the point that this sort of structure neatly provides a solution to Harnad's (1990) symbol grounding problem. This inclusion of both action and visual features within the same representation has obvious parallels with the TEC's suggestion of the common representational domain for perceptual and action features. They also result in similar, mirrored predictions for behaviour. Just as the overlap between action and feature codes leads to actions influencing perception, the object affordance literature predicts that the perception of an object should lead to the activation of its associated actions, even if they are not currently relevant to the on-going goal (Ellis and Tucker, 2000).

Much of the research in the object affordances literature has used stimulus-response compatibility (SRC) tasks, in which the performance of an action is influenced by some visual aspect of the object used as a stimulus. More specifically, these effects tend to be divided into two broad types: the Simon effect (e.g., Simon, 1969), and the affordance effect (e.g., Tucker and Ellis, 1998). The Simon effect arises when participants make bimanual responses to stimuli, based on a feature such as colour, shape or orientation. When the location of the object and the location of the response match (e.g., object on the right hand side responded to with a button on the right hand side) then the responses are performed faster, despite the fact that the objects' location is not relevant to the ongoing task.

The affordance tasks follow a similar process, but examine whether other visual features of the objects will lead to the same effect on responses when they are task-irrelevant. Tucker and Ellis (1998) used the handle location of objects in a task where participants decided if the object was orientated normally, or inverted. Again, the response time was affected by the handle location, with matches between the side of the handle, and the side of the response hand facilitating the speed of the response. From their studies, Tucker and Ellis (1998) further suggested the concept of 'micro-affordances', where the visual appearance of the object activates a specific component of an action. This is a more precise activation of an action, so that rather than a grip being facilitated by any grasping gesture, one particular hand shape may be activated by perceiving a specific size of an object (e.g., Tucker and Ellis, 2001). This is similar in many ways to Symes et al.'s (2008) study showing that preparation of a specific action, such as a precision grip, would enhance perception of a matching size, and demonstrates that the influences of perception on action operate at the same level as those seen when action influences perception.

The two broad types of effect can be classed as either space-based or object-based affordances, and there is some debate as to whether they constitute two separate effects, or if there is some closer relationship. Symes, Ellis and Tucker (2005) examined the differences between the conditions under which the two effects emerged. Under high attentional demand conditions, when participants were cued to respond by the object's category (whether it belonged in a kitchen or garage), influences of both the objects' location and orientation were found on the responses produced. Under lower attentional demands, where the cue was the objects' colour, only the Simon effect emerged, indicating that the two types of affordance may be different.

Two main explanations were initially proposed for the affordance effect, separate from the Simon effect. Both emphasise the close link between perception and action, but vary in the precise manner in which objects' action and visual properties are represented. Tucker and Ellis' original account, as already mentioned, proposed that action information was stored in the representation of an object, and activated due to a match in the properties of the object being viewed(e.g., size activating a grip type). However, as implied by micro-affordances, this is a targeted activation, with specific hand shapes being facilitated by a particular size, and so forth. An alternative, but largely similar account suggested that the coding of actions was more abstract than proposed by Tucker and Ellis. The actions activated by the perception of an object did not have to be a precise match to the object's properties. For example, it was found that affordances could emerge even when participants used left/right foot presses to respond to stimuli, (thus using an effector which would not normally produce the active manipulation when an interaction took place) or responded with their hands crossed (so that the right hand was actually responding on the left hand side, and vice versa, Phillips and Ward, 2002). In both these cases, it is not the specific limb that is being facilitated by perception, but an abstract facilitation of any associated action (i.e. it occurs on the congruent side, but does not have to be the congruent limb). As Symes et al. (2005) point out, a more abstract coding style is in line with the TEC's proposals of a common representational domain, where action and perceptual codes are functionally equivalent. More abstract representations also allow greater flexibility for activating a wider range of actions, and so would be of greater benefit to an active organism.

Explanations for the Simon effect differ slightly; it is suggested the results come from the overlap between the representations for the stimulus and response (see e.g., Kornblum et al., 1990), although early suggestions lacked detail in terms of how the overlap might occur. Of course, the TEC, with its common-coding principle can easily explain the overlap as being due to representations, whether for stimulus or response, sharing the same neural codes (Hommel, 2009). Thus, according to the TEC, as the location of the response in the Simon effect is task-relevant, these codes will be activated by intentional weighting. This will then prime the task-irrelevant location of the stimulus, which overlaps in the representational space with the codes for the response location. To further support the TEC's account for this effect, there are studies which show how the Simon effect can be lost or reduced if the task settings do not allow for the response to be prepared, which would prevent the weighting of the response dimension from taking place (Vallé-Inclan and Redondo, 1998). Thus, the Simon effect is certainly not incompatible with the TEC's proposals, and provides further evidence for the influence of perception on action.

1.3.1 Boundary conditions necessary for affordance effects. An important factor in the investigations into affordance effects is the conditions under which the effects will reliably emerge. The earliest studies into this area emphasised the automaticity of the effects; indeed, it was key to these studies that the feature that affected the response, whether orientation, size or position, was not relevant to the on-going task. In this way, affordance effects are similar to the findings of Riddoch and colleagues, where the potential for action seemed to affect perception even without the intention to act. However, various studies have been conducted to determine if this automaticity is a key part of the effect, and whether there are situations which will influence its presence or strength. Tipper (2010) suggested that, if the strongest form of automaticity was correct, then any time an object was viewed, it would be enough to begin an action which might be disruptive or inappropriate for the situation. Instead, there might be processes that allow for the suppression of the vision-to-action conversion processes if they are not appropriate to the task. Three main areas have been investigated, to determine what influence they might have on affordance effects; levels of attention and where attention is directed; the response the participant makes, and the overall context of the task.

1.3.1.1 Attention. The focus of attention has been suggested to be an important factor in allowing an affordance effect to emerge. Indeed, Tipper (2010) proposes that attention is the key component in allowing (or suppressing) the conversion of perception into an action effect. Various studies have examined how adjusting the attentional focus or the amount of engagement with a stimulus object can influence the emergence of affordance effects in responses.

In their comparison of the Simon and affordance effects, Symes et al. (2005) found evidence to suggest that the level of engagement with the objects was important for the affordance effect at least. In this study, one of the tasks was to respond based on whether the presented object was more commonly associated with a garage environment, or a kitchen. The other task required participants to respond based on the colour of the stimulus object. It was only in the classification task that the affordance effect was detected. Symes et al. (2005) suggested that it was only in this task that the participants engaged with the object's identity, in order to successfully make their decision. As a result, they accessed the full representation of the object, and so the actions associated with it, which facilitated the actions made towards the item. In contrast, colour information was extracted more rapidly from the stimulus, and did not require the same level of engagement with the object.

Similar findings were reported in a study of the compatibility effect; a version of the affordance effect in which participants respond with a pantomime gesture which can be compatible or incompatible with the cue object (Bub and Masson 2006). In this study, the objects were displayed to participants, and then replaced with a picture of a hand performing an action (either compatible or incompatible to the previous object). The object itself was irrelevant to the participant's task, as it was the pictured hand posture they had to copy. Under these initial conditions, a compatibility effect (measured as the time taken for participants to begin making the response gesture) failed to emerge. However, when participants were instructed to name the object after they had made the hand gesture, then the expected pattern emerged, with faster response times when participants performed a gesture compatible with the use of the object they had seen earlier. This again seems to point to the importance of engagement with the objects. When they are passively viewed with no reason for engaging with the images, they do not trigger any kind of response. However, when participants know they must name the object, they examine it with the intention of determining its identity (as in Symes et al.'s study), thus accessing the representation, and the associated responses. If they are then required to form an incompatible response, then this is slowed, as the compatible responses are already primed.

As well as the level of engagement with an entire object, studies have considered how the focus of attention on a particular property of an object might influence the emergence of the affordance effect. In one study, the handle orientation effect was examined when participants were cued to make their left/right responses either according to the colour of the door handle stimulus, or its shape (Tipper, Paul and Hayes, 2006). Affordance effects emerged only when attention was given to shape, and not colour. Tipper et al. (2006) proposed that the shape of an object is more relevant to action processes than its colour, as the shape informs aspects of the grip that must be formed to interact with the object. Attending to this action-affording stimulus, rather than the more visually relevant property of colour, produces the affordance effect. Studies have even shown evidence for this difference due to attentional focus at the neurological level. Schuch, Bayliss, Klein and Tipper, (2010) used EEG recordings to observe the mu rhythm, a sequence of activity observed over the sensorimotor cortex in the frequency range of 8-13 Hz, which has been found to be suppressed during action (and observation of another's action). Schuch et al. (2010) showed that it was also suppressed when observing an action sequence with instructions to concentrate on the action, (i.e., a hand gripping a mug) but not when observing the same sequence while concentrating on the colour of the acted-with object. Schuch et al. (2010) suggested that this indicated the importance of attention to action, and action relevant aspects of objects in order for object affordances to arise. Thus, it seems general attention is perhaps not enough to elicit an affordance effect, and there is some necessity for the object to be examined as an object, which can be achieved either by constraining attention to properties which are particularly relevant to its function, (such as shape), or by engaging with the object by identifying it, and therefore its associated uses.

There is one study that suggests a slightly different way in which attention influences the affordance effect. Vainio, Ellis and Tucker (2007) employed a task in which the presented object was entirely irrelevant to the task requirements, and simply present throughout the duration of each trial. Despite this, the orientation of the object still affected the speed of responses, facilitating the button presses that were made on the same side as the object handle. In contrast to this, when participants were instructed to fixate on a point over the irrelevant object, the orientation had no such effect. This is in agreement with the earlier studies showing the importance of attending to the stimuli in allowing the effect to emerge, but the findings do not entirely fit with the other data. The exogenous attention to the object is apparently enough in this case, although there is no deeper engagement with the identity of the object presented, as in Symes et al. (2005) and Bub and Masson (2006). Instead, Vainio et al. (2007) proposed that attention is necessary, but it is enough for it to be captured exogenously, particularly if the object is displayed at the centre of the attentional focus. Further investigation is needed to clarify how this finding fits with the other studies suggesting that attention must be engaged with the stimulus in an active manner in order for affordances to be seen in response times.

1.3.1.2 Realism of response. Following their attendance to a cue, the participant in an affordance study is then required to produce some type of response. The initial affordance studies simply required responses to be made by pressing a button, regardless of the stimulus object. While the participant is still not required to act with the objects displayed, by introducing more specific responses, this may increase the strength of the intention towards the objects, and so lead to differences in how any affordance effects develop. This version of the affordance effect (termed the compatibility effect) is therefore determining whether the perception of a common object will facilitate not just an abstract response, but a response which is specific to the way that the object is used.

There are very few studies which have incorporated more realistic responses. Bub and Masson's (2006) investigation referred to above used the compatibility effect and demonstrated that a certain level of engagement with the stimulus was required for the effect to emerge. However, further studies using the compatibility effect and pantomime response gestures have suggested that the nature of the response itself may have an influence on the emergence of the effect. This was noted in a second study by Bub and Masson (2006), in which they presented participants with an action version of the Stroop task. Participants were instructed to produce action gestures in response to different colours (e.g., produce a trigger squeezing gesture in response to the colour red). Coloured objects were then displayed in the trials, so that participants had to ignore the actual object that was pictured, and respond only to the colour. Despite the irrelevance of the object, responses were facilitated when the response required by the colour was compatible with the object (e.g., a red bottle of antibacterial spray), and slowed when the gesture cued by the colour was incompatible with the pictured object (e.g. a red calculator). These findings are in contrast to those reported in the previous section, where it seemed that if the cue to act was the colour of the object, then this was not enough for the affordance effect to emerge (Tipper et al., 2006). The possibility that it was the use of more specific gestures was explored further by Bub and Masson (2010) using the handle orientation effect, where button press responses and pantomime gesture responses were directly compared. When cued by object colour to make a response using a button press, there was no advantage found when participants used a hand congruent with the side of the handle. However, when participants responded using a reach and grasp response, then there was an advantage if the handle was aligned with the response hand. This suggests that the intention of the actor in the gestures they will form may have a role in modulating the ease with which the response actions performed too; perhaps stronger than that of where attention is focused on the object in question.

1.3.1.3 Implied realism of setting. As well as the aspect which cues the action, and the response that must be produced, another factor in the emergence of the affordance effect is the level of realism which is implied to be present in the study. How realism is implied varies across the studies, but the methods all have in common the fact that they attempt to make the possibility of action more likely. Tipper et al. (2006) found that responses to images of door handles were facilitated if the handles were presented as though they were in the process of being used (i.e. presented at an angle, as though being pressed down). Here, it is implied that the stimulus is more than just a static picture, but that it is able to move and be acted with. Indeed, Tipper et al. (2006) also found that the affordance effect could be strengthened if participants were primed with video clips of the door handles being pressed down prior to the start of the experiment. Implying the object is capable of being acted on, or is observed in the process of being acted upon is thought to lead to participants simulating the action from the cues provided, which strengthens the activation of the affordances. A similar study examined how the perception of another's actions with an object could affect the affordance effect, but expanded on Tipper et al.'s findings by showing that the plausibility of the actors' interactions influenced the observers own responses. Participants were required to classify large and small items as natural or manmade by making power or precision grips to indicate their choice (Girardi, Lindemann and Bekkering, 2010). While the size of the stimulus objects was irrelevant, the typical affordance effect was found: making the grasp gesture was facilitated when it was compatible with the size of the object displayed. This effect was modulated however, by the introduction of the image of a hand pictured approaching the stimulus object, and in the process of making a power or precision grasp itself. When this actors gesture was incompatible with the stimulus objects, then the participants responses were not facilitated, even if their response was compatible with the object. A version of the study was also conducted in which the actor's hand was shown making the grasp at a distance from the object, as though it was interacting with something else, and not the pictured stimulus. Again, in the absence of a clear coupling between the actor's action and the stimulus object, there was no facilitation of the participant's own compatible gesture. As in Tipper et al.'s (2006) study, it appears that observation of an action can lead to simulation of the action in the observer, but the observed action must itself be plausible and accurate for this simulation to occur.

As well as examining the action possibilities arising from observing another, the realism of the affordance paradigm has been manipulated by changing the participants' perceived ability to act with the pictured objects. Yang and Beilock (2011) examined how the strength of the orientation effect was affected when the stimulus objects were presented either within the action space of the participant, or at a distance, as if the objects were out of reach. It was suggested that this effect may be particularly strong for the orientation effect, as this is a property that is not intrinsic to an object, and so the effect is stronger when there is a greater possibility for action, even though this is only implied by the presentation of the items. These conditions which increase the realism of the paradigm all seem to enhance the affordance effect, although more research is required to determine if they all operate via the same mechanism, and how they might interact together. All these boundary conditions, however, demonstrate that the affordance effect is not an inevitable, automatic response to the perception of an item, but is dependent on different aspects, which all act to encourage a perception of action in the participant making the response.

1.3.2 Boundary conditions for the Simon effect. The Simon effect seems to be less affected by the context of an experiment than other affordance effects. Studies such as Symes et al. (2005) have shown that the effect still emerged when participants attended to low level cues, even when the affordance effect was absent. Pellicano, Iani, Borghi, Rubichi and Nicoletti (2010) found similar results, with the same object stimuli giving rise to both Simon and affordance effects, depending on the task instructions. It seems that the Simon effect is mainly dependent on their being a spatial overlap between stimulus and response, and a chance for this mapping to be prepared before responding, as suggested by Hommel (2009). This is perhaps due to the fact that the Simon effect depends on the position of the objects, rather than a more intrinsic object property, so that the actual nature of the object is less important to the action responses being prepared.

The various types of affordance effect demonstrate clear evidence for the ability of perceptual processes to influence the production and performance of action, filling in the other side of the action-perception loop proposed by situated action theories. While initial studies seemed to suggest that the conversion of perception into action was automatic, later studies indicate that this is not a strong form of automaticity, and is susceptible to influence of the context of the task. In particular, attention appears to be important in the emergence of the effect, with a certain amount of focus being required in order for any influence on action to be seen (although this may be more so for the object-based affordance effects, rather than the location-based Simon effect). Overall, perception can influence action in a similar manner to that by which action influences perception.

1.4 Representations of the Visual World

Theories of situated action have considered how action and perception contribute to object representations, but these proposals have been largely confined to on-line representations, in the course of a task. In contrast, theories of visual memory representations have not typically considered how action could be incorporated. However, embodied views of memory suggest that it is just as important a process for serving action as perception, and so it seems memory could be considered in the same way. In this section, the initial theories of modality-free visual representations will be considered, followed by more embodied theories that attempt to tie memory and action together. Finally, evidence will be considered which suggests that action's influence on perception and perception's influence on action can still be found in the absence of the presence of the stimulus.

1.4.1Theories of visual representation. Initially, the visual representations we form of scenes were thought to be essentially picture copies of the external world. The visual contents of each fixation were added to an image of the overall scene, held in a low-level visual buffer (e.g., McConkie and Rayner, 1975). However, subsequent studies showed the problems with this approach, in particular, those using the change detection paradigm (e.g., Grimes, 1996). Changes made to pictures during interruptions to scene viewing (e.g., during saccades, or simulated saccadic disruptions such as flickers (Rensink, O'Regan and Clark, 1997) or blinks (O'Regan, Deubel, Clark and Rensink, 2000) went unnoticed by the viewers. This was considered to provide evidence against the idea of a highly veridical picture representation of the world, because if the scene was represented in such a faithful fashion, then changes made during disruptions should be easily detected by comparing the ‘before’ and ‘after’ representations of the scene (Rensink, 2002).

Thus, theories developed after these findings proposed either no representation (instead, the world was used as an outside memory source; O’Regan and Noe, 2001) or representations that were exceedingly sparse (e.g., Rensink, 2000; Irwin, 1992). In particular, Rensink’s coherence theory held that only those parts of the scene that were attended would be represented in a stable and detailed fashion. Unattended objects are maintained as volatile proto-objects, which are constantly replaced as vision moves across the scene. When attention is focused on an item, more detailed information is added to the representation, but this extra detail itself is fragile, and would not survive long after the withdrawal of attention. Although the information could be integrated with higher level information relating to scene gist and spatial layout, there is no use of representations that are both highly detailed and stable.

A related proposal was that of object files (Irwin, 1992; see also Gordon and Irwin, 1996). Here again, attention to an object is necessary to create a temporary representation of that object, containing information about the visual features and location. These files can be maintained across several saccades, but will decay over time. However, up to five objects could be maintained at one time, instead of the single attended item proposed by Rensink (2000).

Following these initial proposals, the theories returned to the idea of more detailed representations. In terms of these richer representations, there are two main ideas; that the representations are strongly visual, that is, formed and stored in visual short-term and long-term memory (e.g., Hollingworth and Henderson, 2002), or that the representations are detailed, but abstract (e.g., Melcher, 2001**;** Tatler, Gilchrist and Rusted, 2003).

Hollingworth and colleagues suggest a robust visual representation based on findings from change blindness studies, in which it was found that participants could detect even quite small changes to objects, provided they had fixated the object prior to the change (e.g., Hollingworth and Henderson, 2002; Hollingworth, Williams and Henderson, 2001). The fact these changes were still noticed despite not being directly fixated at the time of the change argues against the sparser ideas of representation, as it shows the representation still being maintained at a level that allows changes to be detected, rather than rapidly decaying. Accurate detection of changes was still high even when up to nine fixations on other objects intervened between the initial fixation on the target object and the subsequent change detection test for that item (Hollingworth and Henderson, 2002). According to this approach, VSTM and VLTM both play a central role in supporting and maintaining these representations. Hollingworth (2004) examined the change detection performance of participants after they had to view object sequences of different lengths after their initial fixation on the changing target object. VSTM was shown to have a role in object representation, as memory performance was superior when the target object was one of the two most recently fixated objects. However, memory performance was still consistently robust on objects fixated 3-10 fixations previously, which Hollingworth (2004) suggested showed the contribution of VLTM. Expanding on these findings, Hollingworth (2004; 2005) proposed that scene representations are built up across multiple fixations, starting with both precise sensory representations and higher level visual representations being produced during each fixation on an area of a scene. After a saccade is made, the sensory information is rapidly lost, but the higher level representations remain, first briefly within VSTM, and then in VLTM, allowing the accumulation of information from eye movements made across the scene, and the maintenance of the representation.

There are similarities between the views of Hollingworth and colleagues, and the idea that scene representations are more abstract in nature. Again, it is suggested that information from scenes is accumulated across several fixations. For example, Melcher (2001**;** 2006) showed that memory for objects improved across both continuous and interrupted viewings of a scene, although he also suggested that a medium-term memory (MTM) store would better explain the integration of information, as there was no indication of a clear change in the memory performance that would suggest a transition from STM to LTM. Instead, the MTM acts as a ‘proto-LTM’, containing information available in early stages of memory that has not yet been fully consolidated into LTM proper. Tatler et al. (2003) also proposed a fairly rapid accumulation of more abstract information. It was suggested that in the earlier stages of scene viewing, the gist of the scene would be extracted (i.e. the overall meaning of the scene), as would the spatial layout (the way in which the objects are arranged within the scene), while other object details would be extracted later on in viewing. This was supported by their study, with participants showing high performance levels regarding the gist of scene after only a second of viewing time, and spatial information after 2 seconds. The object details, such as shape, colour, presence and relative distance, are added later, with different time courses of accumulation being shown for the individual properties (Tatler, Gilchrist and Land, 2005**)**. Thus, while the overall representation is proposed to be more abstract than strictly visual, the representations still contain a large amount of detail about the objects within the scene.

1.4.2 Memory for action. The theories of visual representation outlined above do not give much consideration to the possible effects of action on the representation construction. However, other theories take a much stronger view on the influence of action on memory representations. In particular, Glenberg (1997) proposes an embodied view of memory which has similarities with the proposals made by simulated action theories. Just as perception is proposed to have evolved in order to serve action (e.g., Bridgeman and Tseng, 2011), so Glenberg (1997) proposes that memory storage developed in order to perform the same task. This is a strongly embodied view; Glenberg suggests that we perceive the world in terms of how we can act on it, and categorise objects in terms of how they can be used to complete a goal. In memory, these perceptions, or patterns of possible action, are meshed together with patterns based on our previous experience. Thus, when perceiving an object, we receive information about how we can act with it directly from the environment (in terms of how we individually are able to act with the object), but we also access patterns of previous interaction with that object, which provides the information that we cannot directly access from the environment. Together, these lead to a meshed conceptualisation, from which the overall meaning of the object arises, but importantly, this meaning is strongly in terms of serving action. When we must recall information, or decide on actions we wish to perform, then our perception of the environment must be suppressed, by averting our gaze from any potential stimulation taken directly from our surroundings, and allowing our stored patterns of previous interaction to be accessed (e.g., Glenberg, Schroeder and Robertson, 1998).

This rather constrained view of memory as being only for action has been questioned, however. Koriat and Goldsmith (1997) suggest that while Glenberg's (1997) theory addresses memory in the context of action, it is not able to account for the whole structure of memory, with some aspects unable to account for memory phenomena any better than previously existing explanations. The theory is best able to cope with more implicit and procedural aspects of memory, i.e. those that are perhaps most closely concerned with supporting object interaction. Wilson (2002) also regards Glenberg's (1997) theory as too extreme, as it suggests that objects should be perceived entirely in terms of how we could use them - their functional relevance - rather than as they actually are. However, as Wilson (2002) points out, we are able to encode visual events that we cannot interact with, and recall items that must be recognised based on their visual appearance rather than how we can interact with them (e.g., faces). Thus, not all perception, and so not all encoding, is just for action; we can engage in perception in order to achieve goals that are not linked to an immediate action response. Furthermore, Wilson (2002) makes the point that restricting encoding to only the information necessary for the current task is too strict, and does not allow for the flexibility we can show when dealing with objects. She reasons that if we only encode objects in terms of how we have used them in the past, this would restrict our flexibility if we needed to use the item in a novel way. Indeed, if memory is for action, then it might better serve action by allowing information to be stored without prior commitment to a particular use. According to Wilson (2002), our representations are purpose-neutral, containing information beyond that which is required for the present task. This is in line with the findings of Hollingworth and colleagues, where information is accumulated over multiple fixations, but without any particular bias towards a type of information. Thus, representations can contain both relevant and irrelevant information about objects and scenes, potentially allowing us greater flexibility in interactions.

However, while Glenberg's (1997) theory is less able to account for all the phenomena of memory, it may be that the presence of action will affect the way representations are formed. As noted, the initial studies into the representations were not particularly active tasks, merely requiring participants to view scenes with no intent to interact with them. However, if action were introduced, then certain items would be likely to become more relevant to the task, similar to the TEC's (Hommel et al., 2001) idea of intentional weighting. Similarly, in studies examining eye movements during different tasks, it is clear that the task constraints affect how people direct their gaze. Given the link between fixation and memory accumulation shown in Hollingworth and others' studies, it might be expected that some influence of task would influence the construction of the representation. Indeed, several studies show that task-relevant objects are recalled better than those that are task-irrelevant (e.g., Castelhano and Henderson, 2005; Williams, Henderson and Zacks, 2005). Both studies used a standard memorisation task where participants viewed arrays or scenes, in which certain objects were task-defined targets, whereas others were distractors. There is some debate, however, as to how the task more specifically affects the representation; that is, whether it is simply via the increased number of fixations on relevant objects, or if these task relevant objects are processed in a fundamentally different manner. For example, Hollingworth (e.g., Hollingworth, 2009; Hollingworth, 2012) suggests that while the task may lead to a prioritisation of relevant objects in terms of the number of fixations they receive, all fixations on objects will result in the extraction of the same amounts of information, regardless of whether the item fixated is relevant or not. In contrast, Võ and Wolfe (2012), and Tatler and Tatler (2013) propose that the task also influences how much information is taken from fixations on task-relevant objects, so that the eventual representation is much more specific to the demands of the current task. For example, Võ and Wolfe (2012) reported that searching for a target object was only benefitted by the object having been fixated during an earlier search for it. If it had been fixated in the course of an earlier memory task where it was not the target, then no benefit for subsequent search was found. Similarly, Tatler and Tatler (2013) found that different task instructions affected the memory performance on the same set of objects. When fixation numbers and memory performance were compared across task relevant and irrelevant objects, it was found that for a given number of fixations, memory for task relevant objects was significantly better, indicating that the number of fixations alone did not determine what information was encoded. Rather, the task setting itself has an influence on how much information is extracted during these fixations.

While these studies manipulated the task participants performed, they did not involve any instruction for the participants to act with the objects. From the studies on action influencing perception reviewed above, it is clear that we can consider different stages of action that might influence attention, and thus subsequent memory for scenes and objects. Although there are fewer studies in this area, it is possible to find experiments which have investigated the influence of the potential and preparation for action on the representations, and how the execution of a task can influence memory both during and after the action.

1.5 Action Influencing Memory Representations

1.5.1 Influence of the potential for action on memory representations. Studies investigating the influence of placing the hands close to object displays have also investigated the effect on memory representations. As mentioned, the influence of the hands has been shown to have a functional link, increasing attention in order to aid possible future actions, but does not necessarily depend on an intention to act with the objects in question. Thus, we can differentiate it from the investigations into the effect of task mentioned above; participants do not directly interact with the objects, but they are perhaps more engaged with the display than when simply viewing the objects to memorise them.

In terms of memory, if the presence of the hands biases attention towards proximal objects, then this increased attention might be expected to influence memory in favour of these nearby objects, perhaps at the expense of more distant items. However, the results of these studies have been rather mixed in their support of an action influence from proximal hands. Tseng and Bridgeman (2011) found that the presence of the hands increased participants VWM capacity, enabling them to hold more items in shorter term store. Studies looking at the hands' influence over longer time scales actually suggest a less facilitative outcome. Davoli, Brockmole and Goujon (2012) used an implicit memory test in the context of a visual search task, to determine if participants would show greater improvement in finding targets in repeated scenes when the hands were proximal to the screen. Instead, long term memory for the items was not improved by the presence of the hands compared to the hands absent condition. Furthermore, memory was worsened in the proximal hand condition if the repeated scenes changed their details (e.g., colour) but not the overall structure (i.e. spatial layout). Davoli et al. (2012) suggested that the presence of the hands led to a bias towards details, and a reduction in extracting common information. This would be in line with previous suggestions regarding the hands: if objects near the hands are potentially manipulable, then attention to their details is more useful to inform the later actions. Thus, this leads to memory being similarly biased towards item details when the hands are present, possibly biasing the representation to later action.

1.5.2 Influence of action preparation on memory representations. Similar to the logic behind the proximal hand studies, and the investigations into on-line effects, it might be expected that the preparation of an action will lead to attention being biased towards the task relevant items and features, and so a stronger representation of such objects in the memory representation. However, there are very few studies that have used such a manipulation. Vishton et al. (2007) investigated how action planning might influence perception of visual illusions, and in particular how strongly the illusion was perceived. The planning of the action was found to reduce the strength of the illusion in an equivalent manner to actually carrying out the action, and this effect continued to persist after the illusion was removed, and participants were recalling the test items for a later judgement. Thus, there is some evidence that action planning can affect object representation, but this area is currently lacking in studies.

1.5.3 Influence of action execution on memory representations. In considering the influence actually performing actions might have on the memory representations we form, it is important to make a further distinction here. There are studies indicating that we rely on memory representations during the task being carried out; and those that investigate how the representation is affected after the task has been completed. The use of memory during a task is itself task dependent. Typically, the actor can rely on the information they require being directly available to them in the external world, that is, using the world as an outside memory store (similar to O’Regan and Noe’s (2001) suggestion). As a result, the representations may be fairly sparse in comparison to a task that is solely a memory test. However, the circumstances of the task may change how the actor relies on memory and vision. If visual information is degraded in some way, for example, then memory may provide a more reliable source. Even if there is not such a drastic change to the visual information, in a larger environment, not all items will be within view at any one time. As a result, memory will be required to inform the direction of saccades to locate the next relevant object for the task. There are various real world studies that have shown memory and vision work together during a task, each acting to supply information when the other process may be less reliable.

In particular, several of these real world studies show that spatial information regarding the location of objects is typically preserved. Land et al. (1999) found that participants making tea were able to find the next required object more easily if they had previously fixated it. Hayhoe et al. (2003) also note that participants would scan the work area before beginning a task, which they suggest indicates the acquisition of a rough scene representation for guiding subsequent fixations (although this could equally indicate a more aimless scanning of the scene during free time in the task).

Studies by Karn and Hayhoe (2000) and Aivar, Hayhoe, Chizk and Mruczec (2005) examined the involvement of memory during a more controlled, lab based task. Here, a block copying paradigm was used, in which participants recreated a displayed pattern of coloured blocks by selecting the appropriate items and arranging them in the correct pattern. However, changes to the overall display were made at certain points, by removing a target block from the display during the preceding display. Subsequent saccades to the target had to be made without a visual guide. In both cases, participants made fixations to the location of the missing block, and were often unaware of the change being made, indicating that the spatial information was being retained across the saccades to inform the eye movements to the targets. When visual information was removed or changed, the representation of the scene supplied the correct information required to allow for the task to be completed. Brouwer and Knill (2007) added to this by showing that participants would use both direct visual information and stored spatial information in the course of a task, but vary the amount by which each part contributed to the process. When the location of future targets was changed, participants would still show a bias towards guiding their saccades to the remembered location. This bias was increased when the contrast of the target information was decreased, indicating that it is normal for us to use both the immediate visual information and the spatial representations, and use whichever source of information is most reliable at that point.

Beyond spatial memory, there is evidence that featural information specific to the task may be prioritised during the action. This has been shown clearly in studies by Triesch, Ballard, Hayhoe and Sullivan (2003), and Droll and Hayhoe (2007). In both studies, participants performed a virtual reality block-sorting task, where blocks had to be sorted onto particular conveyor belts, depending on their properties, and the rules the participants had been given. In Triesch et al.'s (2003) study, the height of the blocks determined where blocks were placed, and the rules determined when in the task this feature was relevant; that is, whether it informed the block selection, informed both selection and set-down, or was irrelevant to both parts of the task. On a subset of trials, the size of the block being used was changed while it was handled. Change detection was dependent on the relevance of the changing feature to the task. When it was irrelevant to both pick-up and put-down, detection was low. Participants were better at detecting the change when it was made to a feature which informed the pick-up stage, but performed the best when the changing feature was relevant to both pick-up and put-down. Thus, while there is some advantage in recall for a relevant feature that was involved in the task at some stage, when the feature is known to be relevant to the upcoming stage, then it is preferentially maintained in memory. Task relevance and the ongoing dynamics of the task therefore both influence the task representations. Droll and Hayhoe (2007) used different features of the blocks, such as colour, size and texture, and varied the predictability of the sorting cue. Thus, the cue to pick-up the object could always be the same as the set-down condition; different, but predictable, or different and unpredictable. Examining re-fixations on the blocks when they were being carried to the put-down location showed that participants were less likely to make these re-fixations when the pick-up and put-down cues were the same, but when the put-down cue was unpredictable, re-fixations were much more common. This was so even if the pick-up cue was the same as the put-down cue. Thus, both studies demonstrate that the on-going task demands determine what information is retained. If participants are aware it will still be useful to the later part of the task, they will maintain it in their representation, and so will be able to notice changes to this feature. However, if they cannot be certain this feature will still be informative in the later task, the information will not be stored, but sampled from the environment when needed. These findings imply that the representations we form during tasks contain spatial information to aid locating items, but that more detailed information may only be retained based on the task requirements.

Studies such as Williams et al. (2005) and Tatler and Tatler (2013) have shown an influence of task on memory tested after the task is completed, although they do not involve direct interaction with the objects. Other studies have investigated how representations are influenced after task completion, when participants have been instructed to interact with the objects. As found in the studies into representations during action, spatial information appears to be the most affected by prior interaction, across several different manipulations. For example, Thomas, Davoli and Brockmole (2013) tested participants' memory for the environment and position of objects within it, by comparing their recall of positioning and layout after they had looked at the objects without touching them, or interacted with them as they learnt. Thomas et al. (2013) found that interacting with the objects led to participants recalling them as closer together or within smaller environmental boundaries than if they had not interacted. This was interpreted in terms of the action-specific view, that by interacting successfully with the objects, they were represented as closer in memory, to encourage future interactions.

Interestingly, recent suggestions have been made that influences on perception due to action-specific effects (see e.g., Witt, 2011) are in fact all based in memory, so that our ability to interact successfully with the world actually influences how we recall the items, rather than how we perceive them. Cooper, Sterling, Bacon and Bridgeman (2012) found that after participants had made successful throws of a marble into a target, they only judged the hole to be bigger when they were making the judgement without the visual stimulus of the hole being present. This suggests that the memory representations of size can be affected in a post-hoc manner, after an action has been completed successfully. Cooper et al. (2012) further suggest that other studies in the action specific perception literature may actually indicate an effect on memory representation. While it is not yet clear whether all such effects are located in memory Cooper et al. (2012) certainly provide evidence that the memory representations can be affected by the participants' ability.

Further evidence for an influence of active tasks on subsequent memory representations was shown by Plancher, Barra, Orriols and Piolino (2013), using a virtual reality task. This manipulated how much interaction occurred with the virtual environment, by placing participants in a driving simulator, where they were either a passive passenger; a passenger, but engaged in planning the route, or the driver, following a previously fixed route. Both the planning and the interaction conditions were associated with improvements in participants' spatial memories, but not their factual memories. Plancher et al. (2013) suggest that the participant's active control of the car aided the encoding of information which was connected to motion. In this case, the spatial information benefited from the movement they experienced, and so was better recalled at retrieval. This increased the specificity of the trace and so benefitted recall. Factual information was not recalled as well in the active condition, possibly because the required motor control for the task was an extra load on the attentional resources, impairing memory for this type of information. The spatial information was not affected in the same way due to being more directly and automatically encoded during the participants' movements through the environment. The use of a virtual reality task in Plancher et al.'s (2013) study enabled a more controlled look at how action could affect memory in a wider environment. However, this was not a fully immersive event, as participants were not present in the virtual world, but only viewing on a screen. Furthermore, there was no interaction with actual objects in the scenes. Tatler, Hirose, Finnegan et al. (2013) provided further evidence for action influencing memory in a real-world task where participants were eye-tracked as they either made cups of tea, or only watched first person perspective videos of tea being made. Memory for the objects involved indicated that active manipulation of the objects led to better memory for their spatial information, again suggesting a prioritisation of position information that persists beyond the end of the task.

The studies reviewed here show clearly that action continues to influence memory representations throughout all its stages. Action cannot be ignored when considering visual representations, as they are often created in the service of an actual task. Furthermore, it seems that findings from studies of how action affects on-line perception may apply when examining off-line representations. Although there has so far been less consideration of this area, it seems that it would be interesting to use adaptations of some of the action-perception paradigms in considering further how memory might be affected.

1.6 Perception Influencing Memory Representations for Action

Just as there is evidence for action-perception link influencing the representations we form, there is also work on whether our initial perception of an object can influence the action performed later, when the object itself is no longer visually present. This forms a smaller part of the literature on affordances, with fewer studies focusing on specific conditions under which these effects occur, and instead determining which affordance effects will persist in memory. It is still an important area to be considered, as it provides off-line evidence for the perception-influencing-action side of the perception-action link, just as the previous section shows how action can influence perception without visual stimuli physically present.

The main importance of this area is that it provides more information on how the actions associated with objects are stored. In line with the original proposals of Tucker and colleagues, and the TEC's common-coding principles, the action information is equivalent to the perceptual information, and so should be part of the object representation. As a result, even brief viewing will activate this information, and should allow affordance effects to persist after the object stimulus has been removed. Indeed, if this is not the case, and affordance effects are absent under memory conditions, then this may suggest that the action information is the result of purely on-line processing, arising from the immediate processing of the visual stimulus by areas of the brain responsible for detecting affordances (e.g., the dorsal stream, Goodale and Humphrey, 1998). Thus, it is important to the proposals of these theories that an influence of affordance be found when the visual stimulus is no longer available.

Some early evidence from Tucker and Ellis (2001) suggested that affordance effects may be restricted to on-line processing, when it showed that the strength of the affordance effect decayed over time after the visual object was removed. This finding implies that the effects were transient, and therefore could indicate a separation between visual representations and action information which would go against the idea of common representations containing both action and feature information.

However, later studies have shown that this is not the case. Tucker and Ellis (2004) used grip micro-affordances to examine how the absence of visual stimulus would affect the development of the effect. The standard affordance effect (faster execution of responses when the grip matched the size of the target object) was found both when the stimulus remained visible, and when it was presented for only a brief time period. The authors suggested that the difference between the 2004 and 2001 study came about because only in the later study were participants required to maintain a mental image of the stimulus, in order to select the right response. In their 2001 study, Tucker and Ellis used a Go/No-Go paradigm, where the nature of the task meant there was no need to maintain the object in memory. Thus, action associated effects could still arise and affect on-going action, despite the stimulus no longer being physically present.

Derbyshire, Ellis and Tucker (2006) further extended these findings by using different aspects of the affordance effect: grip compatibility, as in Tucker and Ellis' (2004) study, and the handle orientation of the target object. Again, it was found that grip compatibility effects would still emerge when responding to the mental image of an object, but the effects were absent in the handle orientation condition. To account for these findings, Derbyshire et al. (2006) suggested that this difference comes from the different natures of the two properties used. Grip compatibility relates to the size of the object, and so is an invariant object property which will always occur in that way, with that object (e.g., grapes will always be small, and compatible with precision grips). Handle orientation, on the other hand, will depend on the way the object has been placed for that particular occasion. Derbyshire et al. (2006) propose that properties such as size are ‘intrinsic’, and so stored in the representation of the object, while orientation is ‘extrinsic’, and depend on the situation, and the viewer’s position relative to the object. Thus, these properties must be taken directly from the environment. Both these studies provide evidence that the action information is stored along with the visual information relating to objects, in a shared representation. Affordances do not merely arise on-line, during the action execution, but are activated when we recall or visualise objects in order to carry out a task. Of course, it is very rare that we would ever carry out a real action on an object that we could not see, and Tucker and Ellis (2001) suggest that there will be other on-line effects throughout the course of a real action, but evidence for affordance effects persisting in memory indicates that they may be involved in the earlier stages of action planning.

Similar to the affordance effect, the Simon effect has been found to persist in memory. Studies by Tlauka and McKenna (1998) and Hommel (2002) found that the location of the stimulus objects still facilitated the production of responses when participants were retrieving the information from memory. In these studies, it is suggested that the spatial information is automatically integrated with the feature information, and the retrieval of the information necessary for the response leads to the reactivation of the spatial information alongside it. It is interesting to link these findings to higher-level memory studies involving real world tasks, where spatial information is also maintained in the memory. Under memory conditions, object location is one of the most important pieces of information to retain, to guide attention back to an object currently out of sight. Indeed, Hommel (2002) suggests that the maintenance of spatial information regarding objects allows actors to continue planning actions towards the items before they are fixated again. However, an interesting difference was observed: when conducted with the stimulus still present, many studies have shown that the Simon effect will decay over time (e.g., Eimer, Hommel and Prinz, 1995). In Hommel’s (2002) memory study, the effect instead strengthened over time. Other studies have confirmed this finding (e.g., Zhang and Johnson, 2004), which seems to indicate a different process involved in the Simon effect under memory conditions. It remains unclear whether memory-based Simon effects will behave differently to visual versions of the effect in other ways, but these studies do again show that action processes can be activated from recalled information in an objects representation.

1.7 Object Properties

The previous sections have considered the interactions between action and perception, and within these areas, the findings have been tested and demonstrated with the use of objects, both realistic, or created for the purpose of the study. Frequently, these effects have been shown not only on the object as a whole, but its individual properties. The definition of object properties has varied depending on its context, but for the purposes of this thesis, the properties of objects are considered to be their tangible features, which can be easily quantified. This is in contrast to the more Gibsonian ideas of affordances and properties, where aspects such as ‘sit-ability’ are proposed. Thus, object properties include aspects such as the colour, shape, size, position, orientation and weight.

This idea of object properties as separable aspects is important to many of the studies presented in the earlier sections, where there is a frequent assumption that the features are separate from each other, and so can be used as individual measures of perception (when action contexts are manipulated), or as manipulated variables themselves (as in affordance studies where the different properties attended are cues to the response). These assumptions show two aspects of object properties which need to be considered when they are used in these ways. First, are the individual object properties truly separate, and how far does this separation go? And secondly, if they are independent, are they equivalent? For both these considerations, the studies presented above tend to make the assumption that object properties are both largely independent, and non-equivalent. In this section, the evidence for these views is considered.

How independent properties are has been explored most thoroughly in the memory literature. Studies have been conducted to determine whether object information is stored in memory as object-based representations, where memory capacity is limited by the number of complete objects that are stored; or feature-based representations, where it is individual object properties that limit the memory capacity.

Kahneman, Treisman and Gibbs (1992) first proposed the idea of object files, in which separate object properties were bound into one file to represent a particular object. This idea was highly influential; the event files of the TEC (Hommel et al., 2001) are similar to object files, with the addition of action information. Irwin (e.g., 1992; Irwin and Andrews, 1996) proposed that the object file was the unit of storage in visual short-term memory, and that it was the number of objects that limited memory capacity, rather than the number of features within each object. Further research supported this view e.g., Luck and Vogel (1997) found that visual memory was limited to 3-4 items, but that increasing the number of relevant features that defined these objects did not reduce memory performance. Based on these findings, it would appear that objects are stored in memory as integrated units.

However, Wheeler and Treisman (2002) found evidence to support the alternative view of feature-based memory. In their study, they failed to replicate the findings of Luck and Vogel (1997), and instead found that memory performance was limited by the number of features, not objects. It was suggested that it was the binding information that was vulnerable to decay, and that different paradigms resulted in findings that could either support or contradict the idea of object-based representations. Thus, studies in which there was less competition for attentional resources meant that binding between object features could be maintained, providing evidence for object-based representations, as shown by Luck and Vogel (1997). In studies where there was more attentional competition, the binding mechanism decayed, and so provided evidence that object memory was feature-based. Wheeler and Treisman (2002) suggested that object features were stored in dimension-specific caches, within which there is a limited capacity (so that a large range of colour values might fill the colour feature store), but that there is no competition between these stores (i.e. many colour values would not affect the capacity in the shape feature store). Binding occurs by a separate mechanism, and the integration of the features is particularly vulnerable to interference from distractors.

There are also several studies showing that not all object information is necessarily encoded e.g., Xu (2002a), found participants were worse at recalling features if they occurred on the same object, but on different parts of the object. Fougnie and Alvarez (2011) found that participants forgot features of objects independently of other features of the same object. For example, if participants failed to recall the colour of an object, this did not predict that they would fail to recall the objects' orientation. However, this was only so for those object properties that were separable, or supported by different neural populations. Thus, while the properties of colour and orientation were independent, height and width, which draw on overlapping groups of neurons, did not fail in memory independently of one another.

In contrast to the fairly strong evidence for very independent properties, there are other studies which challenge the idea of pure feature-based representations, as this approach is not able to account for all memory findings either. In particular, there is strong evidence that it is easier for participants to recall multiple features if they are grouped into a single object, rather than across several different objects (e.g., Olson and Jiang, 2002; Xu, 2002b). Based on these and other findings, Brady, Conkle and Alvarez (2011) proposed a model of short-term memory which incorporated both object and feature based characteristics in the representations. In this, the unit of visual memory is a hierarchical structured feature bundle. At the lowest level, individual object properties are maintained by independent neural populations (although some properties are integral, and so share neural groups), while at the top level, the features are incorporated into the object representation. Memory for the individual properties can fail independently, but there is still an advantage for recalling features as part of a single object, as features that are part of different objects will require another feature bundle to be created, which increases the demands on memory, and so leads to the encoding cost. Support for this proposal has been shown by Fougnie, Cormiea and Alvarez (2013), who found evidence for both a same object benefit (participants could more easily recall 10 features in 5 objects than the same 10 features across 10 objects), and independent recall of the features (recall performance for one feature could not predict recall for another feature of the same object). Thus, it seems that object properties are maintained in memory with a level of independence. These findings therefore match with suggestions from other related areas, in which there is similar evidence for object properties being differentially affected by the situation in which they are searched for, or encoded.

While most of the earlier studies of memory for object properties have concentrated on sparse memory displays of simple coloured shapes. Other studies have shown that this independence is present in the representations we form of real-world objects and scenes, despite the higher levels of familiarity and stored knowledge associated with such items compared to simpler displays. Tatler et al. (2003) showed that when gathering information about a scene, the gist and spatial information is extracted quickly, while information about more specific object properties are acquired over several further seconds. Furthermore, this acquisition time varied across the properties, with colour assimilation apparently completed after 4 seconds, while shape and presence information was not entirely complete by 10 seconds. Tatler et al. (2005) added more detail to these findings by showing that the individual properties had different time scales not only for acquisition but also for their stability. While some properties were accumulated over multiple fixations to the object, others could be acquired without a direct fixation on the object. Similarly, some properties were maintained stably over time when the scene was recalled, but others decayed rapidly over the course of several seconds. Brady, Konkle, Alvarez and Oliva (2013) examined the independence of real-world object properties across longer time scales. In their studies, they found, once again that certain properties were forgotten more rapidly than others. At shorter delays, properties were more likely to be recalled or forgotten together, but this decreased at the longer delay periods, suggesting that the initial presentation of all the features in one object aids recall at first, but that the properties are essentially independent, and so can be recalled or forgotten separately from one another. Thus, the findings originally shown in more lab-based paradigms with less realistic stimuli are still found when real-world objects and more complex scenes are used. While there are advantages to memory if properties are presented within the same object, the individual properties have their own time courses.

The second assumption of many of the previous studies is that the individual properties are not equivalent. Studies of action influencing perception have demonstrated how particular properties can be facilitated (or not) by a prepared action (e.g., Fagioli et al., 2007). On the other side of the perception-action loop, attention to different property cues can influence whether the affordance effect is present in the action response (e.g., Tipper et al., 2006).These findings all show that object properties are not identical in the way they are processed, although this variation could be due either to the nature of the properties themselves, or the current situations of the task.

A division that suggests properties are non-equivalent was proposed by Glover (2004), in the context of the planning-control model. For this, properties are divided into spatial and non-spatial groups. Spatial properties include the size, shape and orientation of the object, while the non-spatial properties include the object's weight. During the planning stage of an action, both property types are relevant, to allow for processes such as the selection of a target, and the grip type necessary to deal with it. During the control stage, when the action is executed, only information relating to the spatial properties is required. Thus, spatial properties here are those that can be determined visually, and are thus available during the execution of the task. Information about non-spatial properties comes more from stored information and previous experience. Derbyshire et al. (2006) drew on a similar idea in considering intrinsic vs. extrinsic object properties, considered in the previous section. According to their findings, intrinsic properties (e.g., shape) can be maintained in the representation, as they will not change, but extrinsic properties (e.g., handle orientation) do not have an unchanging value, and so are not maintained as a part of the representation.

Jeannerod (1994; 1997) suggested a more flexible division of properties based on whether they are typically required for either pragmatic or semantic representations. Pragmatic representations are constructed when interacting with the objects. In particular, the task relevance of the object is important, and how this will affect the way in which the actor interacts with and uses the object. Semantic representations are used to create a higher order representation of the scene, in which the different properties are bound together to create a meaningful entity overall. Importantly, Jeannerod (1997) further states that most properties are not only used in constructing one representation; rather, they are both semantically and pragmatically relevant, depending on the situation. Very few properties are purely only in one category: Jeannerod (1997) suggests that colour is a purely semantic property, while weight is a purely pragmatic property, but all others may exist on a continuum between the extremes. Their placement on this scale may depend on the particular task or situation, and the relevance of the property to that situation.

In line with Jeannerod's proposal, in the context of the areas previously discussed, the importance of object properties has largely been in terms of their task relevance. Indeed, the weighting process suggested in the TEC (Hommel et al., 2001) operates in terms of how relevant a feature is to the current event, and there are several studies which provide evidence for this (e.g., Bekkering and Neggers, 2002; Fagioli et al., 2007). Bekkering and Neggers (2002) study is particularly relevant in terms of the property types. While search for orientation defined targets is speeded by grasping, colour defined targets do not receive this bias. As a more strongly visual property, colour is not relevant to the task of grasping, and is not benefitted by the preparation of the gesture. Similarly, in studies of object affordances, Tipper et al. (2006) showed that attending to colour did not prime actions in the same way that attention to shape did (although these findings may be confounded with the type of gesture employed when responding, as suggested by Bub and Masson, 2006; 2010). Also, in memory studies it has been shown that it is the relevant object properties that are best recalled both during and after the task (e.g., Triesch et al., 2003; Tatler et al., 2013). From these studies, it is clear that object properties are not equal. Even without a specific task instruction, they are accumulated and held over different time periods, and stored independently of one another. When task constraints are introduced, there is evidence to suggest that this will also affect how they are processed and stored. Object properties therefore provide a way of measuring the influence of action and perception on the object representations we construct, with relevant properties fixated or maintained while irrelevant ones are ignored, or decay. Within this thesis, object properties will be used to both manipulate and measure the influence of action on memory representations.

1.8 Current research

The research presented in this thesis further investigates the interaction between perception and action, following the grounded cognition proposal that the two processes are equivalent, and closely linked, each able to influence the other via intentional or attentional weighting. In particular, we seek to address the areas in which there is little investigation, namely determining the influence of both action and perception on the resulting memory representations, or actions performed on the basis of these representations.

The TEC is used as a framework to design and interpret these studies, due to its specific focus on how both perception and action can interact. The nature of the TEC is that it is a cognitive model, rather than an ecological one, and therefore incorporates the use of internal representations. The situational weighting, which is a central component of the theory, is suggested to arise from the stored memories of previous encounters with objects in particular task settings (Hommel et al., 2001). Thus, it is consistent with the model that weighting of memory representations should be possible, and measurable. Such weighting, particularly in situations where there is a potential for action, should occur in order to prepare the observer for possible upcoming actions, despite the fact the objects are currently not in view. If no such off-line biases are present, then it may suggest that such weighting of the representations is only present on-line, and that memory representations are more in line with the purpose-neutral construction proposed by Wilson (2002).

In addressing this problem, we have taken a slightly different approach for the two sides of the action-perception loop, based on the information already established by previous studies. For the perception-influencing-action affordance effects, there is research to show that the effect can be found when participants must recall the presented object in order to make their response. However, there is no further investigation into the boundary conditions that may influence this effect; that is, the context which might affect the situational weighting of the constructed representation. This, then, is our main focus in investigating this side of the loop.

In contrast, for the investigations of action-influencing-perception and memory, there is a little more work, found in studies which have examined the influence of active tasks on the resulting memory. However, there is almost no work on how the simple preparation of action can affect the representation, in contrast to the large body of work showing how action preparation can affect perception in visual search tasks, for example. Again, finding evidence for action preparation influencing the construction of the representation would be important for establishing that situational weighting affects off-line event codes, but it would also provide insight into the way in which the realism of the situation might affect construction. That is, will the presence of action preparation lead to an influence on memory similar to that found when participants are able to directly interact with the objects, or will the absence of this direct interaction result in weaker situational weighting of the resulting representation? Investigating this particular aspect of action preparation on perception therefore forms the main focus of the studies conducted to investigate this side of the loop.

The structure of the present thesis is therefore to concentrate on the two sides of the action-perception loop in turn (although based on the findings and the natures of the experiments, rather more studies are conducted to investigate the influence of action on perception and memory than the affordance studies). In order to address these issues, the studies incorporate the idea that object properties may be processed and encoded differently from one another. As outlined in the final section of the literature review above, there is much evidence to suggest that object properties are (relatively) independent of one another, and may be qualitatively different as well, in terms of their relevance to different aspects of a task. Object properties are also central in earlier research, acting as attentional cues, or perceptual measures in both affordance and search studies. Furthermore, much of the research which has established them as separately stored aspects of objects has been conducted in the context of memory. Thus, there is good reason to expect that, if memories or actions are affected by the task context, the object properties will be able to reflect this influence. In the following studies, therefore, object properties are used both as cues to action, and measures of actions influence. The object properties selected to be used are those which are judged to be either particularly related to either action or particularly unrelated to action (thus only primarily relevant to perception).

In the majority of the studies presented, we also employ eye-tracking as a measure of on-line perceptual behaviour, although we are largely interested in the influences on memory. Eye movement data is vital, however: given the link between fixations and memory, it is important to know where participants are looking during a task. Not only does this allow for us to determine if the manipulations are influencing the initial perception of a scene, it also allows for the removal of non-fixated objects from the subsequent analyses.

Figure 1.6 presents a diagram of the TEC, adapted to incorporate the goals of the thesis. The diagram shows that both action and perception are able to influence the formation of the memory representation, and so may be affected by the representation formed (the specific event file for the task). That is, the preparation of an action may drive attention to certain relevant items in a scene, while the focus of attention on particular object features may prime the performance of the actions required to act with an object. The manipulations of action and perception are predicted to change the way a scene or environment is viewed (measured by the recording of eye-movements) and represented (measured by tests of recall). Thus, the objects and their features are predicted to be prioritised differently within the representations formed, due to the influence of the present task or situation.

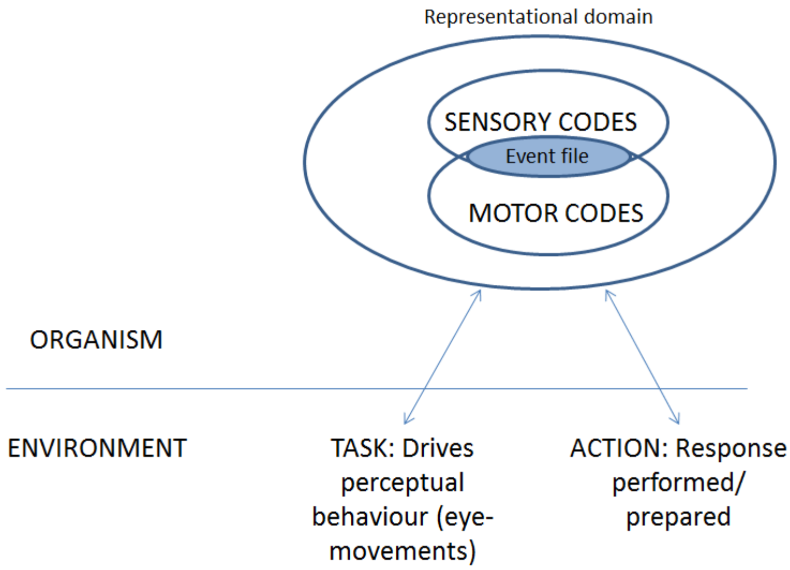


Figure 1.6 Diagram of the TEC's proposals influenced by the manipulations of perception and action in the current thesis

The initial study of the current thesis examines the influence of perception on action in memory conditions, in the context of the affordance effect. Using different property cues and response gestures, this study aims to determine if boundary conditions will influence off-line affordances in a similar pattern to that shown by on-line affordance studies. Chapters 3-5 all use the same paradigm, focusing on the influence of action preparation on the perception and memory for a scene. As the studies focused on memory, it was thought important to address both the input and output processes of memory, encoding and retrieval, as it was likely that the presentation of an action posture at either of these stages could lead to different effects on the recall performance. Thus, Chapter 3 presents a study in which action postures are maintained at encoding, while in Chapter 4, action postures are presented at retrieval. In Chapter 5, action postures are maintained throughout both stages.

Given our interest in how the realism of the situation might affect weighting in representations, for the final studies of this thesis, the veracity of the experimental situations were increased, in order to determine if this would influence the outcomes. Thus, Chapters 6 and 7 both present studies located in a real-world environment. In Chapter 6, the study is a replication of that in Chapter 3, but with the participants and objects sharing the same environment. In Chapter 7, an everyday real-world task is used, in which participants directly interacted with the items presented, in order to determine how acting with objects of differing relevance could influence both perception and memory.

The main goal of this thesis, therefore, is to establish further how the bi-directional link between perception and action may operate under off-line conditions. According to various theories of grounded cognition, perception and cognition have developed to serve action. There is strong evidence to show this is the case when participants are directly observing the objects and items involved in a task. However, it is still necessary to determine whether memory representations will also be influenced by our goals and intentions, and similarly help to serve our actions.

Chapter Two- The influence of the potential for action via attention to action relevant properties

2.1 General Introduction

The link between perception and action appears bi-directional with each process able to influence the other and bias it in favour of a potential action, as expressed by the TEC (Hommel et al., 2001). Evidence for the perception-action side of the loop is shown by the affordance effect (and its variations), demonstrating that the perception of an object can lead to the facilitation of the associated actions. While initial studies of this phenomenon suggested that this action activation was automatic, more recent findings have suggested there are particular boundary conditions to the effect: conditions which must be present in the experiment in order to allow the affordance effect to emerge. While not an exhaustive list, earlier studies have suggested that conditions such as the participant's focus of attention (e.g., Tipper et al., 2006), the type of response they make, (e.g., Bub and Masson, 2010) and the general task context (e.g., Yang and Beilock, 2011) may all be factors in whether the expected effects emerge.

However, thus far all these effects have been demonstrated in on-line versions of the study, where the object remains visible throughout the performance of the task. Beyond the initial studies which showed that it was possible to obtain affordance effects when recalling the object images, investigations of how boundary conditions might affect off-line versions of the affordance effect have been rather lacking. Yet the fact that affordance effects will emerge when the visual stimulus has been removed (see, for example, Derbyshire et al., 2006) is of importance to the more grounded views of cognition, since it indicates that the action information is an integral part of the object representation, rather than being generated during on-line perception only. Thus, if the representation contains all the necessary information, it seems likely that similar boundary conditions will apply when the effects are shown off-line, and it is important to investigate this, in order to further demonstrate the inclusion of action information into the object representation.

Two boundary conditions are particularly important to the areas investigated in this thesis: the focus of attention (i.e. which object property participants are instructed to attend), and the response type (i.e. whether it is a realistic action, or a button press). Object properties have been shown to be of particular importance in constructing a representation biased in favour of an action, for studies examining both sides of the action-perception link. In studies of the action-influencing-perception side of the loop, object properties (and their relevance to action) are used as measures of the influence of the action, (i.e. by demonstrating that the relevant object features are prioritised in tasks, allowing for faster detection times in search tasks, e.g., Fagioli et al., 2007) but in affordance studies, they are used to demonstrate the reverse effect, by influencing the production of the action. Earlier studies by Tipper et al. (2006) and Loach, Frischen, Bruce and Tsotsos (2008) have shown that when attention is focused on an action relevant property (shape or texture) then the affordance effect will emerge: that is, the actions made towards the target object will be facilitated in terms of speed of production or response accuracy. The effect is absent when attention is on a more visually relevant property such as colour. Attention to a property that in some way informs the potential actions is enough to activate the action response, and so prime participants for acting with this object. However, other studies are less clear as to how important the object properties are, particularly when used in conjunction with the second of the two factors: the nature of the response.

Typically, responses to the objects in affordance gestures are simple, abstract button presses, (e.g., Ellis and Tucker, 2001; Symes et al., 2005) making them rather removed from the natural action that would be performed on a particular object when used in the real world. Bub and Masson (2006; 2010) examined the compatibility effect, in which participants produced a pantomime gesture in response to stimuli, and found that this influenced the emergence of the effect. Gestures compatible with the object were facilitated; those that were incompatible were not, indicating that perception of an object does not lead to a general facilitation of all actions, but can be specific to the actions that are known to be appropriate for the use of the stimulus object. Importantly, the property cue used (always colour) seemed to be completely irrelevant to the emergence of the effect, in contrast to Tipper et al.’s finding that attending colour information is not enough to facilitate action. This may suggest that boundary conditions are in some way hierarchical, and the response gesture is a more powerful modifier than that of the property cue, but this remains to be confirmed. Indeed, studies using more realistic response gestures have suggested that property cue is irrelevant. Bub and Masson (2010) compared the emergence of affordance effects cued by the object colour for tasks where the response was a button press, and tasks where participants produced compatible/incompatible handle grasping gesture. While affordances were not seen for colour cued button responses, replicating Tipper et al.

(2006), they emerged strongly for colour-cued gesture responses, leading to a suggestion that the use of a compatible gesture over-rode the participant's initial focus on a non-action-relevant property. However, this study only demonstrates this using the colour cue, therefore leaving unanswered the question of how the effect might emerge if the action appropriate response is cued by an action relevant property, such as shape. If the realism of the response does supersede the property cue, then the affordance effect with such responses should be the same, regardless of the cue used. The use of an action-relevant cue might interact with the realistic response gesture, changing the affordance effect that is seen.

There are therefore two main aspects which this first study aims to explore. Firstly, the current studies aim to compare and contrast the emergence of affordance effects for visible and remembered objects directly. Given that the previous off-line affordance studies have shown that action information is indeed part of the representation, it is likely that the same patterns of behaviour should result from the use of the same cues and responses as has been found for online affordance effects. However, at least one affordance effect- the Simon effect- has been found to act differently under visual and memory conditions (see e.g., Zhang and Johnson, 2004), so that it is possible that different patterns of response will be seen for the two conditions.

Secondly, and more specifically, these studies will investigate the way in which the initial property cue and the subsequent response may interact: that is, how attention to an object property, and intention to produce an action might together influence how the effect emerges. According to the TEC (Hommel et al., 2001), both these processes are means of weighting an object representation in order to prepare it for a task. What is less clear from the theory is how intention (to act) and attention (to object properties) might work together, under conditions where responses are either less specific (a button press) or more specific (a gesture) to the use of an object.

One possibility is that the goal of acting with the object, shown by asking participants to produce a more specific action, will always over-ride the attentional focus of the participant. Therefore, when the response is cued by either colour or shape, whether or not the effect emerges should be the same, as only the goal intention (the action produced as a response) is important for the emergence of the effect. Alternatively, the combination of focus on an action-relevant property and a goal towards acting with the object may lead to an interaction, so that the combination of both leads to a faster response than when a colour cue and an intention to act are combined.

Experiment 1 uses a paradigm similar to that used by Derbyshire et al. (2006) in their investigation of affordances in memory, but the cues used are the action- and visually-relevant properties of shape and colour, as in Tipper et al.'s (2006) study. In order to compare on-line and off-line versions of the affordance effects, two versions of the study were created. One, (the memory version) followed Derbyshire et al.'s (2006) original version by presenting the visual stimuli briefly, before removing them from sight, requiring the participants to make their response from memory. The on-line version of the paradigm simply kept the objects visible throughout the trial.

For both memory and visual versions of the paradigm, there were two methods by which participants could respond, allowing us to compare abstract button press responses, and object-specific response gestures, carried out by pantomiming the use of an object (as in Bub and Masson's 2006 compatibility effect study). These pantomime gestures are described in more detail in the Methods section, but were selected to be either compatible or incompatible with the use of the object stimuli.

For the simple button press response, the affordance measure needed to be changed. In earlier studies (Tipper et al., 2006; Derbyshire et al., 2006), the effect was based on the correspondence between handle alignment and the responding hand. However, when Derbyshire et al. (2006) used this affordance effect under memory conditions, it was found that handle alignment effects were not reliably obtained. Given that a key aim of the current study is to investigate affordance effects and boundary conditions in memory, the use of an affordance effect which might not be seen under this condition was considered unwise. Instead, the Simon effect (e.g., Simon, 1969) was used as the affordance effect, as this can be responded to with the more abstract button press response and, most importantly for this study, has been shown to persist in memory (e.g., Hommel, 2002), thus allowing any effects of cue to be seen. Thus, Experiment 1 consists of four groups: participants responding to visual stimuli with a button press; participants responding to visual stimuli with a pantomime gesture; participants responding from memory with a button press, and participants responding from memory with a pantomime gesture.

Four objects were displayed on the screen per trial. Typically, earlier studies of affordance effects have used simpler scenes, with either single objects, or two at most when testing for the location-based Simon effect. While these scenes offer interesting insights into the tight link between perception and action, it is less clear how the effects generalise across more complex settings. In a real world environment, there are often several objects in view, from which the target must be selected. While the presentation of objects in the current study remains removed from the real world, increasing the number of objects makes the display scene more complex, and so allows for examination of these effects across a broader range of settings. It is necessary to establish whether the effects are robust enough to be maintained when the scene increases in complexity. Otherwise, while the effects remain interesting, they may be less informative for, and representative of, the link between action and perception in more real-world settings.

It is hypothesised that when participants are cued to respond with a button press to objects by focusing on an action relevant property such as shape, this will prime them for acting with the object. As a result, the responses made that match this preparation for action (i.e. that are congruent with using the object, due to the response location matching the target object location) will be produced faster than those that do not match (i.e. when response and stimulus are located at opposite sides of the screen). These effects will not be present for responses cued by the more visually-relevant cue of colour (Tipper et al., 2006). Such effects are expected to be seen in both on-line and off-line versions of the study, following previous work showing that they persist after the visible stimulus is removed (e.g., Hommel, 2002; Derbyshire et al., 2006). In contrast to the Simon effect, when participants are cued to respond using a pantomime gesture that is compatible with the actual use of the object, then the affordance effect should be observed for both property cues, as shown by Bub and Masson (2010). However, it is possible that while the compatibility effect will be present for both property cues, it will be stronger for the shape-cued gestures, because in that situation, attention to a cue and intention to act are in agreement, with both focused on aspects relevant to acting with the object (a shape cue and a compatible intention). Again, these effects will be investigated for both visual and memory versions of the task. There are no previous studies that consider the compatibility effects under memory, and so the present study also allows us to examine if object representations constructed under fairly brief viewing conditions will continue to facilitate the production of specific gestures, as shown in on-line studies of the effect.

The findings from the present study will allow us to consider more closely the idea of perception influencing action, by determining what factors, both attentional and intentional, are necessary for the influence to emerge. Furthermore, if similar effects are found for responses performed under memory conditions, then this will show that the representation of an object can be primed by a task and maintained over time, even after the removal of the visual object.

2.2 Experiments 1a and 1b: Method

2.2.1 Participants

Participants were 32 University of Dundee students (5 males), aged 18-25. Three participants were left-handed (measured by self-report), and with normal or corrected-to-normal vision. Half of this group participated in the Simon effect version of the study (Experiment 1a), and half in the compatibility effect version (Experiment 1b). Within each group of 16, half participated in the visual version of the study, and half in the memory version. Participants were recruited using the on-line SONA recruitment system, and each received course credits upon completion of the study.

2.2.2 Apparatus and Materials

2.2.2.1 Stimuli. The stimulus set was composed of 32 colour photographs of individual mugs. Four mug shapes were used, (named tall, round, square and curved). Figure 2.1 shows grayscale examples of these four shapes. All mugs were photographed against the same uniform background in one orientation. Copies of each photo were then reversed in Photoshop, so that a mirror image of each shape was created, producing versions that were compatible with both left-handed and right-handed handle grasps. Coloured filters were applied to copies of each shape variation, so that each shape was represented in each of four colours (red, green, blue and yellow). In total, 8 versions of each mug shape were thus created.

2.2.2.2. Apparatus. Stimulus presentation and response collection was controlled by scripts written in MatLab, using the PsychToolBox (Brainard, 1997; Pelli,

1997) extension. Participants viewed the stimuli on a monitor (pixel dimensions 1920 x 1200). The images were displayed at a size of 400x400 pixels.

Figure 2.1. Examples of stimuli shapes used (from left to right, shapes defined as tall, round, square and curved)

2.2.3 Procedure

Participants were first given an association to learn between a cue (colour/shape) and a response. In Experiment 1a the response was to press a particular key. In Experiment 1b the response was to perform a particular gesture. These two types of response allowed us to consider two affordance effects: the Simon effect (Experiment 1a) and the compatibility effect (Experiment 1b).

In Experiment 1a, participants made their responses using the keyboard of the computer presenting the stimuli, The response keys were the 'A' and 'Z' keys (as they were the leftmost keys on a standard keyboard), and the 'apostrophe' and 'forward slash' keys (as the rightmost keys on a standard keyboard). All response keys were marked with stickers, so that the irrelevant identity of the key could not be seen by the participants. Orange stickers were used, as this colour did not appear as a stimulus option in the experiment.

In Experiment 1b, participants made their responses by pantomiming a gesture that was compatible or incompatible with the use of the mugs presented. The incompatible gestures were 'pressing a button on a calculator' and 'squeezing the trigger on a spray gun'; while compatible gestures were 'lifting a mug by the handle' and 'lifting a mug by the body'. Participants used the 'H' key (chosen due to its central location, also labelled with a sticker) after they had performed the gesture in order to end each trial and move to the next one.

In both experiments participants were encouraged to spend a small amount of time rehearsing their responses before the experiment began, and also practised producing the responses in 10 practice trials at the beginning of each block.

In both Experiments 1a and 1b participants were divided between a visual condition and memory condition. In all versions, participants began each trial holding down the space bar with their dominant hand. They were presented with a screen displaying a central fixation point. This was presented for 900 ms, before being replaced by a screen displaying a set of four mugs. In the visual condition, this screen was presented for 1500 ms before the central point was replaced with a letter (A, B, C or D). This indicated in which quadrant of the screen the target mug was located (A= Top left, B= Top right, C= Bottom left, D= Bottom right). Participants then released the space bar to make their response (pressing the correct response button in Experiment 1a or produce the correct gesture for the cue in Experiment 1b).
In the memory condition, the scene disappeared after the 1500 ms period, and the screen remained blank for a further 700 ms. After this point, the letter cue appeared in the centre of the screen, prompting participants to make a response to the recalled object that had occupied that space, as described above. See Figure 2.2 for the events sequence in the visual and memory conditions.

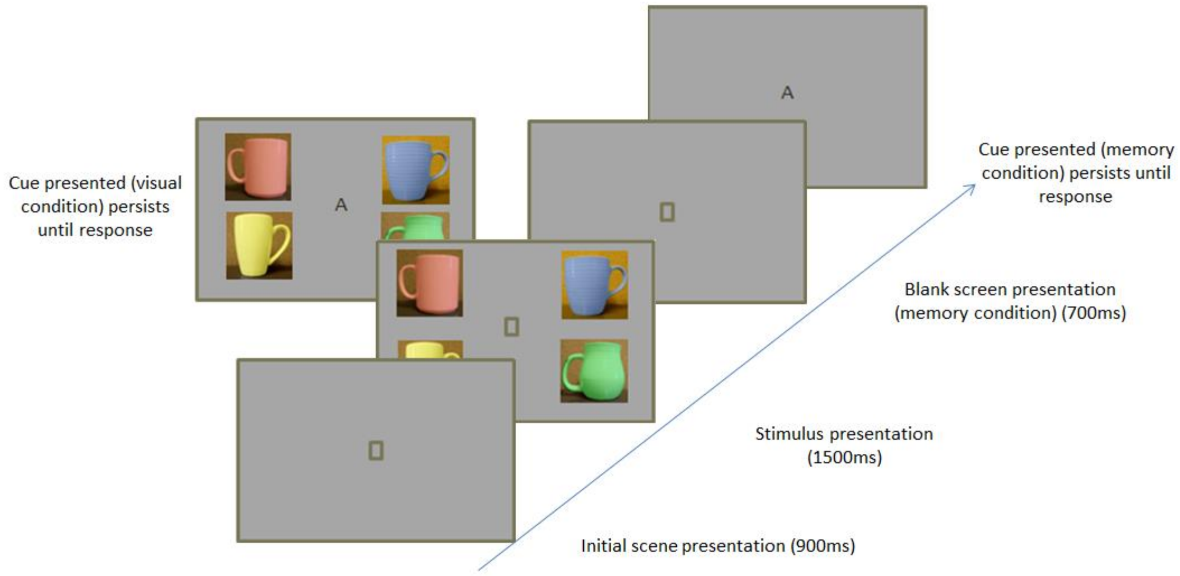


Figure 2.2. Diagram of stimulus display and time course for Experiment 1 (Visual and Memory) conditions

After the response was made, in all conditions, the screen was blanked, and a message was displayed to the participant to press the space bar when they were ready for the next trial. After they did this, another message was displayed, reminding them to press and hold the space bar to start the next trial.

If participants released the space bar too early (before the presentation of the letter cue), the trial was aborted, and a message was displayed to remind participants to hold the space bar down. They then pressed the space bar to continue onto the next trial. In order that no trials were lost from this, the aborted trial was added to the end of the block, so that all participants saw the full 80 trials per block. Errors caused by pressing the incorrect button were recorded.

The experiment blocks contained 80 trials, and participants performed two of these blocks, responding to shape cues in one block, and colour cues in the other. The association participants learnt between the response and colour/shape cue was counterbalanced using a Latin Square design, and the order in which the cue blocks were presented was also counterbalanced, so that half the participants began by responding to colour cues, and half began by responding to shape cues. Thus, participants performed 160 trials in total, plus 10 practice trials at the beginning of each block.

Stimulus photographs were presented in sets of four, such that each shape, colour and handle position appeared as part of the target object at each of the four locations on the screen across the trials. The remaining three areas were filled with distracters, which were selected so that they showed the remaining colours and shapes not shown by the target, preventing duplicates of the target's properties appearing in the same screen display. Presentation order of the targets was randomised. Half the trials in each block were congruent, so that either the response and target side matched (Simon effect) or the gesture was congruent with the use of a mug (compatibility effect). In incongruent trials, the response and target side were opposites, or the gesture was incompatible.

2.2.4 Design

The experiment manipulated two independent variables: the property of the object which cued participants to respond (colour or shape), and the congruency between the response and the object. In Experiment 1a (the Simon effect), congruency referred to whether the position of the target mug on the left or right of the screen matched the side of the keyboard on which the required response was made. For Experiment 1b (the compatibility effect) congruency referred to whether or not the type of gesture required matched an action that could be involved in the use of the mug.

The dependent measure of the study was the response time to initiate a response to the target stimulus. That is, the time from the presentation of the cue letter to the participant releasing the space bar. We used this measure of RT for three reasons. First, execution time for different actions cannot easily be equated in Experiment 1b and as such may confound response time measures once the response is under way. Second, this RT measure can allow comparisons between Experiments 1a and 1b despite the difference in response types. Third, we are interested in how accessing visual or remembered information influenced the preparation to act and as such the time to initiate the response is a suitable index of this.

2.3 Results

2.3.1 Experiment 1a: Simon effect under visual and memory conditions

Experiment 1a examined the emergence of the Simon effect in response to two property cues (colour and shape).

Error rates within the conditions are shown in Table 2.1 and were examined using a 2 (cued property: colour, shape) x 2 (response congruency: congruent, incongruent) within-subjects ANOVA. Overall, error rates were low, although there was a significantly higher rate of error in the responses to colour cues, $F(1,7)=14.91$, $p=.006$, $\eta_p^2=.68$. No other effects were significant.

Table 2.1

Percentage of trials on which participants responded incorrectly to visible objects when cued by shape or colour.

	Congruency	
Cue	**Congruent**	**Incongruent**
Colour	1.09	1.87
Shape	0.312	0.468

After removing the incorrect trials, a similar 2 x 2 within-subjects ANOVA was conducted on the measure of response initiation times, and revealed a main effect of cued property, $F(1,7)= 5.91$, $p=.045$, $\eta_p^2=.46$, such that responses were faster to the colour cued target than a target cued by shape. However, no significant effect of response congruency was found ($F<1$), so that responses made on the same side as the target's position were made no faster than those on the opposite side. There was no significant interaction between property and congruency ($F<1$).

Figure 2.3 shows the mean response initiation times for participants when cued by shape or colour.

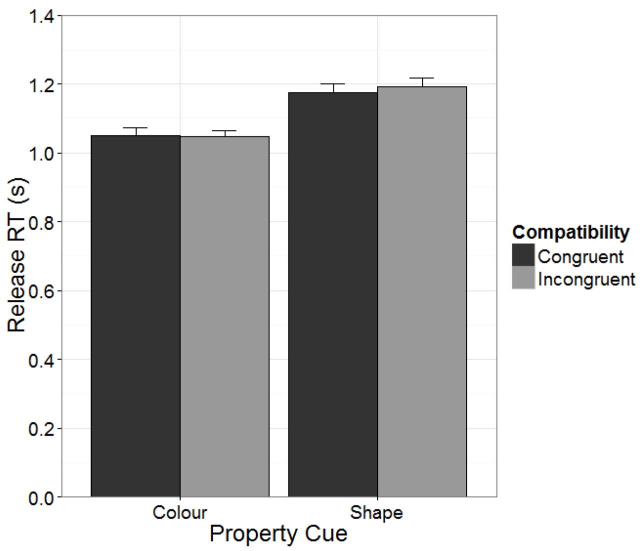


Figure 2.3. Mean Release RT for the Simon effect under visual conditions

The emergence of the Simon effect was then examined when images were removed before the response was cued (i.e. in the offline condition). In this condition, therefore, the response required the participant to access stored information about the previously seen objects.

Error rates were examined for the memory condition using a 2 x 2 within-subjects ANOVA. The error rate was significantly higher for the participants in the shape cued condition, $F(1,7)=14.06$, $p=.007$, $\eta_p^2=.66$, although there was no difference between incongruent and congruent responses. These error rates are presented in Table 2.2.

Table 2.2.

Percentage of trials on which participants responded incorrectly to remembered objects when cued by shape or colour.

	Congruency	
Cue	**Congruent**	**Incongruent**
Colour	2.34	0.781
Shape	14.21	15.15

For time to initiate the response, a 2 x 2 within-subjects ANOVA revealed a main effect of cued property, $F(1, 7)=12.25$, $p=.010$, $\eta_p^2=.64$, with faster response initiation times to colour cues than to shape cues. There was no main effect of congruency, $F(1, 7)=2.79$, $p=.14$, $\eta_p^2=.29$. However, there was a significant interaction between property and congruency, $F(1, 7)=13.27$, $p=.008$, $\eta_p^2=.66$, (Figure 2.4).

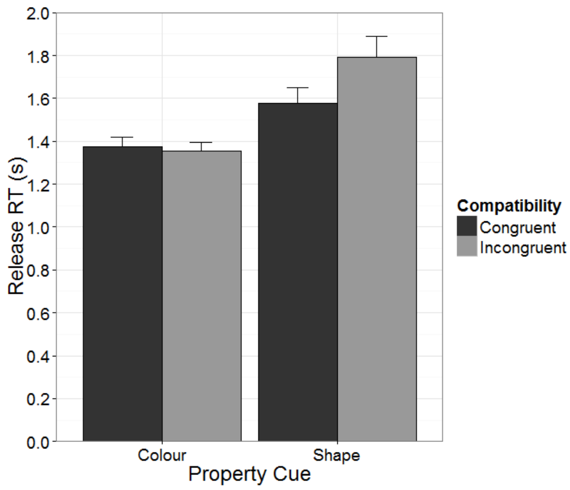


Figure 2.4. Mean Release RT for the Simon effect under memory conditions

As a strong main effect of property was observed, the interaction was broken down by examining congruency effects in response to each property cue separately, using paired-sample t-tests. For responses to colour cues, there was found to be no significant effect of congruency, *t*(7)=.47, p=.65. However, for responses to shape it was found that responses made on the side congruent to the position of the target object were faster than those made to objects positioned incongruently with respect to the response position, *t*(7)=-2.65, p=.03.

2.3.2 Experiment 1b: Compatibility effects under visual and memory conditions

Experiment 1b examined the emergence of the compatibility effect for the two different property cues, under either visual or memory conditions.

Error rates when performing gestures in response to visible targets are shown in Table 2.3. Overall, error rates were higher than those for Experiment 1a, indicating that the use of gestures was harder for participants, however these errors do not show strong biases towards a particular condition. No significant effects or interactions were found.

Table 2.3.

Percentage of trials on which participants responded to visible objects with an incorrect gesture when cued by shape or colour.

	Congruency	
Cue	**Compatible**	**Incompatible**
Colour	2.34	0.938
Shape	1.09	0.625

For response initiation times, a 2 (cued property: colour, shape) x 2 (response congruency: congruent, incongruent) within-subjects ANOVA revealed that responses to colour cues were initiated significantly faster than those to shape cues, $F(1,7)=16.30$, $p=.005$, $\eta_p^2=.70$. There was no main effect of gesture compatibility, ($F<1$), but there was a marginally significant interaction between gesture compatibility and property cue, $F(1,7)=4.14, p=.081$, $\eta_p^2=.37$.

Due to the strong main effect of property and our *a priori* interest in whether property cues differentially influence the emergence of any compatibility effect, the marginally significant interaction was explored by examining the responses to each property separately, using paired sample t-tests. For responses in this condition cued by colour, there was a marginally significant effect of compatibility, $t(7)=2.05$, $p=.080$. This was such that incompatible responses were produced faster than compatible responses when cued by the colour of the object. There was no significant main effect for responses cued by shape, $t(7)=-1.62$, $p=.15$. Thus, there was no difference between response times when producing compatible or incompatible gestures for the more action relevant property cue.

Comparing incongruent and congruent responses between the two different property cues showed that while there was no significant difference in the speed that people responded to colour and shape with congruent gestures, $t(7) = -1.05$, $p= .328$, they were significantly slower to produce incongruent responses to shape cues than colour cues, $t(7) = -4.04$, $p=.005$.

Figure 2.5 shows the mean response times for the compatibility effect when responding to visible objects

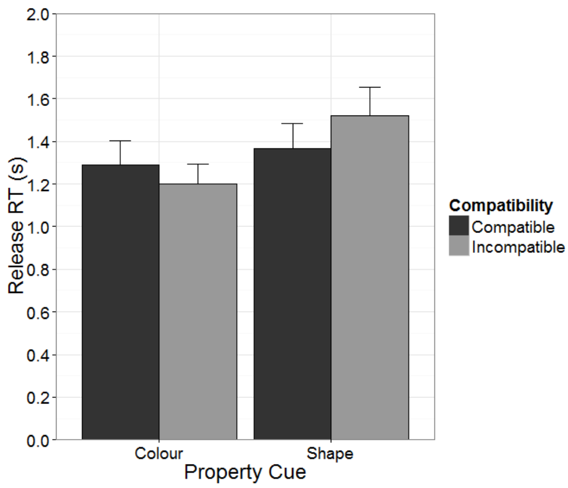


Figure 2.5. Mean Release RT for the compatibility effect under visual conditions

The compatibility effect was also examined when the items were no longer present at the time that the participants were cued to make a gesture (the offline condition). Here correct responses required participants to access stored memory representations of the previously-seen objects.

Error rates when responding to remembered objects with gestures were higher than those for Experiment 1a in general, but, like Experiment 1a, showed a significantly higher error rate for the shape cued conditions, $F(1,7) = 15.22$, $p=.006$, $\eta_p^2=.69$. Furthermore, higher error rates were found in the incompatible responses to shape, $F(1,7) =6.73$, $p=.036$, $\eta_p^2=.49$, (Table 2.4).

Table 2.4.

Percentage of trials on which participants responded to recalled objects with an incorrect gesture when cued by shape or colour.

	Compatibility	
Cue	**Compatible**	**Incompatible**
Colour	0.781	1.36
Shape	0.195	0.977

For response initiation times to produce gestures for remembered objects, there was no main effect of cued property, $F(1,7)=1.64$, $p=.24$, $\eta_p^2=.19$; thus reaction times to shape cues and colour cues did not significantly differ. There was also no main effect of compatibility, ($F<1$). There was however a significant interaction between cued property and compatibility, $F(1,7)=7.17$, $p=.03$, $\eta_p^2=.51$.

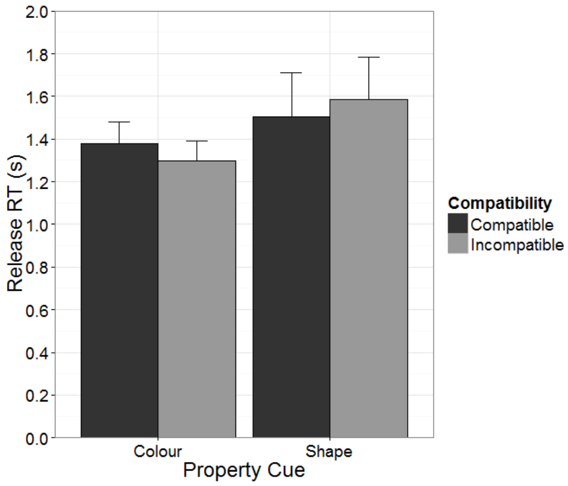


Figure 2.6. Mean Release RT for the compatibility effect under memory conditions

This interaction was explored by first looking at compatibility effects for each cued property. There was no significant difference between compatible and incompatible responses to the target objects when cued by colour, $t(7)=1.41$, $p=.200$. There was also no significant difference between compatible and incompatible responses when cued by shape, $t(7)=-1.32$, $p=.23$. When considering cued property effects for congruent and incongruent responses separately, there was no significant difference between colour and shape cued targets for congruent responses, $t(7) = -.883$, $p = .407$, or for incongruent responses, $t(7) = -1.57$, $p=.161$. While the memory-based responses to the mugs showed no significant differences within the interaction, it is worth noting that the pattern of responses is similar to that for the visual responses, with incompatible responses made faster for colour cues, while compatible responses show this advantage for shape.

2.4 Discussion

For Experiments 1a and 1b, it was hypothesised that the cue type (shape or colour) would influence the emergence of both Simon and compatibility effects, in visual and memory conditions. The Simon effect was found when responses were made to remembered stimuli, but only when cued by the shape of the object. No Simon effect was found when responses were made to visible objects. For the compatibility effect, an interaction between cued property and response congruency emerged in both visual and memory conditions for the shape cue, although the interaction was stronger under visual conditions.

2.4.1 The Simon effect under on-line and off-line conditions (Experiment 1a)

No Simon effect was found in Experiment 1a, when participants made property cued responses to visible stimuli. Given that the Simon effect is fairly robust, this absence is unusual, but the most likely explanation is the nature of the experiment. Previous studies have found that the strength of the Simon effect will decrease and eventually disappear over a long period of time (see e.g., Hommel, 2002; Eimer et al., 1995). Hommel (2002) suggested that this is due to the way in which the information is represented, with position and featural information held in parallel, rather than being bound into a single representation. As a result, the position information is more transient, and any increase in the time taken to make the response will decrease the strength of the Simon effect. Previous studies examining this have suggested that the decay of the affordance effect will occur rapidly within a few hundred milliseconds (typically 300-400 ms, De Jong, Liang and Lauber, 1994; Zhang and Johnson, 2004). The response times for Experiment 1a, show that even in the faster condition (when responding to colour) participants take, on average, over a second to begin acting. Given the time period for the Simon effect suggested by earlier studies, the current response times are clearly long enough for decay to set in. By using four items in each screen, the present task was more complicated than the standard affordance study set-up, and it seems likely that this extra complexity had an influence in increasing the participants' response times.

As a consequence of this null effect, it is not possible to determine whether the property cues had any influence on the emergence of the effect. It is possible that differences did emerge, but decayed before they could be measured.

In contrast, there were rather different findings for the Simon effect conducted under memory (off-line) conditions. Firstly, the effect did emerge, adding further support to previous findings that affordance effects in general (e.g., Derbyshire et al., 2006), and the location-based Simon effect in particular (e.g., Tlauka and McKenna, 1995) will persist when participants are responding to a mental image rather than a visual one. These findings therefore continue to support the idea that object representations contain both action and visual/feature information, supporting more grounded theories of cognition (e.g., Hommel et al., 2001).

While our findings for off-line conditions are in line with earlier studies, considering these results in relation to the on-line version of the current study shows a potential difference between the processes that occur in visual and memory versions of the task. Under off-line conditions, participants still take over a second to respond (indeed, the responses to colour cues show an average production time of 1.4 seconds, longer than that for the visual responses to these cues). Despite this, the Simon effect is still found under memory conditions. However, this apparent discrepancy between on-line and off-line investigations into the Simon effect has been noted and examined in previous studies, and appears to be a consistent finding (see e.g., Hommel, 2002; Zhang and Johnson, 2004). Zhang and Johnson (2004) showed that, under memory conditions, Simon effects could be found after a delay of up to 2400 ms, and make the suggestion that this is due to a different treatment of the spatial codes when working off-line. While spatial codes are suggested to be formed in parallel to the featural information when the Simon effect is produced under on-line conditions, in off-line conditions it is thought that the spatial information is coded into the memory representation, providing information on the context of the effect. Once bound into the representation, the spatial information is no longer susceptible to decay, and the effect is maintained. Thus, our results regarding the off-line version of the memory effect are consistent with previous studies demonstrating the different time courses of this effect, depending on the off-line/on-line state under which it is performed.

Of more interest to the aim of the current study is the finding that the Simon effect only emerged when cued by the object shape, and was absent for the colour cue. This is surprising, given that previous investigations of the Simon effect have suggested that it is largely unaffected by boundary conditions such as these. Indeed, Pellicano et al. (2010) compared the circumstances necessary for Simon and affordance effects to emerge, and found that the Simon effect was robustly present, as long as there was overlap between object and response location. Only the object-based affordances (in this case, the handle affordance effect) were affected by features of the task, such as the action-relevant nature of the property cue. However, this and many other studies investigating the Simon effect have been conducted on-line, and, as discussed above, there are indications that different processes are responsible for the Simon effect under visual and memory conditions Thus, the findings presented here suggest that, under off-line conditions, when an integrated representation is formed containing position information, the context (in this case, the property cue) can have an influence on the emergence of the Simon effect. As suggested by Tipper et al. (2006) and Loach et al. (2008), it seems that when attention is focused on a property which is integral to performing an action, an action is primed (although this is a fairly general action in the case of the Simon effect, priming a movement towards a location rather than a more specific feature of the object). Actions prepared and performed towards an object are facilitated and the expected position congruency effect emerges, but only in conditions using an action-relevant cue. It is possible that, when the position information is bound into the object representation, as is suggested to occur for the Simon effect in memory, then the Simon effect itself becomes more susceptible to boundary conditions, due to the integration of the spatial and feature codes.

2.4.2 The compatibility effect under on-line and off-line conditions (Experiment 1b)

For Experiment 1b, the compatibility effect was examined, under both visual and memory conditions. For both these conditions, there were similar patterns; colour cued responses showed a small (non-significant) advantage for the incompatible gestures, while shape cued responses showed a similarly non-significant advantage for the compatible gestures. In both versions, significant interactions between gesture and property cue were found, with participants taking longer to respond with incompatible shape-cued gestures than incompatible colour-cued responses; although further investigation showed this was only significant in the visual version of the study.
The fact that the visual and memory effects were so similar indicates that compatibility effects, like other affordance effects, persist beyond the removal of the visual image of an object. However, it appears the visual effect is stronger, indicating that there is an extra advantage if the object remains in view.

More specifically, it seems that the property cue is again important for the effect, as it leads to different outcomes in response; and again, only the shape cued responses show an influence in the expected direction. This is not in agreement with the findings of Bub and Masson (2006; 2010), where the more specific responses appeared to remove or override the influence of the cue.

One possible reason for this difference between the present results and Bub and Masson's (2010) findings is the design of the two studies. Bub and Masson (2010) used colour cues to inform participants which hand they should use to make the gesture, but the gesture itself was a constant for each participant. This is a reversal of the current study, where the hand used was fixed, but the particular gesture was informed by the colour or shape. Such a difference makes Bub and Masson's (2010) study more similar to the intentional studies of Fagioli et al. (2007) and others, where the gesture or grasp type is prepared before the target object is seen. The differences in compatibility effect between the present study and Bub and Masson (2010) may, therefore, be used to suggest that the order in which the processes are carried out is important. If the intention to perform an action is formed before the cue is detected (as in Bub and Masson's studies), then the cue is irrelevant to this action preparation, but if the property cue must be determined first (as in the present study), then the nature of the cue has more of an effect.

However, while the pattern of behaviour is as expected for the shape cue, attending to the colour cue facilitated the incompatible responses. One possible (if rather speculative) explanation for this pattern is that the attention to the two different cues leads to different processes being set in motion. When attending to an action relevant property such as shape, this facilitates the preparation of actions, and leads to the expected facilitation effects. However, attention to the more visual property cue of colour is not thought to do this. As a result, when responding to colour cues, the participants might simply learn the association between colour and gesture, without associating it with the identity of the object itself. For incompatible gestures, this would be enough, as the gestures themselves do not connect with the object presented. However, for the compatible gestures, their production might be delayed by the relevant action (and its association with the object), leading to a deeper processing of the target object beyond the initial examination of the item to extract the colour information.

Such an explanation could also account for why the memory version of the study shows a weaker effect for the memory conditions: when the target remains visible, the participant is able to engage in continued processing of the mug, delaying the production of the gesture, and so increasing the response time in this condition. Taking this into account, Experiment 1b therefore could be used to suggest that attention to a particular property influences the representation separately to the intention of the observer, but must come prior to the formation of the intended gesture to have its influence. However, it should also be noted that the complexity of the experimental set-up might also have an influence. Previous work has not investigated how compatibility effects might be affected by the complexity of the situation (although studies examining the time course of the effect do not indicate that it decays over time like the Simon effect, see e.g., Fischer and Dahl, 2007).Thus, since Experiment 1b did use a more crowded scene than previous experiments, this may have contributed to the pattern of effects observed here and the differences between the present and previous studies. Further exploration of this factor is therefore required, to determine if it is a relevant influence on the outcome of the effect.

Overall, the results of Experiment 1.1 are mixed in their support of the hypotheses. The findings from the Simon effect suggest that it can be influenced by the property cue that is the participants' attentional focus before they produce the action. However, these findings are limited to the memory condition. The compatibility effect seems to show that the property cue is relevant for more specific gestures, for both visual and memory conditions, although the visual presence of the object leads to a stronger effect. The findings also extend previous work by suggesting that the order of the cue and response has an influence on the pattern of results. The property cue may have an influence, but only if it is attended prior to the planning for the production of the gesture, otherwise it is over-ridden.

Given that the complexity of the scene may be a confounding factor in the emergence of the visual Simon effect, (and possibly also one for the compatibility effect), it is important to further investigate this. As a follow-up to Experiments 1a and 1b, simpler versions of the two designs were created. These reduced the number of objects and responses from four to two, in order to determine whether the complexity of the task setting had an influence on the emergence of the effects being investigated.

2.5 Experiments 1c and 1d: Method

2.5.1 Participants

Participants were 32 University of Dundee students (4 males), aged 18-25. Half participated in the Simon effect condition (Experiment 1c), and the other sixteen in the compatibility effect condition (Experiment 1b). Within each group, eight participants took part in the visual version, and eight in the memory version of each study. All participants were right handed, and with normal or corrected-to-normal vision. Each received payment upon completion of the study.

2.5.2 Stimuli, Procedure and Design

These were the same as for Experiments 1a and 1b, with the following exceptions. The stimuli used were reduced to only two colours (blue and yellow) and two shapes (tall and round). As before, these were combined to create the different targets. On each trial, two images were presented to the left and right of the central point. The letter cues used to indicate the target for that trial were either 'A' or 'B', only, where A= Left and B=Right. The two response buttons in the Simon effect were the 'A' and 'apostrophe' keys. For the compatibility effect, the response gestures used were also reduced to two: 'lifting a mug by the handle' (compatible) and 'squeezing the trigger on a spray gun' (incompatible).

As there were fewer positions for images to appear (left and right only), the experiment blocks required only 64 trials, to allow each shape and colour to appear as the target object in each location. Again, each participant performed two such blocks, responding to colour cues in one, and shape cues in the other, leading to 128 trials in total (plus the ten practice trials at the beginning of each block). Half of the trials in each block were compatible with the response, and half incompatible, as before.

2.6 Results

2.6.1 Experiment 1c- Simon effect under visual and memory conditions

Experiment 1c examined the emergence of the Simon effect when cued by either colour or shape when the number of targets and possible button press responses were each reduced to two. As in Experiment 1.1, the emergence of the effect was examined under both visual and memory conditions.

Error rates for button press responses to visible targets in Experiment 1c are shown in Table 2.5 and show that overall, the rates were low. A 2 x 2 within-subjects ANOVA revealed that participants did make marginally more errors on incongruent responses than congruent ones, $F(1,7) = 4.83, p=.06$, $\eta_p^2 = .40$. No other effects were significant.

Table 2.5.

Percentage of trials on which participants responded to visible objects with an incorrect button press when cued by shape or colour.

	Congruency	
Cue	**Congruent**	**Incongruent**
Colour	0.781	1.36
Shape	0.195	0.977

For the time to initiate the button press response, a 2 (cued property) x2 (response congruency) within-subjects ANOVA found that there was no main effect of cued property, $F(1,7)=.010$, $p=.925$, $\eta_p^2 = .001$, such that responses were no faster to the colour cued target than a target cued by shape. There was a significant main effect of congruency, $F(1,7)=9.29$, $p=.024$, $\eta_p^2 = .542$. Responses made on the same side as the targets position were faster than those made on the opposite side to the stimulus. There was no significant interaction between property and congruency, $F(1,7)=.414$, $p=.540$, $\eta_p^2 = .056$.

Figure 2.7 shows the mean response times for the Simon effect when responding to visible objects

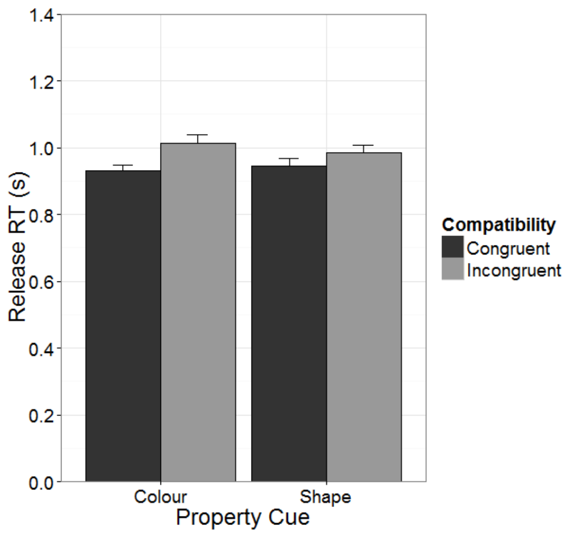


Figure 2.7. Mean Release RT for the Simon effect under visual conditions

Error rates for the memory version of Experiment 1.2a are shown in Table 2.6. As in the visual condition, participants found incongruent responses more difficult than congruent ones, $F(1,7) = 6.28$, $p=.041$, $\eta_p^2 = .47$. However, again the overall error rate was low.

Table 2.6.

Percentage of trials on which participants responded to recalled objects with an incorrect button press when cued by shape or colour.

	Congruency	
Cue	**Congruent**	**Incongruent**
Colour	0.781	0.835
Shape	0.977	0.410

A 2x2 within-subjects ANOVA, found no main effect of cued property, $F(1, 7)=.021$, $p=.889$, $\eta_p^2 = .003$ such that responses were no faster to the colour cued target than a target cued by shape. There was however, a significant main effect of congruency, $F(1, 7)=10.83$, $p=.013$, $\eta_p^2 = .607$ so that button responses made on the same side as the target's position were faster than those made on the opposite side to the stimulus. The interaction between property and congruency approached significance, $F(1, 7)=3.71$, $p=.095$, $\eta_p^2 = .347$. As in Experiment 1.1a, we have an *a priori* interest in how the two property cues might differently influence the affordance effect. Thus, in order to further examine this potential interaction, paired samples t-tests were conducted on the congruent and incongruent responses for each property separately. For both cued properties, a significant Simon effect was found (colour, $t(7) = -2.45$, $p=.044$; shape, $t(7) = -3.04$, $p=.019$) so that congruently positioned targets were responded to faster than were incongruently positioned targets across both property cues, although the significance of the effects do suggest that the effect is marginally stronger for shape-cued responses.

Figure 2.8 shows the mean response times for the Simon effect when responding to memorised objects.

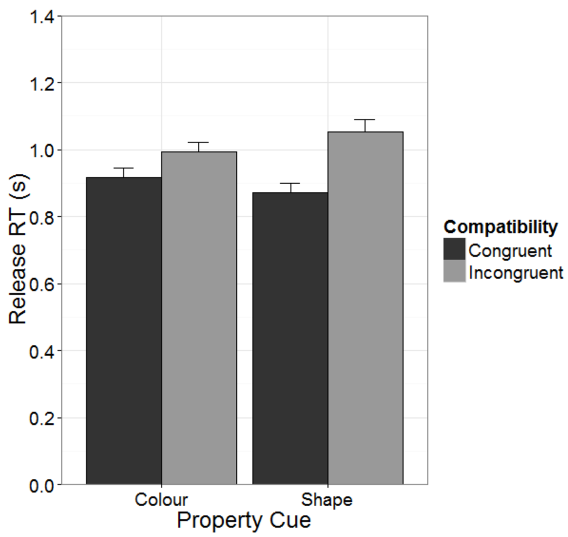


Figure 2.8. Mean Release RT for the Simon effect under memory conditions

2.6.2 Experiment 1d: Action compatibility effect under visual and memory conditions

Experiment 1d examined the compatibility effect under visual and memory conditions when the number of target objects and response gestures was reduced to two.

Error rates when responding with gestures to visible targets in Experiment 1d (Table 2.7) showed an interaction between the property and compatibility, $F(1,7) = 5.65$, $p=.05$, $\eta_p^2 = .45$. While responses to incompatible cues showed a higher percentage of errors for colour cues, for shape cues, it was the compatible responses that resulted in more errors. However, the error rates were again lower than those for Experiment 1b, indicating this was an easier task for participants.

Table 2.7.

Percentage of trials on which participants responded to visible objects with an incorrect gesture when cued by shape or colour

	Congruency	
Cue	**Congruent**	**Incongruent**
Colour	0.586	0.781
Shape	0.977	0.195

For response initiation times, a 2 (cued property) x2 (response congruency) within-subjects ANOVA found no significant main effects in this version of the study, so that there was no difference between responses to different property cues, $F(1,7) = 1.15$, $p = .32$, $\eta_p^2 = .14$, or between compatible and incompatible responses, $F(1,7) = 1.90$, $p = .21$, $\eta_p^2 = .214$. There was also no interaction between the property cues and the compatibility of the gesture, $F(1, 7) = .33$, $p = .58$, $\eta_p^2 = .045$.

Figure 2.9 shows the mean response times for the compatibility effect when responding to visible objects

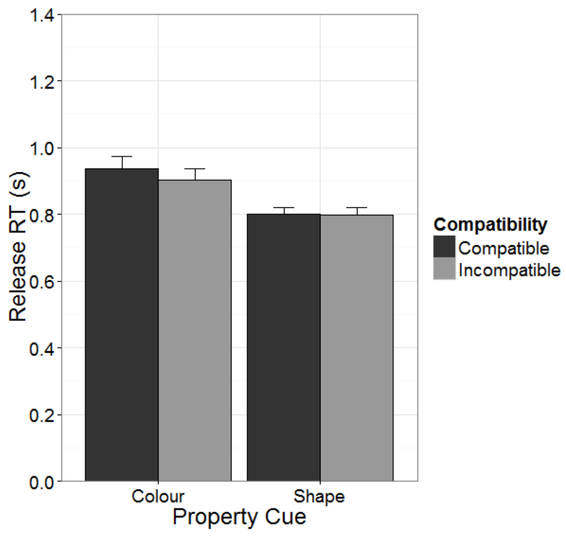


Figure 2.9. Mean Release RT for the compatibility effect under visual conditions

Next, the response times to the off-line version of Experiment 1d were examined, showing how participants responded when producing gestures according to their recall of the target stimuli.

Error rates for gesture responses made to remembered objects in Experiment 1d are shown in Table 2.8. No differences were found between the error rates for property or compatibility, and overall, the percentage of errors made in this condition was low.

Table 2.8.

Percentage of trials on which participants responded to remembered objects with an incorrect gesture when cued by shape or colour

	Congruency	
Cue	**Congruent**	**Incongruent**
Colour	0.390	0.586
Shape	0.586	0.195

For response initiation times, again, no main effects were found to be significant in this version, so there was no difference between responses to colour and shape, $F(1,7) = .47$, $p = .52$, $\eta_p^2 = .063$, and compatible and incompatible responses, $F(1,7) =$

3.22, p = .12, η_p^2 = .315. There was also no significant interaction between property and compatibility, *F*(1, 7) = .20, p = .66, η_p^2 = .028. Figure 2.10 shows the mean response times for the compatibility effect when responding to visible objects.

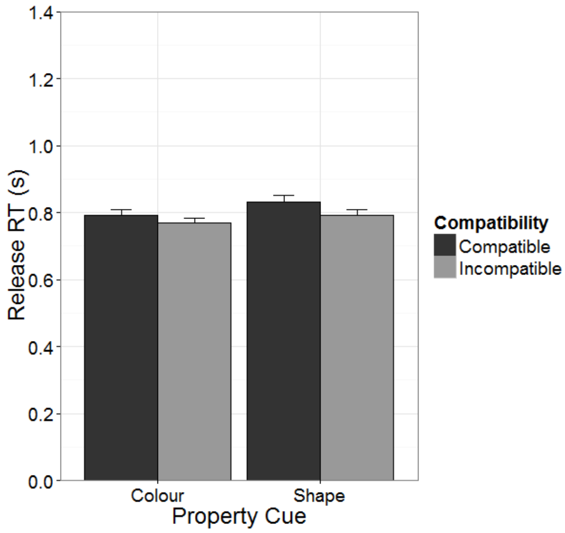


Figure 2.10. Mean Release RT for the compatibility effect under memory conditions

2.7 Discussion

Experiments 1c and 1d investigated the emergence of the Simon and compatibility effects under both visual and memory conditions, as in Experiments 1a and 1b. However, here the demands of the task were reduced by presenting participants with only two objects to respond to, rather than four. It was thought that by reducing the attentional demands in this way, effects that were otherwise absent in the previous study would now emerge. The Simon effect was found in both visual and memory conditions, but was apparently unaffected by the particular property used to cue it. The compatibility effect did not emerge at all, and was unaffected by cue or response type used.

The changes made to the object displays had three clear effects on the participants' performance. Firstly, the main effect of property that was present consistently in Experiments 1a and 1b was no longer found in Experiments 1c and 1d. Participants responded to colour and shape cues within the same amount of time, consistent with our suggestion that the longer response times to shape cues in Experiments 1a and 1b were due to a greater difficulty either processing or maintaining the four shapes that were viewed or recalled. When the number of shapes was reduced in Experiments 1c and 1d, RTs in response to shape were no longer than for the colour-based responses. Indeed, response times in general were faster in Experiments 1c and 1d, while error rates were lower. These factors suggest that the less complex presentation of the stimuli did successfully reduce the difficulty of the experimental set-up.

Secondly, we found a difference in participants' responses to the Simon effect. The visual version of the Simon effect (Experiment 1c) gave clear results, with the effect emerging in both the on-line and off-line versions of the study. Given that the RTs in Experiment 1c are shorter than those in Experiment 1a, this finding is consistent with our earlier suggestion that the emergence of the effect might depend upon the time taken to make the response. Previous studies (e.g., Hommel, 2002) have shown the Simon effect decays over time, and we speculated that this was the case in Experiment 1a, with the response times too long for the Simon effect to remain. With the reduction of response times in Experiment 1c, perhaps due to the reduced complications in the task, the Simon effect emerged.

Under off-line conditions, the Simon effect continued to emerge, as it did in Experiment 1a. We suggested in Experiment 1a that the memory version of the Simon effect was not affected by time taken to respond (in line with earlier studies e.g., Zhang and Johnson, 2004), and so would not have expected changes in response times to have a particular influence on the off-line version of the effect. This result is therefore in agreement with our assumptions.

However, a difference emerges when considering how the participants' focus on a particular property cue influenced the emergence of the Simon effect. Both on-line and off-line versions of the study showed no influence of the property that cued their responses, with the standard Simon effect emerging for both shape and colour cues. For the visual version of Experiment 1c, this can be explained with reference to the earlier studies suggesting that the Simon effect is driven only by the presence of an overlap between the stimulus location and the response location, and is impervious to other contextual factors, such as cues (see, for example, Kornblum et al., 1990; Pellicano et al., 2010). Our on-line results for the effect are therefore in agreement with previous work, and add further support to the suggestion that the Simon effect is not affected by boundary conditions in the way other affordance effects are.
The finding is less clear, however, for the off-line version of the Simon effect in Experiment 1c, given that the off-line version of Experiment 1a did show an influence of the property cue, with only shape-cued responses showing the typical facilitation when stimulus and response locations matched. The findings of Experiment 1c seem to suggest that memory based Simon effects act like visual ones, at least in terms of the contextual influence, in direct contradiction of the findings from Experiment 1a, and other studies indicating a difference between on-line and off-line effects (e.g., Hommel, 2002; Zhang and Johnson, 2004). However, it is interesting to note that there was a small interaction between property and response in this condition, which appears to come from a stronger effect in the shape cued responses, indicating that there is perhaps some difference in the way the cues influence the processes under memory conditions.

Thirdly, there was also a difference between the patterns of response seen in the Experiment 1d, and those found in Experiment 1b for the compatibility effect. While the faster overall response initiation times again suggest that the task is easier for participants, the influence of the property cues found in Experiment 1b was no longer present, and the compatibility effect itself was also absent. One possible explanation for this could be the reverse of the decay effect suggested as an explanation or the pattern of results for the Simon effect in Experiment 1a. That is, the simpler study procedure allowed people to respond sooner, before the compatibility effect could fully develop. There is some evidence that, like the handle affordance effect, the compatibility effect increases across the time course of an experiment (e.g., Bub and Masson, 2010). However, this does not seem a likely explanation for the present results. The time course of Experiment 1d was the same as that of 1b, with the same amount of time allowed for the presentation of items and cue to act. This total time was over a second, long enough to allow the effect to develop. An alternative explanation is that the participants were able to learn the associations between the objects and response gestures more easily when there were only two possibilities. As a result, they no longer needed to process the objects as deeply, and could produce the correct response easily after a cursory examination of the stimulus that was presented, without demonstrating action-based effects.

It would appear that for both Simon and compatibility effects, there was an effect of the set size used. Essentially, with larger object sets, where more objects were present, the influence of the cued property was strongest. When the set size was reduced, the cued property (and, for the compatibility studies, the effect itself) was lost. This may suggest that in more complex environments, where there are several potential objects, the influences of the property and intentional response are most pronounced, as perhaps this is when they are the most useful.

2.8 General Discussion

Across two sets of studies, the influence of property cues on the emergence of affordance effects was examined. Two main areas were studied: the condition under which the response was generated (from memory, or with the stimulus object still visible), and the cue and response requirements (action or visually relevant cues, and abstract or specific response gestures).

When the experimental set-up contained four items (three distractors and one target), there was an influence of the property cue on the compatibility effect in both visual and memory conditions, and for the Simon effect under memory conditions only. When the set-up was simplified to two items (one target, one distractor), the Simon effect was present under both memory and visual conditions, but unaffected by the property cue. The compatibility effect was absent completely under these less demanding conditions, for both visual and memory settings. We consider these findings in terms of three sets of comparisons: between the two types of affordance effect used (Simon and compatibility); between the number of object stimuli used (four or two), and between the two study conditions (on-line or off-line responses to stimuli).

2.8.1 Comparison between the Simon effects and compatibility effects

The Simon and compatibility effects differ both in the type of response they require and the feature that is assumed to drive the effect. While the compatibility effect depends on the relationship between a specific gesture and the object identity (e.g., Bub and Masson, 2006), the Simon effect depends on the object's location in relation to the location of the response (e.g., Symes et al., 2005), and requires only a button press in response. There is some debate as to how equivalent the two effects are and, indeed, in the present study, the two effects do show clear differences in how they emerge under the conditions investigated.

Previous studies have shown that Simon effects may emerge independently of the property used to cue the response (Kornblum et al., 1990; Pellicano et al., 2010), which agrees with the findings from Experiment 1c, but not those of Experiment 1a. In terms of the TEC (Hommel et al., 2001), it is suggested that preparation of an action towards a location leads to weighting of location as a relevant feature. Hommel (2011) suggests that attention towards a particular location, such as the left side of a display screen, will lead to activation and facilitation of actions towards the left side, as the codes for the location of stimulus and action overlap within the representation. As such, the attentional focus on location is enough to lead to weighting, and the nature of the object at the location is less relevant. However, there is a little evidence to suggest that some contextual factors can influence the emergence of the effect. For example, locating the targets in the right or left eye of a face led to Simon effects for the right and left, even when the picture was rotated by 90° (Hommel and Lippa, 1995). This was considered to indicate that the familiarity of the visual context (a face) influenced the coding of locations based on the viewer's typical experience with the context (that is, the eyes are coded as left and right, even if on this occasion they are presented as being located up and down).Thus, it is not entirely unlikely that some influence of context could emerge, under the right conditions. For Experiment 1a, attending to the shape of the objects prior to making the response might have weighted the representation in favour of acting with the object, along with the weighting of the location, and so led to the facilitation of responses on the congruent side, which might be a precursor to acting with the object. Given that this effect occurred only for the memory condition in Experiment 1a, there is also the suggestion that the difference in how position information is thought to be maintained in memory (i.e., integrated into the representation) might be responsible for this effect. However, this explanation cannot adequately account for Experiment 1c, where even under memory conditions, any influence of the property cue is absent: instead these findings suggest a reduced influence for the task context, at least in terms of the cue to produce an action. As this effect occurs when the number of stimuli is reduced, it may be linked to the complexity of the study, and this is considered in the next section, which compares the results based on this factor.

The compatibility effect, like the Simon effect, does not emerge under every version of the study. However, when the effect is present (in Experiment 1.2), then the pattern of results can be more easily explained in terms previous findings (e.g., Bub and Masson, 2010) and in terms of the action-relevance of the property, in accordance with the TEC (Hommel et al., 2001). Focus on the shape of the object leads to the activation of shape related actions, such as lifting, in the representation. This activation weights the representation in favour of acting with the object, and so influences the production of the associated action. Producing un-associated actions is slowed when previously attending to object shape and attending to object colour is suggested to lead to no initial priming of the relevant gesture.

The difference between the Simon effect and the compatibility effect may come from the specificity of the relationship between the action response, and the form or use of the target object. The Simon effect is referred to as a ‘space-based affordance’ in some discussions of the effect, in contrast to ‘object-based affordances’ such as the compatibility effect, which involves gestures strongly linked to the shape and form of an object, unlike location (e.g., Symes et al., 2005). While the Simon effect seems therefore to be (largely) dependent on the overlap between stimulus and response locations, we can suggest that the compatibility effect is more dependent on the nature of the cue to act. The action-relevance of the cue (e.g., shape information informing gesture forming) may therefore be more important to this affordance effect.

2.8.2 Comparison between four and two item studies

The finding that the simpler versions of the studies had a considerable impact upon the emergence of the Simon and compatibility effects was unexpected. In Experiment 1a the Simon effect was found only for remembered objects cued by shape. When the number of objects, properties and responses were reduced, in Experiment 1c, the Simon effect was found both when making responses to visible and remembered objects, and was found irrespective of the property used to cue the response (although there is an indication that the effect when cued by shape was larger than that cued by colour).

The absence of the Simon effect in Experiment 1a under visual conditions is most likely due to the previously established decay of the effect when the responses are delayed (Zhang and Johnson, 2004). The emergence of the effect in Experiment 1c is therefore an indication of the influence of the reduced complexity, allowing participants to form their response before decay occurs.

However, the difference between the four-item studies (Experiments 1a and 1b) and two item studies (Experiments 1.c and 1d) in terms of the influence of property cue is a little more complex. A likely explanation for these findings is the distribution of attention, in combination with the cue types in each of the two versions. For Experiment 1c, there was more time to examine each object (as there were only two), while in

Experiment 1a the examination of the four items might have to be more cursory. Presentation time for items in both Experiments 1a and 1b and Experiments 1c and 1d were the same, thus, under the conditions of Experiments 1a and 1b, participants did have less time available per object. This could affect the shape cues in particular: while colour names would be well known to participants, it was less likely they would have previously encountered the shape names as labels applied to the particular object stimuli used, or the examples of the cups themselves. Cup shapes and their given labels are therefore possibly less familiar to the participants. As a result, identifying the colours would be quick, but identifying the shapes might require more time to examine each item and recall its label, time that was not available under the conditions of Experiments 1a and 1b.

In support of this, there is evidence that suggests the amount of attention, as well as its focus, is a key factor in the emergence of affordance effects. Vainio et al. (2007) reported findings that suggested that some amount of attention to an object is necessary for affordance effects to emerge. While the target in the four item display is quite likely to be attended at some point in the viewing period, it seems reasonable to suggest that the time spent on each object would be reduced. Furthermore, studies employing eye movement techniques (e.g., Tatler et al., 2005) found that the extraction of colour information from objects could occur without direct fixations on the objects, possibly suggesting that this information doesn’t require overt attention to obtain it. Thus, for the current study, while participants could respond correctly to the colour cues, under the more crowded four-item condition, they may have done this without constructing an action representation for the object that supported the emergence of the Simon effect. For the two-item condition, this smaller study set allowed increased and equivalent attention to objects, whatever the cue. Such an account would suggest that the observed differences between the findings of Experiment 1a, Experiment 1c and previous studies showing no influence of the property cue on the Simon effect might arise from the extent of attentive processing of objects, resulting in property-based differences only emerging under more demanding task conditions. It might also explain the small interaction between cue and location seen in the memory version of Experiment 1c. The fact that the items are removed after the short viewing time might again make this task a little more difficult (although not as complex as the four item version). As a result, the difference in the focus of attention to colour and shape cues again emerges, and influences the difference in strength seen in this version of the Simon effect.

While the explanation above could account for the Simon effect changing between the two Experiments, it is a less satisfactory account for the compatibility effect, where the result vanishes altogether under the simpler conditions of Experiment 1d. One possibility here has already been mentioned: that the smaller set size led to participants learning the associations between the cue and gesture quickly, and so being able to produce the response before the influence of the object could affect it. Again, Vainio et al. (2007) suggested that the repetition of the same target item can lead to pre-preparation of responses to that target. That study referred to the repetition of a single item across the course of the experiment, but while Experiment 1.2 used more than one object, across the large number of trials, both would be targets multiple times, and so participants might well be able to simply learn the associations for the two objects and produce both response types equally quickly. Other studies have shown compatibility effects while using smaller set sizes (e.g., Bub and Masson, 2006). However, unlike the present study, they used a wide range of objects, not just examples of a single object type as we did. As a result, it might have been harder for participants to learn the repeated associations between a stimulus and response, as they could not be aware of what object would be presented on each trial.

Due to the nature of this study, measures of the attentional focus were not taken, and so there are no empirical data to support these speculations. However, it is unmistakeable that the number of objects present in the scene had an effect on the emergence of the effects, and that, regarding the effect of property cues, they are at their most effective in the more complex version of the scene. This may indicate that more complex scenes in general are needed to investigate effects such as this, as sparser and less realistic settings may not allow the full influence to be seen.

2.8.3 Comparison between visual and memory conditions

Across nearly all the Experiments presented here, it seems that the pattern of results present in the visual version of the study was also present for the memory version, or, in the case of Experiments 1a and 1b, was found only for the memory version. These findings all add further support to the earlier studies which first demonstrated that affordance effects would persist beyond the removal of a visual stimulus, and strengthen the concepts of grounded cognition which suggest that both action and featural information are maintained together, in equivalent representations.

The current study extends previous understanding by demonstrating that that the compatibility effect persists in memory. This finding suggests that it is not solely the recollection of the object that leads to re-activation of the action properties, but the situation in which the representation was formed, in terms of what features were attended. Studies investigating a more grounded approach to memory, and in particular, the retrieval of information can be related to this suggestion (e.g., Ross, Wang, Kramer, Simons and Crowell, 2007). These studies have found that the production of actions associated with the item when retrieving the information influence the recall. The current study demonstrates that the recall of information about the target object can influence the production of associated gestures. This is consistent with the idea of perceptual and action features sharing the same representational domain, and the bi-directional link between the action and perception features that the TEC (Hommel et al., 2001) proposes. Thus, the weighting of representations extends beyond representations for immediate performance, and into those conducted under memory conditions.

2.8.4 Conclusions

Tipper et al. (2006) showed that the emergence of affordance effects might be affected by which properties of the objects were attended. Bub and Masson (2006; 2010) extended this by showing that the influence of the type of response was also important. Together, these studies suggest that both attentional focus and more specific intentions to act on an object can influence the processing of the object, leading to the facilitation or inhibition of subsequent actions. The current studies further this by suggesting that, at least for effects that are dependent on the nature of the object, both the property and intention can influence the emergence of action-related effects, but that this may depend on the order in which they are considered. Bub and Masson suggested that the presence of the intention response would over-ride the property cue that was attended, but the results shown here suggest that when the response is dependent on the property, then the nature of the property can still affect the emergence of the effect. Focusing on colour leads to a delay in preparing the relevant actions, while focusing on shape leads to a delay in producing the incompatible actions for the object.

The TEC (Hommel et al., 2001) suggests that both attentional focus and intention to act can be used as ways to prime an event file and lead to the weighting of the representation. In everyday situations, it is likely that both these processes work together, but in the experimental situations, the two can be separated. This is most clear for the compatibility effect: Bub and Masson (2010) showed that the preparation of an action prior to viewing the object led to an advantage for producing the action that matched that object, in line with previous studies showing the influence of intention preparation (Fagioli et al., 2007). By preparing an action, the relevant features (such as handle location) are primed, and weighted within the representation. While the object colour informed the hand to be used, it did not affect the preparation of the action, as it is not relevant to grasping. This priming affects perceptual detection of the items, and also speeds the production of the required response. However, when the property cue is given to determine the response, then the type of cue becomes more relevant, as in the current study.

Shape as a property has strong links to the planning of actions with an object, as the shape of the object is linked to its identity, and the associated grips that are congruent with the object. Thus, preparing an action via attention to shape primes the associated action responses in the representation, and again, facilitates their production. Focusing only on colour, in the absence of any other indication of what the action required is, doesn't require the early planning that leads to action facilitation. The findings do suggest that, for the compatibility effect, there is a difference between object properties that may relate to their action relevance: although as Jeannerod (1997) suggests, the division into action and visual properties may not be so clear cut. Certain properties can be considered as both to one extent or another, while only a few are solely in one category. As stated, colour is most likely to be the purest visual property, and this distinction may be a factor in allowing the present results to emerge, as the use of two clearly distinct properties helps the difference between the action and visually relevant properties to be observed.

Finally, the difference between Experiments 1a and 1b and Experiments 1c and 1d suggest that these effects are likely to be most present in more complex situations. While the reason for this is for the moment unclear, it does point to future studies perhaps concentrating on more crowded experimental environments, i.e. those that are a little closer to a real world environment. It may be that the facilitation of action preparation is most useful in more crowded environments, so under these conditions, the effects are easier to see.

In conclusion, it appears that under certain conditions, object properties can influence the early stages of planning and execution of an action towards an object. Thus, the attended property seems to be another factor which can influence the weighting of an object representation, along with more specific intentions to act, and the complexity of the scene. Action and perception are again shown to be tightly linked, with perceptual focus able to influence the production of action as action is able to influence the perception of a scene.

Following these findings, particularly those regarding an apparent influence of scene complexity, the next studies conducted in this thesis will increase the amount of detail in the stimulus scenes. This will be done by using either photographs of real world scenes, with large numbers of objects, or actual real-world scenes. It is hoped that such increases in complexity will provide situations in which effects of weighting due to the task can be observed.

Chapter Three- The influence of the potential for action at encoding on the formation of object representations

3.1 General Introduction

There are increasing numbers of studies of the influence of action on perception, demonstrating how the preparation for action can influence the way a scene is viewed (e.g., Bekkering and Neggers, 2002, Symes et al. 2008). However, much less research has been conducted into whether memory representations are similarly affected. Furthermore, studies that do examine influences of action on memory tend to focus on the influence either during or after the task, measuring the effect that performing the actions might have on the acquisition of information throughout the interaction, (e.g., Triesch et al., 2003), or how the completion of the task influences the subsequent recall (e.g., Williams et al., 2005). Preparation for an action has been largely ignored in terms of its influence on memory, yet there is good reason to expect that it could have an effect. Earlier studies such as Bekkering and Neggers (2002) show how an action preparation can affect where we look in a scene, and how long it takes to fixate certain items. There is also a wealth of evidence that shows how important where we fixate is for the inclusion of that item into the eventual representation (e.g., Hollingworth and Henderson, 2002). Thus, if action preparation can influence perception, it follows that it may also prime the memory representations following that perceptual experience.

If memory representations can be primed from this action preparation, it is important to consider how this weighting might be shown. As with many of the previous studies, both for on-line perception and off-line representations, the properties of objects (e.g., shape, colour, etc.) offer the best way of determining this. On-line, it is the detection of properties (for example, as the defining features of targets in a search task) that is affected by the presence of action preparation (e.g., Fagioli et al., 2007), while for representations, there is much evidence to show that such properties are maintained in memory in a relatively independent manner (e.g., Brady et al., 2011; Fougnie and Alvarez, 2011). Thus, an influence of action preparation might be detected in participants' memory for particular properties that are relevant to the situation.

Following a determination of how any weighting might be detected, it is also necessary to consider how the weighting might be achieved in terms of the actions used. Previous studies have used a range of approaches, such as preparing particular grips or pointing actions; Fagioli et al. (2007) for example, used either pointing or gripping actions to weight the detection of single action-related items. For the purposes of a memory study, it was necessary to have a range of objects observed by participants and subsequently tested, to prevent the memory task becoming too simple, leading to ceiling effects in the responses, and possibly resulting in any effects of action being washed out. In terms of the actions that could be used to influence perception, the types employed by previous studies have typically been either pointing gestures, or particular grasping actions. An object-specific action such as pointing was less ideal for the current study, since such an action requires a single particular object as the target, rather than a range of objects to be memorised.

Grip types, however, are more flexible. The preparation of a grip type presupposes physical interaction with an object in a different way to that of pointing. Furthermore, there are clearly defined grip patterns that have formed the basis for previous research: power and precision grips (Napier, 1956). Precision grips are used when manipulating smaller objects, or specific parts of larger items, using the thumb and index finger, while power grips are used when manipulating larger objects, requiring the item to be held between the fingers and the palm of the hand. Of the studies into action influencing perception, Symes et al. (2008) specifically used the preparation of power and precision grips to influence search for size-related objects, thus there is evidence that the grips do reliably influence perception. Furthermore, the affordance literature suggests that the grip type associated with an object is an important intrinsic property, which may be a part of the object's representation (e.g., Derbyshire et al., 2006). Neurophysiological studies have shown that premotor neurons will respond to the presentation of graspable objects, with some neurons activating specifically to either power or precision grips (Raos, Umiltà, Murata, Fogassi and Gallese, 2006). Thus, given the bi-directional nature of the perception-action link, it is reasonable to assume that the preparation and maintenance of particular grip types should lead to particular biases towards matching items.

Another method for weighting representations in favour of action is to use the influence that proximal hands have on the viewing of a scene. The presence of the hands seems to influence the distribution of attention across a scene, favouring those near hand items (e.g., Abrams et al., 2008), and increasing the potential for action with such objects by favouring processing via the action linked magnocellular pathway (e.g., Gozli et al., 2012). Using proximal hands in this way is therefore a simple method to potentially increase the participant's focus on acting with the displayed items. Also, there is earlier evidence that the presence of the hands can have some effect on participants' memories for a scene (e.g., Davoli et al., 2012). In particular, it is interesting that Davoli et al.'s (2012) study seemed to indicate that the presence of the hands might lead to a bias towards the detail of the objects close by. When the structure of a stimulus scene was repeated over several trials, the presence of the hands slowed participants' ability to extract this information about the broader scene construction, despite its repetition. Instead, participants were more focused on the specific detail changes of the scene colour. It is unclear, however, whether this bias to detail will be seen for object properties besides colour, and whether any such effects will be equally strong for all of them. The current study will allow us to investigate the influence of proximal hands on the recall of a wider range of object properties.

A final point to be considered is that of the environment in which the stimulus objects are presented. Most of the previous work into perception influencing action has been conducted on low-level stimulus arrays, with simple items such as coloured squares acting as the target stimuli. However, it is important to determine if these effects will still take place with common objects, particularly if the action cues used include power and precision grips, which can be more easily associated with specific objects. Using every-day objects then means we must consider how the background of the scene might have an influence. Previous investigations have studied how the consistency between scene and foreground objects affects both perception and memory. Eye tracking studies have found that it was the inconsistent objects which received longer fixations (e.g., Friedman, 1979; Loftus and Mackworth, 1978), which is suggested to indicate that the inconsistent items take longer to process in the unusual context. When the goal is to identify the objects, some studies have shown a consistency benefit, with more accurate reporting of those objects which matched the background (e.g., Boyce, Pollatsek and Rayner, 1989; Davenport and Potter, 2004), although other studies have suggested that object processing is unaffected by the scene context, as they fail to find any evidence of such a consistency effect (e.g., Hollingworth and Henderson, 1998, 1999). Davenport and colleagues (Davenport and Potter, 2004; Davenport, 2007) support the idea of a strongly interactive model of scene and object identification, where both background and foreground identification are affected by the consistency of the other. This discrepancy has been suggested to be due to the differing sensitivity of the tasks used by the studies to explore the consistency effect. Overall, the findings are mixed, but there is certainly reason to suggest that the initial exploration and inspection of the objects used in the present task will be affected by the nature of the scene behind them.

In terms of memory, studies have shown that it is the inconsistent items that were better recalled than the consistent objects (Lampinen, Copeland and Nueschatz, 2001; Kishiyama and Yonelinas, 2003). Given the previous studies showing that these items receive longer fixations than the consistent items, this is in line with other work showing that increased fixations on objects improves the recall for those items (Hollingworth and Henderson, 2002). From earlier work, it appears that the influence of scene context is an important one in both the initial inspection of, and memory for the objects, and so in the present study, the selection of both stimulus objects and their backgrounds must be carefully controlled.

In order to facilitate the selection of object stimuli, both in terms of the object's associated environmental location and their associated grip type, a pilot study (Experiment 2.1) was conducted, to determine the grips and backgrounds for potential object stimuli. Based on these findings, Experiment 2.2 was conducted using the items selected. In this study, the influence of action preparation on perception and memory was examined. In Experiment 2.2, the action influence was only present at encoding, to determine how the action manipulation at this initial stage of memory acquisition might affect the construction of the memory representation.

3.2 Experiment 2.1: Introduction

In order to select objects appropriate for the later studies, it was necessary to find items that were strongly linked to a particular location and grip type.

Earlier studies such as Davenport and Potter (2004) and Lampinen et al., (2001) showed the importance of the background information in scene perception and memory. According to the interactive link Davenport and Potter (2004) found between background and foreground, it is possible that object identification and later recall could be affected if the items presented do not match the environment. However, it is also interesting to consider whether the background environment will contribute particularly towards the object property memory. For example, perhaps by presenting the objects in a congruent environment, this will trigger associations with using the object in that context. As a result, this might have a particular impact on participants' memory for action-relevant properties in objects that are congruent with the environment. However, the typical finding of the memory studies into the influence of object/scene consistency has been that it is the inconsistent objects that are better recalled, due to the increased time spent fixating these items (e.g., Kishiyama and Yonelinas, 2003). It is therefore not clear what effects we might expect from the scene category in terms of the memory results. In order to address these possibilities, it was decided to have two separate scene types to draw objects from. This allowed for the same objects to be presented both as congruent and incongruent with the particular environment, controlling for any differences that might come from the individual items themselves. In several previous affordance studies (e.g., Tucker and Ellis, 2004), tasks have required participants to determine whether objects come from a garage or kitchen environment, as these are two scene types where the associated objects tend not to overlap. Following this idea, one of the aims of this study was to assess whether potential objects were strongly associated with one of these two locations, and thus allow us to identify a set of objects which were consistently considered to be congruent or incongruent with the background presented.

Objects were also assessed in terms of their association with the two grip types, power and precision. These are considered to be the two main categories of grip, even in terms of neurological representations (e.g., Raos et al., 2006). While most objects, therefore, will fit into one particular group, it was necessary that the objects selected were consistently rated as either power or precision grip compatible. Thus, a second aim of the study was to determine which items were strongly associated with a particular grip type by observers.

Finally, the study considered how participants categorised object properties, in terms of their relevance to either acting with the items, or the appearance of the item. This area does not inform the design of later studies, but is an interesting question. Previous studies that use object properties as a cue or similar frequently assume a difference between features such as shape and colour, (e.g., Tipper et al., 2006). While these assumptions are reasonable, they are usually not the result of any particular investigation into how people judge properties. Furthermore, while more common properties like colour may be relatively easy to class, this may not be as clear for properties like texture, which participants might not be so consciously aware of in their everyday dealings with items. Of course, participants' judgement of properties may not be relevant for how the current task settings affect the perception of object properties: we rarely explicitly consider the shape of a mug when we are reaching for it. However, by investigating what properties people do consider to be most important with regards to viewing or using an object, we can determine which properties it might be of most importance to test for in the future memory investigation.

3.3 Method

3.3.1 Participants

Twelve participants (1 male) with a mean age of 20.2 (SD 2.3) were recruited for the study, with 6 completing the forced choice version of the questionnaire, and 6 the free response version. All participants were undergraduate Psychology students at the University of Dundee, with access to the on-line study recruitment system. Participants received course credit in return for participating.

3.3.2 Apparatus and Materials

The study employed two versions of a questionnaire designed for the purposes of the experiment. One version used AFC questions, while the other allowed free responses to most of the questions. This allowed us to determine if there were other options for the background environment or property type which had not been considered in the choices provided in the forced choice questionnaire. Both questionnaires were divided into 19 sections, for the 19 objects selected as potential stimuli. Within each section, participants were asked to decide what location they would most often find that object; what they thought the main use of the object was; what properties of the object they thought were most related to its use; what properties of the object they thought were most related to its appearance, and what grip they thought the object would be most usually held in.

3.3.2.1 Background. For both questionnaire versions, participants were asked what room they would most expect to find the particular object in the question. The four options in the forced choice questionnaire were 'Garage', 'Kitchen', 'Office' and 'Bathroom'. The objects would be assessed in terms of their compatibility with the Garage and Kitchen environments in particular, in accordance with previous studies which have used objects from these two different environments, (see, for example, Symes et al., 2005; Derbyshire et al., 2006). These two environments are particularly useful for such studies, as there is very little or no overlap between the objects typically found in each area. The alternative two options, Office and Bathroom, were included as they were judged to be sufficiently different from the Garage or the Kitchen, and allow participants a wider range of options. Without these, the participants might opt for a 'best fit' approach for categorising the objects, leading to items being assigned to one location simply on the grounds that they were never found in the alternative environment, rather than due to a true association with the selected background. The presentation order of the four options was randomised across the 19 object sections. The free response option allowed a response of up to 60 characters.

3.3.2.2 Object use. In both versions of the questionnaire, this was a free-response question, allowing a response of up to 60 characters. This question was intended as a check that the participants knew what the object was, since it was not possible to include pictures as part of the questionnaire. Answers to these questions were not used in subsequent analyses.

3.3.2.3 Properties. In both questionnaires, participants were given the examples of shape and colour in the question text, to give them some information as to what was meant by the term 'properties'. For the forced choice version of the questionnaire, eight property options were provided for both the use and the appearance of the object: 'Colour', 'Shape', 'Size', 'Weight', 'Handle orientation', 'Object orientation', 'Decorative patterns' and 'Texture'. Up to eight options could be selected by the participants. The options were not randomised across the 19 object sections. For the free response questionnaire, participants were allowed a response of up to 60 characters.

3.3.2.4 Grip. As it was unlikely that participants would know the terms 'Power' and 'Precision' when classifying grip types, this question was presented as a 2AFC in both questionnaire versions. In the question text, descriptions of the two grip types were given, so that participants were informed about the differences. The descriptive text ran as follows: *'When we use objects, we can hold them in one of two different grips. In one, we hold the object with a PRECISION grip: holding the object between the thumb and fingertips. The other grip is a POWER grip, where the object is held using all the fingers against the palm of the hand.'* Participants would then be asked to select the appropriate grip type when using the object in that question.

3.3.3 Procedure

The study was conducted using an on-line questionnaire, available to people signed up to the Dundee University Experiment Manager System. After participants had registered for the study, they were immediately presented with the questionnaire. No time limit was imposed for completing the study, and participants' responses were saved to the system prior to being downloaded for analysis. To prevent overlap, the system stopped participants from signing up to both versions of the questionnaire.

3.3.4 Design and Analysis

The responses relating to location, properties and grip were considered separately. For the location and properties options, where alternative options could be provided by participants, the free response results were coded and combined with the options in the forced choice questionnaire. This is explained in more detail in the results section. For the questions relating to grip, responses from the two questionnaire types could be combined without any changes. Between-subjects ANOVAs were conducted on the location options for each object to determine which option was most commonly associated with that object. For object properties, pairwise t-tests were conducted to determine if each of the properties was more commonly associated with the use or the appearance of the object. Similarly, independent t-tests were conducted for each of the objects to determine if they were associated with one grip type significantly more than the other.

3.4 Results

The responses generated in the free-response questionnaire were combined with those from the forced choice version. Most of the free responses were the same or very similar to the multiple choice options, and so could be easily incorporated. More detail on the extra options that were produced is given in the relevant analyses sections below. Responses to the question about object use showed that all participants understood what the object was, and how it was normally employed.

3.4.1 Background

Participants responding to the free response questionnaire did not generate many new locations for this section (that is, those not presented in the forced choice questionnaire). The options most commonly provided were 'Garage' and 'Kitchen', or alternative names for locations that were judged to be very similar e.g., 'Utility room' and 'Garden shed' were considered to be similar to Garage, while 'Dining Room' was considered to be similar to Kitchen. Other options provided by the participants were 'Living Room', 'Dark Room', 'Bedroom', 'Hallway' and 'Porch', which were judged to not be close enough to any of the four options provided in the forced choice options. As the aim of the location questions was to determine whether objects belonged most strongly in the Garage or Kitchen, the other options were combined into the single category of 'Other'.

Free and forced choice responses were combined for the following analyses. Seven objects were unanimously classed as belonging in the Kitchen location, so no analyses were carried out on these. These objects were the mug, kettle, eggcup, peppermill, teaspoon, herb jar and juice bottle. For nine of the remaining 12 objects, only two of the three options were selected, so comparisons were made between them using dependent t-tests. In order to calculate the scores, the number of times a location was selected for an object was counted, and the mean calculated by dividing by twelve (the number of participants). These means were compared using a t-test for each of the objects. Table 3.1 displays the means and t-values for these items.

Table 3.1.

Mean location scores and t-values across objects

Object	Garage	Kitchen	Other	t-value
Hammer	0.750	-	0.167	3.92**
Saw	0.833	-	0.083	5.74**
Key	-	0.417	0.583	-1.48
Iron	-	0.750	0.250	1.92
Paint tin	0.750	-	0.167	2.55*
Weed killer	0.917	-	0.083	5.00**
Superglue	0.750	0.250	-	1.92
Clothes-peg	-	0.833	0.167	2.97*
Spanner	0.833	-	0.083	4.18**

**significant at the .001 level

*significant at the .05 level

For the remaining three objects responses were made across all categories, so these were analysed using one-way ANOVAs and post-hoc Bonferroni corrected comparisons. Two of these objects were rated as being significantly more likely to appear in the Garage location: the screwdriver, $F(2,22)= 16.08$, $p<.001$, and the knife, $F(2,22) =7.21$, $p=.004$. The measuring tape was marginally significantly more likely to appear in the Garage, $F(2, 22)=2.96$, $p=.073$.

3.4.2. Grip Type

Selection of power or precision grip was forced choice in both questionnaires, as participants were unlikely to have come across the terms normally, thus data from the two questionnaires could be easily combined by tallying the number of times each grip was selected for each of the objects. Means were calculated by dividing the total for each grip type by twelve, and dependent t-tests were conducted on the resulting averages. In some cases, a participant would decline to respond to the question, leading to proportion scores which did not sum to one: however, this was not a prevalent response.

For nine of the objects, the most associated grip type was unanimously decided, so no further analysis was necessary. Items that were always associated with a power grip were the hammer, saw, paint tin and spanner. Items that were always associated with a precision grip were the key, stanley knife, teaspoon, clothes-peg and superglue. For the remaining ten objects, Table 3.2 displays the mean scores for power and precision responses, and the t-values from the dependent t-tests carried out.

Table 3.2.

Mean power and precision scores and t-values.

Object	**Power**	**Precision**	**t-value**
Mug	0.667	0.333	2.35*
Kettle	0.917	0.083	7.42**
Screwdriver	0.667	0.25	2.80*
Eggcup	0.083	0.917	7.42**
Peppermill	0.667	0.25	2.80*
Juice bottle	0.833	0.167	3.55*
Iron	0.917	0.083	7.42**
Weed killer	0.833	0.167	4.69**
Measuring tape	0.25	0.75	3.32*
Herb jar	0.5	0.417	1.00

**significant at the .001 level

*significant at the .05 level

Together, the location and grip findings allowed us to determine how to class the objects for potential use in subsequent studies. Table 3.3 shows all 19 objects and how they have been grouped according to location and grip type. Those marked with * are the ones which were to be used in further experiments. As well as choosing items that had a clear association with a location and a grip, it was also necessary to consider how easy it would be to obtain examples of the objects that would vary in properties, such as colour or shape, while still remaining a clear example of that item. Due to this, the measuring tape and superglue were among the objects chosen for stimuli, although their

Location scores showed that they were only marginally more likely to be associated with a Garage location.

Table 3.3.

Most common grip type and location associated with objects

Object	**Location**	**Grip Type**
Hammer*	Garage	Power
Saw*	Garage	Power
Mug*	Kitchen	Power
Kettle*	Kitchen	Power
Screwdriver*	Garage	Power
Key	Other/Kitchen	Precision
Eggcup*	Kitchen	Precision
Peppermill	Kitchen	Power
Teaspoon*	Kitchen	Precision
Juice bottle*	Kitchen	Power
Iron	Kitchen/Other	Power
Paint tin	Garage	Power
Weed killer	Garage	Power
Clothes-peg*	Kitchen	Precision
Superglue*	Garage/Other	Precision
Stanley knife*	Garage	Precision
Measuring tape*	Garage/Other	Precision
Spanner	Garage	Power
Herb jar	Kitchen	Equal

3.4.3. Properties

From the free response questionnaire, participants most frequently produced properties that matched the options provided in the forced choice questionnaire, e.g., colour, shape, size, weight and patterns. Participants also suggested handle presence, materials and labels or marks. The property of materials was added to the texture responses, and both labels and marks were added to pattern responses. Handle presence was considered to be more closely linked to shape than handle orientation, but was often produced alongside the shape option.

In the following analyses, the handle presence option was used, but was only taken from the 6 participants who responded via the free response questionnaire. Similarly, handle orientation scores come only from the forced choice questionnaire responses. Also, the property of object orientation was not produced at all in the free response questionnaire, and so again, scores were only calculated based on that set of participants' responses.

The responses from the two questionnaire types were combined, and mean scores for each property were calculated. Scores were calculated as a proportion of the times the property could have been selected, across all the 19 objects, with the exception of the score for the properties of handle orientation and handle presence, where only the 12 objects with prominent handles were considered. The means and standard deviations were then calculated from these proportions. Table 3.4 shows the means and standard deviations for each properties action and visual score, while Table 3.5 gives the means and standard deviations for the separately considered properties handle orientation, object orientation and handle presence. Dependent t-tests were carried out on each properties action and visual score, to determine if there were significant differences in terms of the times each property was associated with use or appearance. The t values and their significance are presented in the final columns of Table 3.4 and Table 3.5 below.

Table 3.4.

Means and Standard Deviations (SD) of property action and visual scores

Property	Action		Visual		t-value
	Mean	**SD**	**Mean**	**SD**	
Colour	0.368	0.597	3.89	1.59	10.76**
Shape	8.47	1.65	8.11	1.7	-1.07
Size	7.21	1.13	5.42	1.22	-7.20**
Weight	4.26	1.69	0.579	0.507	11.67**
Pattern	0.3684	0.761	1.63	1.71	3.19 *
Texture	0.684	0.749	0.211	0.419	-2.96 *

**significant at the .001 level

*significant at the .05 level

Table 3.5.

Means and SDs for properties considered separately

Property	Action		Visual		t-value
	Mean	**SD**	**Mean**	**SD**	
Handle Presence	2.08	1.44	2.50	1.09	-1.82
Handle Orientation	4.75	1.19	2.17	0.866	-9.94**
Object Orientation	1.68	1.01	0.579	0.507	4.85**

** significant at the .001 level

* significant at the .05 level

With the exception of shape and handle presence, all properties were strongly classed as either action or visual. Further comparisons were made between the properties to determine if some properties were more readily associated with either the action or visual category. Some properties, such as object orientation and texture were never produced in the free response category. In the case of texture, free-response participants did produce answers such as ‘materials’, which might have been intended to convey the same idea. However, as it wasn’t certain that participants intended this, it was decided that the data from the forced choice and free response questionnaires would be considered separately.

Scores were again calculated as a proportion of the number of times a property could be chosen as either an action or a visual feature, across all objects and participants. Both action and visual property scores were compared using within-subjects one-way ANOVAs.

For the both the forced choice and free response questionnaires, the ANOVAs showed a main effect of property, indicating that the individual properties were considered to be of differing importance for the use of the objects by participants. This main effect was found to be strong for both the forced choice questionnaire, $F(3.65, 65.68)=92.17$, $p<.001$, and the free response questionnaire, $F(3.49, 62.85) = 31.57$, $p<.001$. Post-hoc Bonferroni comparisons were carried out to determine where the differences lay, and again, the patterns were very similar. Figure 3.1 displays the scores for responses made in both the free and forced choice questionnaires.

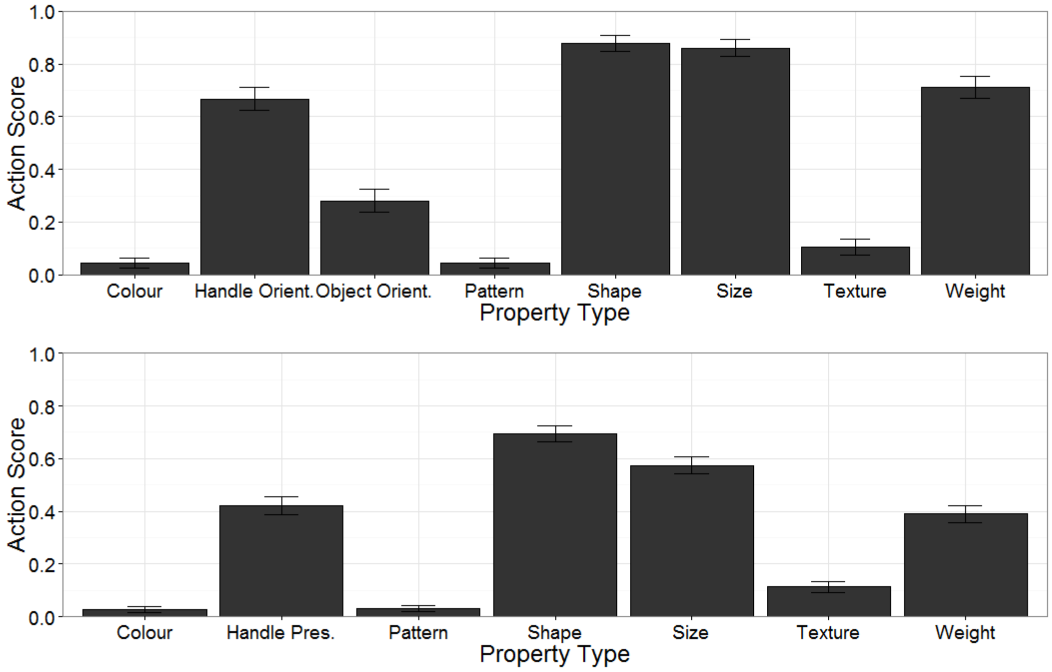


Figure 3.1. Mean scores for the properties when rated as relevant to object use, top: forced choice responses, bottom: free choice responses.

The forced choice response participants selected shape as the most important property for using an object. Size and weight were also often selected; while less than Shape, the amount did not significantly differ (p>.999) Size and weight also did not differ significantly from handle orientation (p>.999), and this property was also only marginally less selected than shape (p=.059). Object orientation was the next most important, chosen significantly more often than the remaining properties, texture, pattern and colour (p<.05). The selections of participants in the free response condition showed a very similar pattern. Again, shape was the most commonly selected action-relevant property, significantly more so than size (p<.001), the next most important. Handle presence and weight were the next most important properties selected, significantly more than texture, pattern and colour (p<.05).

For the assessment of how visually relevant the properties were, a significant main effect of properties was again found for both groups of participants: participants responding to the forced choice questionnaire showed a strong main effect, F(3.19, 57.42)=56.81, p<.001, as did those participating in the free choice version, F(4.25, 76.56)= 20.14, p<.001. Figure 3.2 displays the mean scores for the visually relevant ratings, and Bonferroni corrected post-hoc tests were again conducted.

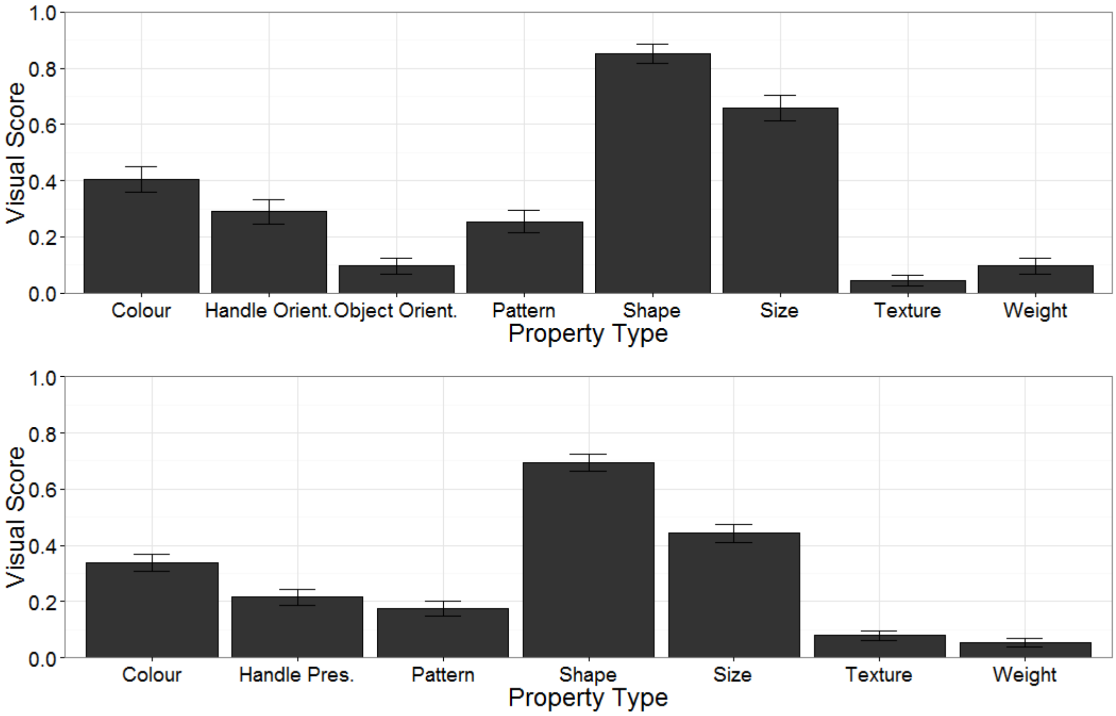


Figure 3.2. Mean scores for the properties when rated as relevant to object appearance, top: forced choice responses, bottom: free choice responses.

For participants responding to the forced choice questionnaire, shape was selected as the most important visual property, significantly more than any other (all ps<.001). Size was selected as the next most important, significantly more than colour, patterns and handle orientation (p<.001). The least selected options were weight, orientation and texture, with no significant difference between them (p>.999). Similarly, participants using the free response questionnaire selected shape as the most important visual property, significantly more than size, handle presence and colour, (p<.001). These three properties were selected equally often as important visual properties, (p>.99). Colour and size were also selected significantly more than pattern, (p<.001), although handle presence and pattern did not differ (p>.999). Both pattern and handle presence were selected significantly more than weight and texture. These two properties did not significantly differ in their selection (p>.999).

3.5 Discussion

The findings from Experiment 2.1 were used to inform decisions about the objects that will be used in future studies. By asking about the typical location and grip type of a set of everyday objects, we can go some way to determining if the objects are appropriate for use as stimuli, due to their associations with the relevant factors. Data from these questions is simply confirmatory, but nevertheless important for ensuring the validity of the studies that follow.

The data gathered from the questions regarding properties are not intended to inform the design of the later studies. These property judgements are entirely subjective on the part of the participants, and so it would not be wise to try to draw strong conclusions on the basis of these data. However, it is interesting to consider how these subjective ratings relate to previous literature and assumptions about object properties.

Firstly, it is clear from the questionnaire data that some object properties are seen as important when considering objects in terms of both appearance and use. This is particularly true for the properties of shape and handle presence (which, it could be argued, is strongly linked to the shape of an object). Both these properties were equally often selected as action and visually relevant properties, indicating they are considered to be equally important to the appearance and use of an object. Indeed, this makes sense: not only is an object's shape important to its use, for example, by informing the user of the appropriate grip, it is also an inherent part of the object's identity as that particular object. There are perhaps some links here to Jeannerod's (1994) suggestions that properties are not permanently either pragmatic or semantic, but dependent on the situation for how relevant they are to an action or not. Interestingly, while colour was strongly rated as a visual property, and weight as an action property, participants still occasionally selected colour as action-relevant and weight as visually-relevant. This is in some way surprising, given that Jeannerod (1994) suggested that these two properties were the ones which would be most strongly linked to only one classification. It is possible to consider situations in which a property could be relevant to its alternative category, (e.g., the colour of the element on a stovetop indicates whether it is hot, and so informs how we act with it), but this most likely reflects a problem with measuring properties in this subjective manner. It is much harder to tell exactly how participants were interpreting the questions.

We can link these findings to studies which have used this assumed difference between action and visual properties. Tipper et al. (2006) compared affordance effects using shape or colour cues, while Phillips and Ward (2002) did the same using texture and colour. These studies do not report any particular process used in deciding how to categorise the properties. Instead, it was simply assumed that the divisions fall in this way. The assumptions made are reasonable, and borne out by the ratings generated here: while shape may be important both visually and for action, it was rated as more action relevant than colour; and texture, while less often selected, was more so for action as well. However, given that there may be differences in how people rate properties depending on the task, it could be useful to make some checks before designing stimuli.

A final point to consider is the absence of any orientation-related properties in the free response version of the questionnaire. It is tempting to consider that this might reflect ideas such as Derbyshire et al. (2006), where orientation is suggested to be a more extrinsic property and so not an integral part of any object representation. However, this is perhaps too speculative a suggestion based only on the current questionnaire study. Without the suggestion in the forced choice version of the study, participants may simply have not thought of orientation as relevant to the objects at all. Perhaps if the questionnaires had included visual images of the objects being tested, then this would have prompted more consideration of orientation as a relevant property.

While the conclusions we can draw from the properties section of the questionnaires are perhaps slightly limited, the other sections have provided us with a set of object stimuli and their associated classifications for location and grip type. These can now be used to inform the analyses of the studies that follow.

3.6 Experiment 2.2: Introduction

Previous work has shown that action preparation can influence the perception of objects, biasing attention towards relevant items. Furthermore, memory representations can be affected by the nature of the task, with the relevant objects better recalled than irrelevant items. However, much of the previous work on how memory representations can be affected has focused on the influence that action has either when the task is being performed, when it might influence the on-going decisions the participant makes (e.g., Droll and Hayhoe, 2007), or after the task, where the resulting memory may have been influenced by the actions that have been performed (e.g., Tatler et al., 2013). Very little research has addressed how action preparation might also influence the resulting representations. The use of preparation means that the study paradigm would involve no physical interaction with the objects; instead, the actions are formed almost as an aside to the main task. This can be seen in earlier on-line studies, such as Fagioli et al. (2007), where the action preparation was interrupted by the search task. Given the strong link between action and perception, and perception and memory, it is expected that action preparation will affect not only the on-line examination of the scenes, but also the representations that are formed.

In order to examine how perception is affected, the eye movements of participants will be tracked as they view the scenes. Eye movements are an invaluable measure, as they allow us to determine how the presence of action preparations affects how participants perform a strongly perceptual task. Another advantage of the measure is that it allows us to determine which objects are not fixated in the course of a task. Following the findings that fixated items are better recalled at test (e.g., Hollingworth and Henderson, 2002), it is also the case that non-fixated items will not be recalled well, if at all. Thus, the records of the eye movements allow us to remove any items that were not fixated, and therefore would not be expected to be strongly maintained in the representation.

Memory measures, on the other hand, focus on participants’ ability to recall particular properties of the displayed objects. A large amount of memory literature shows that object features are stored in a relatively independent way, even without the influence of task (e.g., Fougnie et al., 2013). However, various studies have shown that task will also influence the memory for properties, making them a useful measure for the influence of action preparation on object representations (see e.g., Triesch et al., 2003; Tatler et al., 2013).

The work previously conducted in Experiment 2.1 provided a set of objects that are strongly associated with one of the two main grip types. These grips are easy to describe to participants in order for them to prepare them, and most objects are closely associated with one or the other. Thus, the influence of the grips can be examined in terms of the specific objects that relate to them. The presence of the hands at the edge of the display screen is used as another means of manipulating the participants' action intentions. This manipulation is not particularly linked to specific objects in the display; instead, it allows us to determine if the perception and memory of objects in a particular location are affected. Typically, studies which have used the presence of the hands near the screen have shown that participants will allocate more attention to items which are close to the hands (Davoli et al., 2010; Abrams et al., 2008). Thus, in the present study, items which are positioned at the left and right of the screen will be closer to the hands than those in the centre, so may receive more attention during the encoding stage, and be better recalled at the subsequent memory stage.

By using real objects presented against real backgrounds, we aim to determine whether the presence of action preparations during the encoding of information influences both the immediate allocation of attention to the objects, and the subsequent storage and retrieval of information in memory.

3.7 Method

3.7.1 Participants

Participants were 46 undergraduate students (13 males), with a mean age of 23.4 (SD: 3.6). All participants had normal or corrected-to-normal vision. Handedness and eye dominance were measured by self-report: the sample contained 8 left handers and 15 participants showing left eye dominance. They received course credits or payment (£3) for their participation in the study.

3.7.2 Apparatus and Materials

3.7.2.1 Object stimuli. Using the results of Experiment 2.1, 12 objects were selected from the original 19 presented in the questionnaire. To be selected, objects had to be clearly associated with one location (either garage or kitchen) and one grip type (power or precision). The object also had to be available in a range of colours and shapes, to allow different exemplars to be obtained for the stimulus sets. In the final set, 6 items were associated with kitchen locations, and within that group, 3 were classed as precision items and 3 as power items. The other 6 objects were associated with a garage location, and again, half were precision and half were power grip objects. (See Table 3.3. for the selected items).

To create the scenes viewed by the participants, three sets of the 12 selected objects were obtained. The 12 object types were repeated across the three groups, but the properties of colour and shape differed across the sets (i.e. each set contained a mug as an object, but each mug differed from the other in these intrinsic properties).
Three scenes were created: a kitchen scene, in which each set of objects was placed on a work surface; a workshop scene, in which the objects were positioned on a work bench and a neutral scene, in which the objects were positioned on a table top, with no distinguishing background behind them. Figure 3.3 shows an example of one of the versions of the neutral environment.

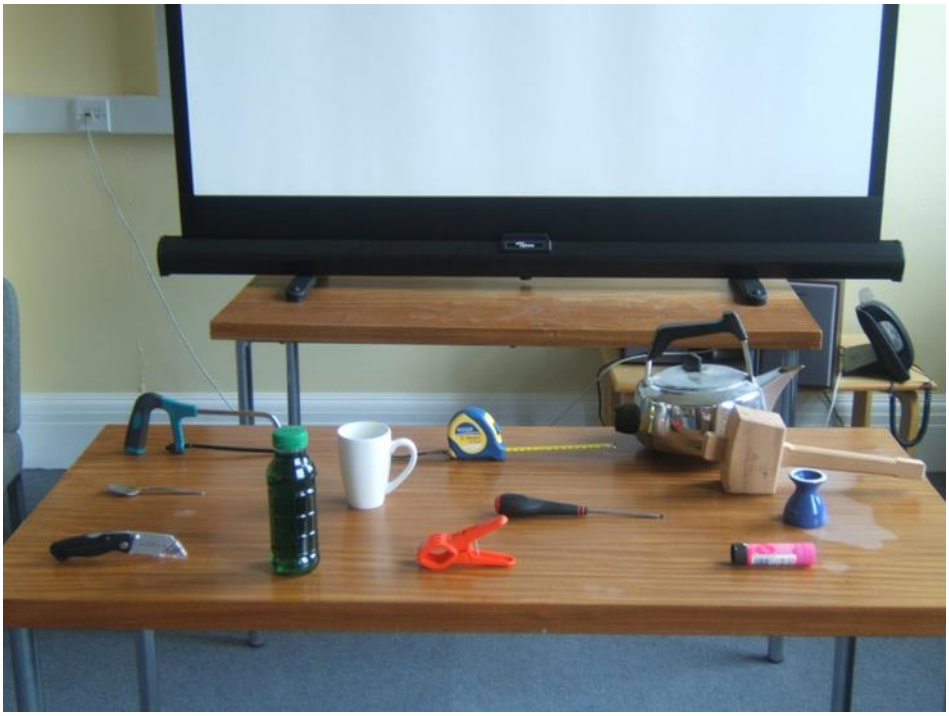


Figure 3.3. Example of neutral scene and object group viewed by participants

The extrinsic properties of orientation and position were counterbalanced across the three scenes, so that objects were equally likely to appear in the centre or at the edges of a scene, and at different orientations over the three environments. For each environment, three scenes were created, each featuring one 12-item set of objects. In total, nine stimulus scenes were created.

3.7.2.2. Stimulus questionnaires. For each object, five questions were created, to test participants' memory for the objects presence, colour, shape, position and orientation. These were designed as four-alternative forced choice (AFC) questions, with the exception of orientation, which was tested using a 2AFC question. For presence and colour, the questions presented the participant with four words (object or colour names), of which one was the correct response. For shape, the four options were line drawings of shape variations of the target. For orientation, two drawings of a standard example of the object were presented, shown orientated to the left or right. These orientation drawings did not appear as any of the options for shape, and were not the actual shape of the object (this was explained to participants). For position, a line drawing of the scene outline was presented, with four positions indicated on the table top, labelled A-D. The incorrect position options corresponded to the positions of other objects within the scene. In all cases foils were plausible for the type of object under test. Figure 3.4 displays examples of the questionnaire images for a single object.

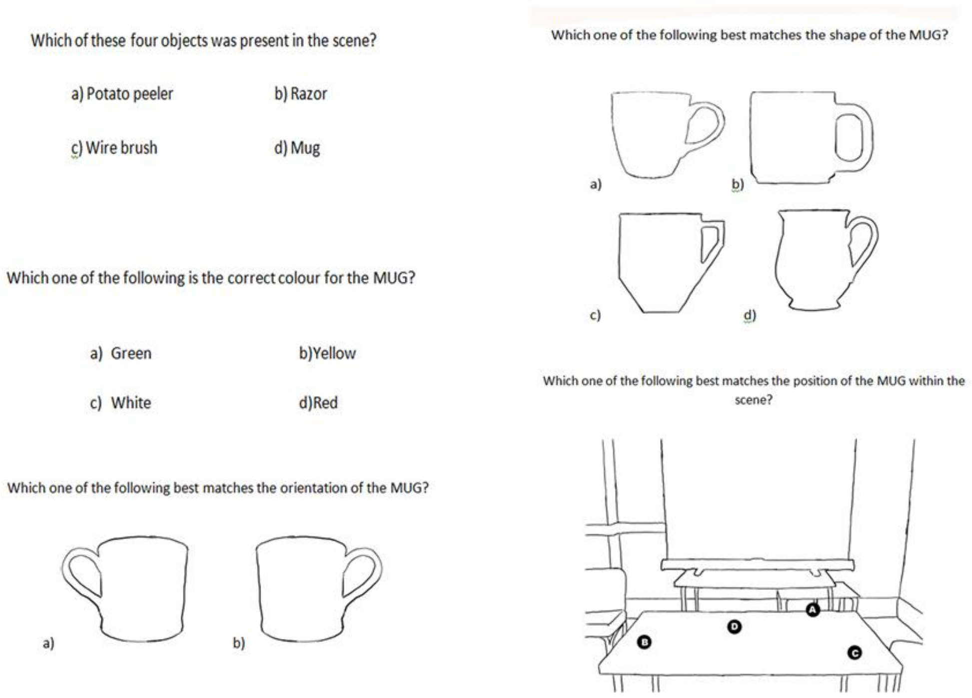


Figure 3.4. Example questions for the presence, colour, orientation, shape and position of a mug in a neutral environment

Stimulus presentation and response collection was controlled by scripts written in MatLab, using the PsychToolBox and EyeLinkToolBox extensions (Brainard, 1997; Pelli, 1997; Cornelissen, Peters and Palmer, 2002). Both the stimulus photographs and the question screens were displayed to the participants on the display monitor of the EyeLink 1000, at a resolution of 1024 by 768.

3.7.2.3 Eye tracking. Participants' eye movements were monitored and recorded on the EyeLink 1000 eye tracker, set to track the participants' dominant eye. A 9-point calibration grid, followed by a 9-point validation grid were used to fit and test the spatial accuracy of the eye tracker at the start of each experiment. If the validation procedure showed a mean spatial accuracy worse than 0.5 degrees or a maximum spatial accuracy worse than 1 degree, calibration and set up were repeated. Saccades were detected using the standard SR Research algorithm.

3.7.3 Procedure

Each trial began with a central fixation marker, with scene onset triggered by the experimenter. The scene was then presented for 20 seconds. Scene presentation order was counterbalanced across participants.

Participants were assigned to four experimental groups, with each group required to maintain a different pose with their hands during scene presentation. In the passive viewing condition, participants simply observed the scene with no further action pose (Figure 3.6a). In the 'hands' condition, participants were asked to hold the edges of the monitor with both hands; that is, they sat with their arms outstretched, and hands touching the edges of the display screen (Figure 3.6b). In the two grasp conditions, participants held a device which ensured they were making either a precision grip (finger and thumbs gripping a smaller object; Figure 3.6c) or a power grip (the whole hand grasping a large object; Figure 3.6d). This device was similar in dimension to the response device used by Symes et al. (2008) in their change detection study, with a power grip component of 3.5 cm diameter, and a precision grip component of 1.25 cm in width and length. To avoid using the grip names, in case this caused participants to make conscious associations between their actions and the stimuli, the power component was referred to as the black section, and the precision component as the white section (see Figure 3.5).

Figure 3.5. Grip device used to maintain power (black component) or precision (white component) grips

Action poses were terminated at the end of scene presentation on each trial (that is prior to the memory questions). Figure 3.6 shows the poses adopted by participants in the four conditions.

Figure 3.6. Top left- bottom right: examples of Passive, Hands, Precision and Power intention conditions

The monitor was positioned 45 cm from the observer for all conditions. In the grip conditions, the placement of the grasp device meant the dominant hand was 30 cm from the screen.

After viewing the scene, participants were presented with the object questions for the object set they had just observed. Questions were presented on the same monitor on which the scenes had been viewed and objects were tested in random order for each participant. For each object, the question about its presence was asked first, followed by the questions relating to its particular properties, in random order.

Participants responded to the questions by pressing keys labelled ‘A’, ‘B’, ‘C’ and ‘D’ on the keyboard (actual keys were the numbers 1-4 on the keyboard number pad) corresponding to the option they believed was correct for that question. After answering the 60 questions for that scene, they were re-calibrated on the eye-tracker and asked to resume the intention position they had been holding. They then followed the same procedure for the next two scenes and associated question sets.

3.7.4 Design

One between-subjects independent variable of viewing condition was manipulated; this had four levels, passive viewing (baseline), viewing with hands on the edge of the screen, and viewing whilst making a grip gesture, either power or precision The dependent variables of the study were the participant's memory for the displayed objects, and their properties (colour, shape, position and orientation), and their eye movement behaviour as they viewed the scenes. The measures taken from the eye tracking for further analysis were the average fixation number (the average number of times objects were fixated during the scene presentation), the average fixation duration (the average total time participants spent fixating objects during scene presentation) and the primacy fixation number (a measure of how early or late in the presentation period objects were first fixated by participants).

3.8 Results

Objects that were not fixated were removed from the analyses that follow, as we were interested in how the action postures might affect the extraction of information within and between fixations. The influence of the intention condition was examined both for the eye-movements of the participants, and their performance on the memory questions. The influence was examined in terms of effects on objects classed by their grip type (power or precision), their location within the scene (left, right or centre), and their congruency with the background environment (congruent or incongruent). As well as how fixations related to objects within the scene, the way in which intention affected the overall inspection of the scene was also examined.

In reporting the results of ANOVAs and other analyses, full statistical results will not be given if the results are such that F values are less than 1. This will be so for analyses in all following chapters. Similarly, all post-hoc investigations are carried out using Bonferroni-corrected tests.

3.8.1 Influence of intention on inspection

3.8.1.1 Scene inspection. Before considering how the intention groups might affect the deployment of attention to individual objects in the scenes, we examined how the overall inspection of the scene might be affected. In particular, we were concerned with how the presence of the hands might influence inspection, as there are several studies which suggest an influence of the hands on the distribution of attention, with increased attention to items and areas near the hands. Following this idea, scene inspection was analysed by splitting the scenes into thirds-left, centre, and right- and using these as the regions of interest for analysis. The average total fixation number and average total fixation time across all scene areas were examined as functions of the intention groups. A third measure of fixation was the average first fixation to a region. By determining how many fixations participants made within a trial, it was possible to determine an average score which showed how early (or late) in the trials participants first made a fixation to a particular scene region.

Mixed factorial ANOVAs were conducted for the three levels of scene region (left, centre and right), and the four levels of intention group (passive, hands, power grip and precision grip). The total fixation time spent on each region was first examined.

For fixation numbers, a significant main effect of the region was found, $F(1.80,73.89)=82.03, p<.000$, with more fixations on the central region (M=26.8) than the left (M=18.6) and right (M=16.4, ps<.01), but no influence from the intention group, or interaction between them (Fs<1). As there was a strong tendency for participants to fixate the central region (in line with the standard finding of a central bias in scene viewing), a second ANOVA was run without the data for the central region, in case this was masking other effects. Without this data, the main effect of region was still present, $F(1,41)= 5.12$, $p=.029$, with participants making more fixations on the left hand side than the right. However, there was still no main effect of the intention group, and no interaction between them.

Similar findings emerged when the average total fixation time was used as the measure. A main effect of scene region emerged, $F(1.87, 76.71)= 71.55$, $p<.001$, but this was again driven by the participants tendency to fixate the centre (M=7744 ms). When only left (M=5290 ms) and right (M=4877 ms) regions were compared, this main effect disappeared, $F(1,41) = 2.11$, $p=.154$. The effect of intention and potential interaction between intention group and scene region were not significant in either analysis (all Fs <1).

Examining how the intention group might influence the scene regions in terms of the average first fixation to a region was more promising, as it allowed us to examine the initial explorations that participants made to the scenes. It was found that all participants made their first fixations to the central region, presumably due to the presentation of a drift correction point in the centre of the blank screen that preceded the stimulus scene. As a result, the central data was again removed to prevent the results being skewed. Here, it was found that there was a strong main effect of the scene region, $F(1,41) = 23.03$, $p<.001$, with fixations made earlier to the left region of the scene (M=8.3) compared to the right, (M= 17.8). No main effect of the intention group ($F<1$) was found. However, there was also a significant interaction between the intention group and the scene region, $F(3,41) = 3.15$, $p=.035$. Post-hoc comparisons showed that this interaction was driven by the power and precision groups in particular. Both showed significantly earlier looks to the left hand side of the scene than the right (precision left M=5.4, power left M=6.0; precision right M=22.4, power right M=19.6, $ps<.05$). Meanwhile, participants in the passive and hands intention groups appear to first fixate the left and right sides equally early on in the trial. Figure 3.7 displays the average first fixation number to the left and right regions across the four intention groups.

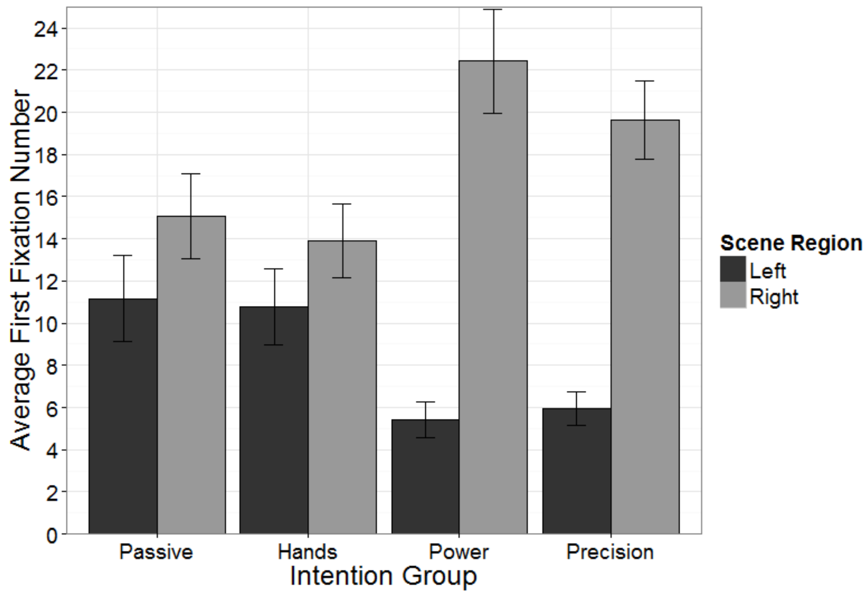


Figure 3.7. Average first fixation on left and right of scene across intention groups

When exploring the presented scenes, it seems that participants tended to fixate the left side of the screen earlier than the right side, regardless of the intention condition they were in. However, this pattern is at its strongest for those participants who formed power or precision grips during the scene viewing stage.

3.8.1.2. Object category. Analyses were conducted to determine if object category (kitchen or garage) and its congruency with the backgrounds (garage, kitchen or neutral) had an influence on the way particular objects were examined. Measures of fixation numbers and durations on the objects in each category were analysed using within subject ANOVAs.

For measures of average total fixation time, a main effect of the object category was found, $F(1,45) = 44.00$, $p<.001$, such that participants spent significantly longer fixating objects compatible with a garage environment (*M*=1848 ms) than a kitchen environment, (*M*=1519 ms). No main effect was found for the scene category, $F(2,90) = 1.53$, $p=0.22$. However, the interaction between scene and object category was significant, $F(2,90) = 6.19$, $p = 0.003$. The same pattern of results was found for fixation number, with a main effect of object category, $F(1,45) = 55.71$, $p<.001$, again due to more fixations on garage type objects (*M*=6.5) than kitchen objects (*M*=5.2), but no significant effect of the scene environment, $F(2,90) = 1.43$, $p=0.25$. The interaction between the two was again significant, $F(2,90) = 6.74$, $p = .002$. Figure 3.8 displays the findings for the measure of fixation numbers and total fixation duration.

The interactions for both measures showed that the tendency to fixate garage objects more than kitchen objects was consistent across all scene types (all ps<.05). Looking at the two object categories individually showed that kitchen objects were fixated less often in the kitchen environment (M=4.7) and for less time (*M*=1409 ms) compared to garage (fixation number *M*=5.3, fixation duration *M*=1592 ms) or neutral environments (fixation number *M*=5.5, fixation duration *M*=1556 ms, all ps<.05), while the inspection of the garage objects was unaffected by the environment (fixation number, p=0.22; fixation duration, p=0.34).

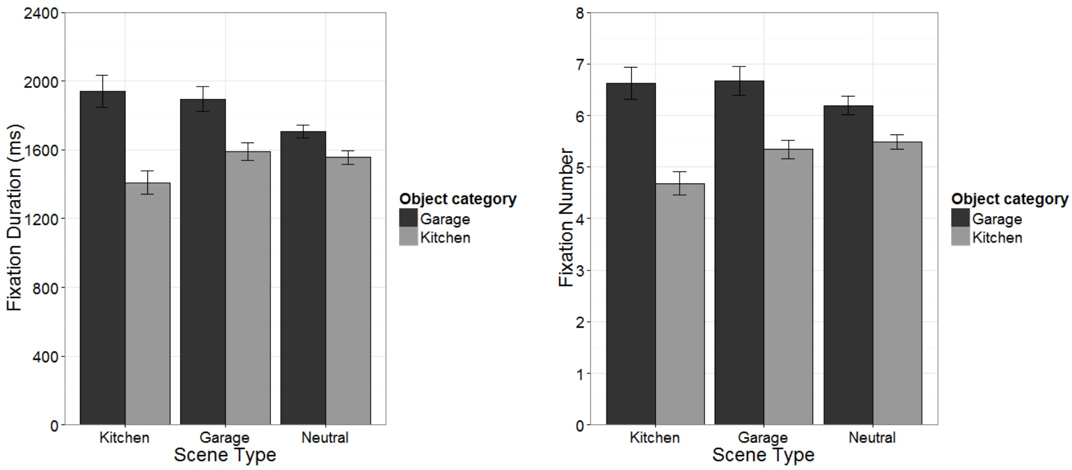


Figure 3.8. Mean fixation durations (left) and fixation numbers (right) to object types across the three scene categories

3.8.1.3 Object grip type. We examined whether the grip associated with the stimulus objects and the intention position maintained by the participants would have any influence on their inspection of the objects displayed. Mixed factorial ANOVAs were conducted for the two types of grip (power and precision), and four levels of intention group (passive, hands, power grip and precision grip). Both average total fixation time and number of fixations were used as measures.

Measures of total fixation time showed a main effect of the object grip type, $F(1,42) = 63.60$, $p<.001$, but not of intention, $F(3,42) = 1.06$, $p = .378$. Participants spent longer fixating the power grip-compatible objects (*M*=1822ms) than precision grip-compatible objects (*M*=1536ms). The interaction between the two factors was significant, however, $F(3,42) = 3.82$, $p = .017$. Post-hoc comparisons showed fixation durations on objects compatible with precision grip manipulations differed depending upon the intention condition under which they were observed: total time spent fixating these objects was significantly longer when participants were generating a precision grip *M*=1672 ms) than when they were generating a power grip (*M*=1444 ms, $p < .05$) or were grasping the monitor sides with both hands (*M*=1415 ms, $p < .05$). No other comparisons for precision grip objects were significantly different. The total time spent fixating objects compatible with a power grip was not influenced by the intention condition in which it was observed.

Figure 3.9 shows the average total fixation times on object types across the intention conditions.

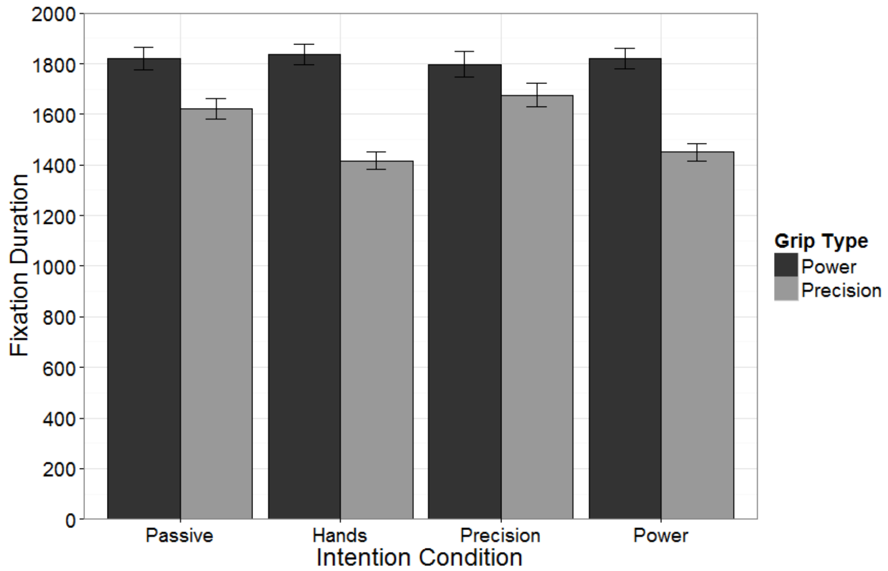


Figure 3.9. Average total fixation times across intention groups and object grip types

The same analyses were conducted for the measures of fixation number, and a similar pattern emerged. There was a main effect of object grip type, $F(1,42) = 108.88$, $p<.001$, with more fixations made to power grip-compatible items (*M*=6.7) than precision-compatible items (*M*=5.1) and only a marginal effect of intention condition, $F(3,42) = 2.55$, $p = .067$, with a significant interaction between the two, $F(1,42) = 2.92$, $p=.045$. Again, participants in all intention groups did not differ significantly in the number of fixations they made to power-grip objects, but showed a significant difference in the average number of fixations made to precision objects across the groups. Marginally more fixations were made to the precision-grip objects (*M*=5.7) by participants in the precision grip group, compared to those in the power (*M*=4.5, p<.06) or hands intention conditions (*M*=4.6, p<.08). Figure 3.10 displays the data for the fixation number analysis, which shows clearly that there is a similar pattern occurring with regards to the fixations to precision-compatible objects when participants are in the hands or power intention condition.

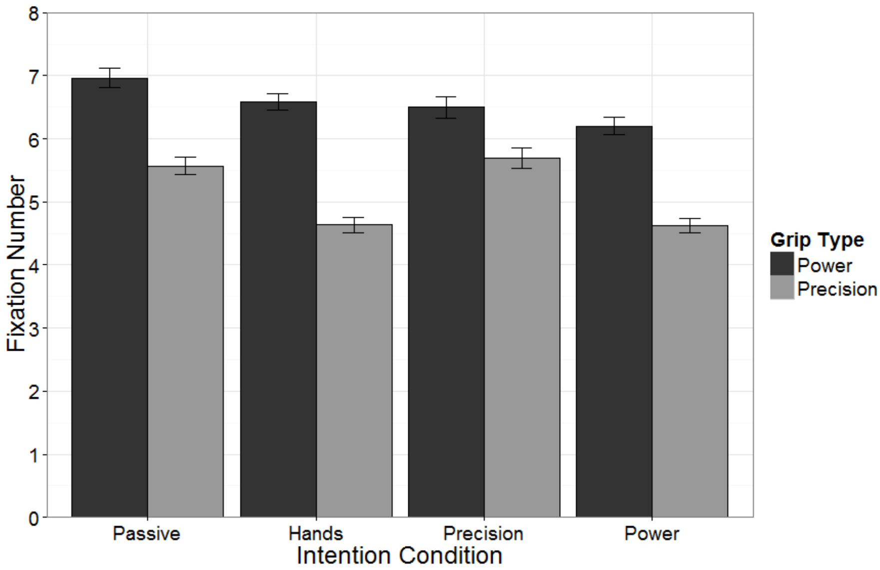


Figure 3.10 Average fixation numbers across intention groups and object grip types

3.8.1.4 Object position. To examine the influence of position on the fixation measures, a similar approach was used to that when analysing inspection at the scene level: objects were coded as being located on the left, right or centre of the screen. This analysis was conducted largely to further investigate the influence of the proximity of the hands to the objects, and how it might affect the attentional allocation to objects at the left and right of the screen. Mixed factorial ANOVAs were conducted on the three levels of position (left, right and centre) and four levels of intention (passive, hands, precision grip and power grip). As DVs we measured total fixation time and number of fixations on objects, and the ordinal number in the trial on which an object was first fixated.

For total fixation time on objects there was no main effect of the intention group (F<1), but there was a main effect of position, $F(2,84) = 4.31$, $p=.016$. Post hoc comparisons showed this was driven by participants' tendency to fixate objects on the right hand side (*M*=1763 ms) for shorter periods of time in comparison to those on the left (*M*=1552 ms, p<.05). There was also no interaction found between the intention group and the objects' positions (F<1).

For the measure of fixation number, a marginal main effect of intention was found, F(3,42) = 2.58, p=.066, as well as the main effect of position, F(2,84) = 9.74, p<.001, and no interaction between them. The main effect of position was due to the greater number of fixations made to the right side of the scene (*M*=5.2) compared to the left (*M*=6.0) and centre (*M*=6.1, p<.05). After splitting the data into the individual intention groups, it was found that the marginal effect came from the precision and power grip groups. Participants in both these groups made significantly fewer fixations to objects placed on the right hand side (power *M*=4.7, precision *M*=5.1) than those in the centre (power *M*= 5.9, precision *M*= 6.3, all ps<.05). Figure 3.11 displays the mean fixation duration and fixation number data for the scene positions across the four intention groups.

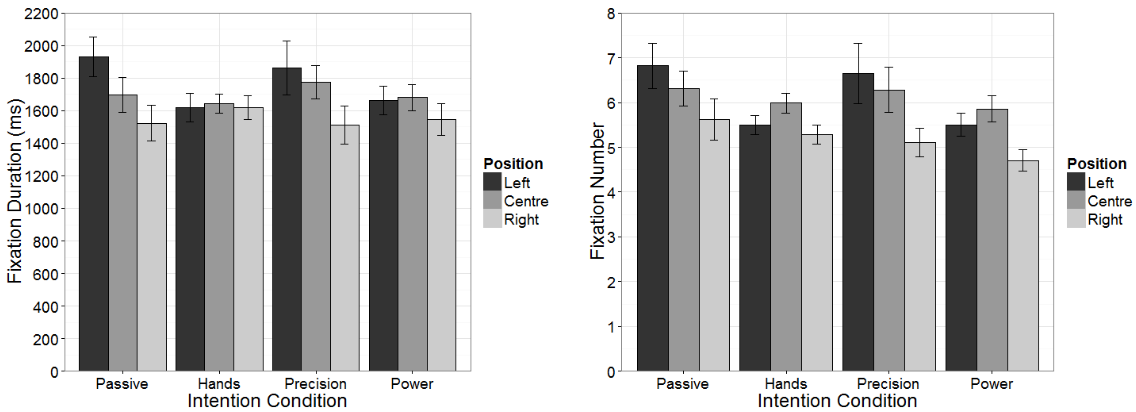


Figure 3.11. Mean fixation durations (L) and fixation numbers (R) across position and intention groups

Measures of the average first fixation to the objects showed main effects of the position, F(2,84) = 14.26, p<.001, but not of intention (F<1), although there was an interaction between them, F(6,84) = 2.75, p=.017. The main effect was driven by a tendency to first fixate the objects on the right hand side of the screen (*M*=23.5) significantly later than the left side of the screen (*M*=16.6, p<.01).

To explore the interaction between intention and position, the data were split by both the separate positions, and the intention groups. Three one-way ANOVAs were conducted across the four intention groups, each using data from only a single location. For objects on the left of the scene there was an effect of intention, $F(3,42) = 4.82$, $p=.005$. Post-hoc tests revealed that participants in the hands condition looked later to objects on the left (*M*=20.6) than subjects in the precision grip (*M*=13.8, $p < .05$) or power grip (*M*=14.0, $p < .05$) conditions. For the other positions in the scene there were no effects of intention condition.

Examining the differences in position within each of the intention groups showed main effects for the power and precision grip groups. For these conditions, on average the first fixation to the right hand side (power *M*=24.3, precision *M*=27.8) was significantly later than that to the left hand side (power *M*=14.0, precision *M*=13.8) and the centre (power *M*=17.2, precision *M*=17.7; all differences $p<.05$). A similar pattern is seen for participants in the passive intention group, but this was not significant. The hands intention group shows no such influence, with a more even distribution of fixations across the scene. Figure 3.12 shows the average first fixation number to objects across the screen as a function of the intention condition during viewing.

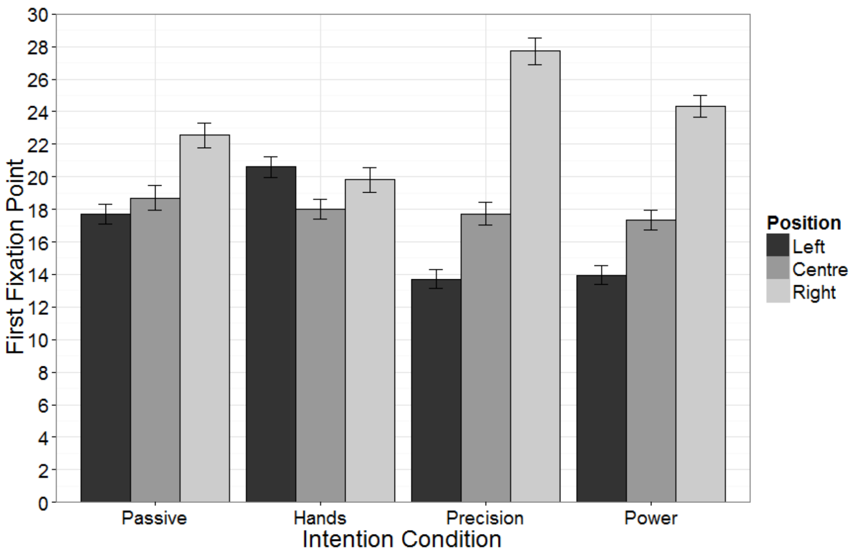


Figure 3.12: Average first fixation number across intention groups and object positions

A possible reason for the inspection patterns seen in participants in the grip groups was that they were spending more time on items compatible with their grip posture on the left hand side of the screen, reducing the time spent on the right hand side, and increasing the time it took them to first fixate that area. To investigate this, each intention group was analysed in terms of the influence both grip and position had on the fixation measures.

Passive. For measures of fixation number, there was a main effect of object grip type, F(1,10)=18.44, p=.001, with power items receiving more fixations (power *M*=7.0, precision *M*=5.5) but no effect of position, F(2,20) = 2.34, p=.12, and no interaction between them, F(2,20) = 1.44, p=.26. A similar pattern was seen for the fixation duration measures, with longer fixations on power grip objects, F(1,10)=5.46,p=.042, (power *M*=1825 ms, precision *M*=1616 ms), and a marginal difference between the object positions, F(2,20)= 3.45,p=.052 with shorter average fixations on right hand side objects than the left (right *M*=1519 ms, left *M*=1938 ms, p=.01), but still no interaction between them (F<1).

Hands. For fixation number, there was a main effect of both grip, F(1,11) =49.65,p<.01, with more fixations on power grip objects (power *M*=6.6, precision *M*=4.6). A main effect of position was found, F(2,22)=3.96, p=.03, with means indicating more fixations made to the centre of the screen (*M*=6.1) than the left (*M*=5.6) or right (*M*=5.2), although post-hoc comparisons did not reveal a significant differences between these fixations (ps>.05). No interaction between the factors was found F(2,22) = 1.87, p=.17. Measures of fixation duration showed only a main effect of grip, F(1,11) =47.39,p<.01 with an advantage for power compatible objects, (power *M*=1836 ms, precision *M*=1426 ms)and no effects of position, or interactions.

Precision. Fixation numbers showed more fixations on power grip objects, F(1,10)=11.57,p=.007, (power *M*=6.5, precision *M*=5.6) and a marginal effect of position, F(2,20)=3.36,p=.055, with more fixations on objects on the left hand side (*M*=6.7) than the right *(M*=5.1, p<.05); but no interaction between them (F<1). Measures of fixation duration showed a marginal effect of the grip, F(1,10)=4.30, p=.065, (power *M*=1792 ms, precision *M*=1652 ms)but not position, and no interaction between them (F<1).

Power. Significantly more fixations were made to power grip objects, F(1,11)=57.25, p<.001, (power *M*=6.2, precision *M*=4.4) and to items on the left hand side than the right hand side, F(2,22)=10.87,p<.001 (left *M*=5.6, right *M*=4.5, p<.05). In fixation duration measures, significantly longer fixations were made to power grip objects, F1,11)=33.38,p<.001, (power *M*=1823 ms, precision *M*=1572 ms) but no difference was found for the fixation durations on objects at each position, $F(2,22)=1.48, p=.250$. Neither measure showed an interaction between the two factors ($Fs<1$).

The tendency to fixate power objects more was consistent across all intention groups, but there seems to be no influence of the object grip type on the fixations at particular locations in the scenes, when the individual groups are examined. Only when all positions were examined in a single analysis did the effect occur. While participants in the power and precision intention conditions did show the expected increased fixations to the left hand side of the screen, this did not appear to be due to spending increased time on the objects with grip types compatible with the posture they were maintaining.

Thus far, the investigation of the influence of action postures on inspection patterns has shown the postures to have some influence on the way in which the scenes were viewed. In general, participants tended to inspect the scenes by moving from left to right. This was so at both the scene and object level. The intention condition of the participant influenced this left-to-right progression, with participants in the power and precision conditions spending longer on the left hand side, and not inspecting the right hand side until later in the trial. In contrast to this, participants in the hands condition did not show this pronounced left-to-right progression, showing a pattern of first fixations which are more evenly spread across the scene.

While different scene backgrounds were used, this factor did not appear to influence inspection, and participants consistently spend more time fixating objects that were compatible with a garage location, regardless of the actual scene background.

The intention condition seemed to affect the fixation patterns in regards to the object grip types. Those participants in the hands and power intention conditions made fewer fixations, and spent less time fixating objects that were compatible with a precision grip, compared to conditions in which the participants formed the precision grip during the viewing period.

3.8.2 Influence of intention on memory

The memory data were first examined by determining whether the memory responses were above chance level for each property question, across the intention groups. Intention groups were considered separately at this stage, as later analyses would require examining the memory performance of each intention group independently also. Table 3.6 presents the mean scores for the property questions across the four intention groups. By analysing the properties separately, we can examine differences that emerge between the property types, and determine if these can be related to previously considered differences in the properties, such as their action or visual relevance (e.g., Tipper et al., 2006), and their relevance to the action manipulations participants performed.

Table 3.6.

Mean memory scores for individual property questions across intention groups

	Question				
Intention Group	**Colour**	**Shape**	**Orientation**	**Position**	**Presence**
Passive	0.553	0.520	0.583	0.627	0.856
Hands	0.563	0.528	0.593	0.616	0.808
Precision	0.515	0.492	0.626	0.551	0.841
Power	0.486	0.484	0.551	0.569	0.789

One-sample t-tests were conducted to determine if responses were above chance. Performance on the memory questions for the properties of colour, shape and position was found to be above chance (0.25) in all cases (all ps < .01). For the questions regarding orientation, the use of 2AFC questions meant chance was rated at 0.50, and again, the mean responses across the intention groups were found to be significantly above this level (all ps<.05). The object presence question was discarded, as performance in trials 2 and 3 were near ceiling, presumably because participants realised that the same types of object were present in each scene they viewed: it was only the properties of the object that varied between trials.

3.8.2.1 Object category. An initial analysis of how participants' overall memory score was affected by the object and scene type used the memory score across all responses to the three intrinsic property questions, (colour, shape and position). A main effect of the scene type was found, $F(2,90) = 17.87$, $p<.001$, and also a main effect of object type, $F(1,45) = 24.84$, $p<.001$, with significantly better performance on objects that were classed as kitchen items. Better performance was found for those objects that were present in the garage and neutral scenes compared to those in the kitchen environment (p's <.001). The interaction between the two was not found to be significant ($F<1$).

Another possibility was that individual properties might be separately affected by the environment and object type. Thus, the data were split according to the four properties, and examined again using mixed factorial ANOVAs.

Colour. Participants responses to colour questions showed a main effect of the scene type, $F(2,90) = 6.65$, $p=.002$, and of the object category, $F(1,45) = 23.34$, $p<.001$. Again, participants showed better recall for object colours when they were kitchen objects (kitchen *M*=0.60, garage *M*=0.48), and worse performance on those items that were present in the kitchen environment (kitchen *M*=0.47, garage *M*=0.58, neutral *M*=0.56, ps<.05). The interaction between the two was found to be marginal, $F(2,90)= 2.65$, $p=.076$, with participants showing no significant difference on responding to kitchen or garage items in the kitchen environment, but advantages for kitchen objects over garage items in the garage (kitchen *M*=0.64, garage *M*=0.53, ps <.05) and neutral environments (kitchen *M*=0.65, garage *M*=0.47, ps <.05).

Shape. For shape, a main effect of scene type was found, $F(2,90) = 8.70$, $p = .003$, as was a main effect of object category, $F(1,45)= 26.48$, $p<.001$, but no significant interaction between them, $F(2,90)= 1.12$, $p=.331$. Performance on this property question followed the same pattern, with participants recalling the shape of kitchen objects better than garage items (kitchen *M*=0.57, garage *M*=0.46), but performing poorly on objects in the kitchen environment compared to the other backgrounds, (kitchen *M*=0.46, garage *M*=0.53, neutral *M*=0.56, ps<.05).

Orientation. For orientation, the effects of scene type and object category were both found to be only marginally significant. However, again the patterns were similar to that of the other properties. For scene type, $F(2,90) = 2.71$, $p=.072$, performance was worse for the kitchen environment (kitchen *M*=0.55, garage *M*=0.60, neutral *M*=0.63, ps<.05), while for object category, $F(1,45)= 3.34$, $p=.074$, it was the kitchen items that were better recalled (kitchen *M*=0.62, garage *M*=0.57). The interaction between them was non-significant ($F<1$).

Position. For position, again, there was a significant main effect of the scene type, F(2,90) = 11.14, p<.001, and for object category, F(1,45) = 9.46, p=.003, as well as a significant interaction between them, F(2,90) = 5.03, p=.008. The interaction showed that while participants were better at recalling kitchen items in the garage (kitchen *M*=0.73, garage *M*=0.55) and neutral environments (kitchen *M*=0.68, garage *M*=0.59, ps<.01) there was no such difference for the kitchen environment (kitchen *M*=0.50, garage *M*=0.50). As for the other properties, participants showed an advantage for recalling the position of kitchen objects, (kitchen *M*=0.64, garage *M*=0.55) but were poorer when the objects were presented in the kitchen environments (kitchen *M*=0.50, garage *M*=0.64, neutral *M*=0.64, ps<.05).

Overall, it seems that performance on the property questions largely follows that of participants' overall performance in terms of the effects that the object category and scene type have on memory. Figure 3.13 presents the memory scores for each of the four property types for the two object categories and three scene types.

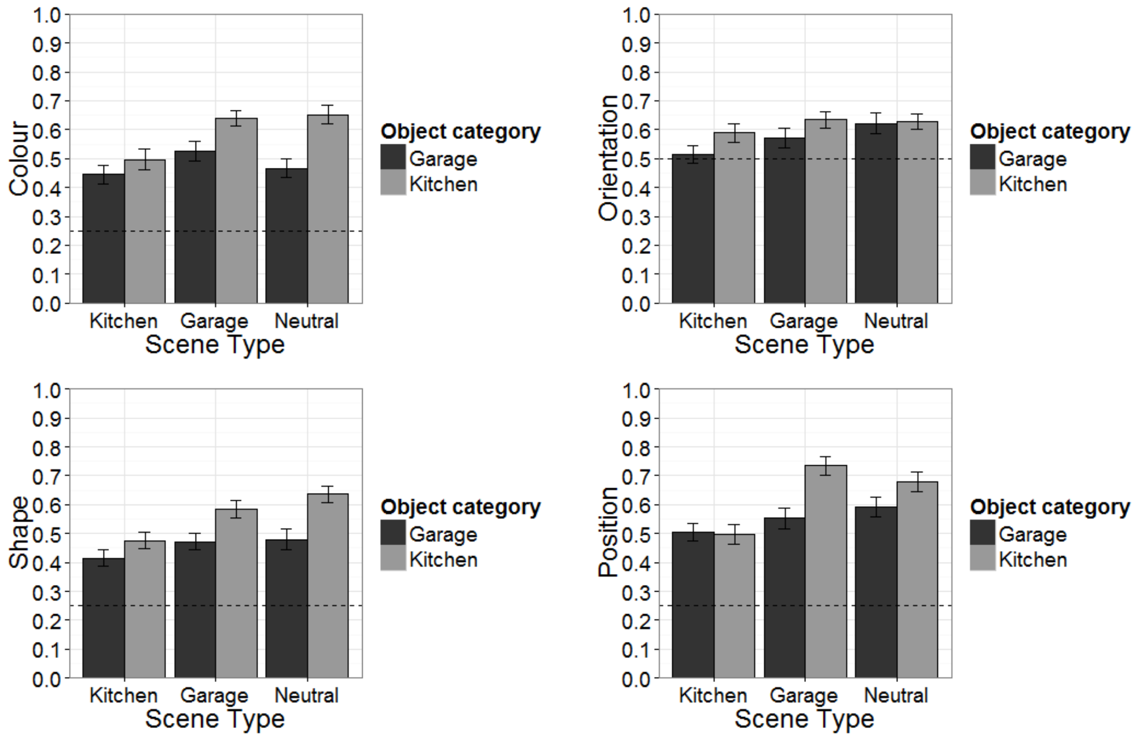


Figure 3.13. Memory scores as proportion correct for the four property questions across the three scene categories and two object categories (Left to right, top to bottom: colour, orientation, shape and position)

3.8.2.2 Object grip type. To investigate any potential effects on memory, the data set were split by the intention group, and within subjects ANOVAs were conducted on the object grip type and question type within each group. This was to determine whether the intention condition influenced responses to the questions relating to items that were compatible or incompatible with the type of grip, or afforded grip, in the case of the hands condition. While the properties of Colour, Shape and Position were included within the same ANOVA, Orientation was considered separately, due to its presentation as a 2AFC question. Furthermore, while the one-sample t-tests at the object level showed participants were scoring above chance for the orientation questions, when the scores on orientation questions were examined at the level of different grip postures, it was necessary to determine whether these scores were above chance too. These tests were performed as appropriate throughout the following sections.

Passive observation. For participants who did not produce an action pose during viewing, there was a main effect of question type, $F(2,20) = 6.40$, $p = .007$, and a marginal interaction between the question type and object grip type, $F(2,20) = 2.78$, $p = .086$, but no significant effect of grip ($F<1$). In examining the influence of the question type further, post-hoc comparisons showed a significant difference between performance on position (M=0.63) and shape questions (M=0.53, $p<.01$) and a marginally significant difference between position and colour (M=0.55, $p<.1$).

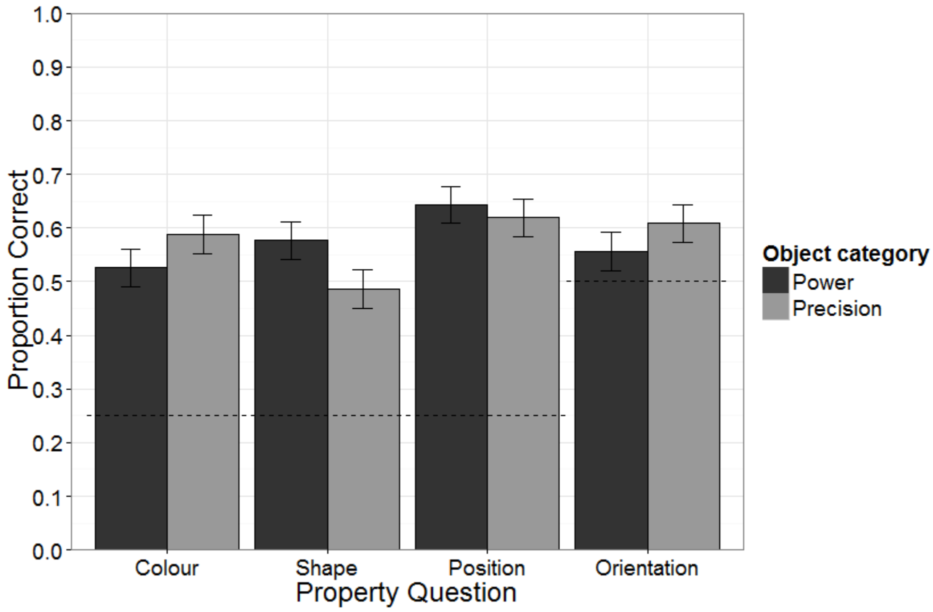


Figure 3.14. Mean proportion of correct responses to power and precision objects following passive observation during encoding

We further investigated effects across the property questions specific to the power and precision grip objects, using one-way ANOVAs. The passive observation group showed a marginal effect of question type for power grip objects, $F(2,20) = 3.10$, $p = .067$. Post hoc comparisons showed a marginal difference, with an advantage for position (*M*=0.64) over colour (*M*=0.53) and shape (*M*=0.58, $p<.1$). For the precision grip objects, there was an effect of question type, $F(2,20) = 5.97$, $p = .009$. Post hoc comparisons showed that shape (*M*=0.48) was answered significantly worse than position (*M*=0.62, $p<.05$), but no difference between position and colour responses (*M*=0.56).

For the orientation questions, it was found that while the memory score for precision compatible items was significantly above chance ($p=.002$), the score for power compatible objects was not ($p=.116$). These scores were also found to not be significantly different from one another, $t\ (15.53) = -1.40$, $p=0.181$.

Hands intention. When participants grasped the sides of the monitor while viewing the scenes, a marginal main effect of question type was found, $F(2,22) = 4.91$, $p=.017$, however there was no effect of object grip type ($F<1$), and the interaction between grip and question type was not significant ($F<1$). Post-hoc comparisons showed position questions (*M*=0.62) were responded to significantly better than shape (*M*=0.52, p<.05) but were not significantly better than colour (*M*=0.57).

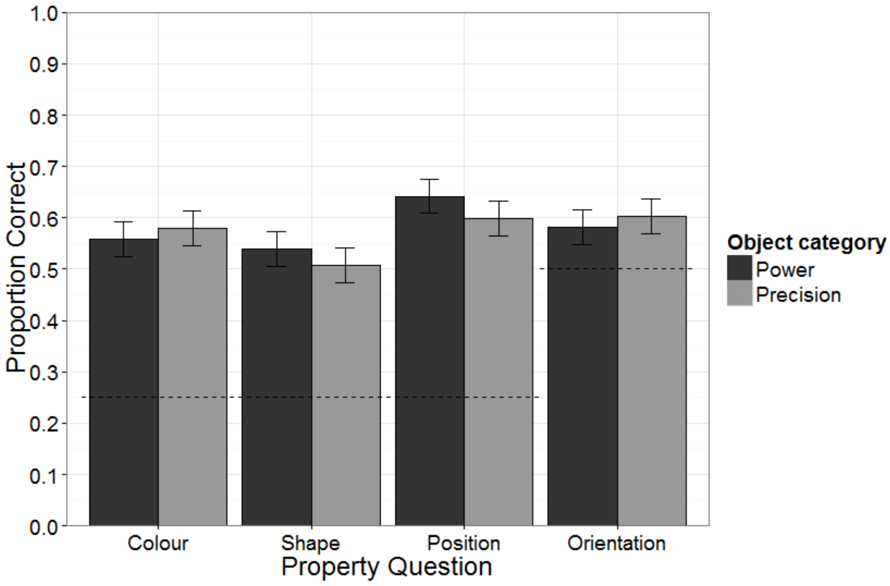


Figure 3.15. Mean proportion of correct responses to power and precision objects following proximal hands at encoding

For responses to questions on power grip compatible objects, a significant main effect was found, F(2,22) = 3.72, p=.041, which arose from a marginally significant advantage for position (*M*=0.64) over shape (*M*=0.54, p<.1). For responses to precision object questions, while a marginal main effect was found, F(2,22)=3.10, p=.065, post-hoc comparisons did not show significant differences. The trends in the data however, suggest a similar position advantage (*M*=0.60) over the shape questions (*M*=0.51).

For both power and precision compatible objects, the score on orientation questions was significantly above chance (p=.01 and p=0.003, respectively). No difference was found between scores for power and precision objects, t(21.93)=-0.604, p=.552.

Precision intention. When participants maintained a precision grip while they viewed the scenes, no main effects or interactions were found within the group. Participants showed no difference in their recall of the three question types, F(2,20)=1.05, p=.368, or for the two object grip types, F(1,10)=2.40, p=.152. The interaction between the two factors was also not significant, F(2,20)=2.21, p=.136.

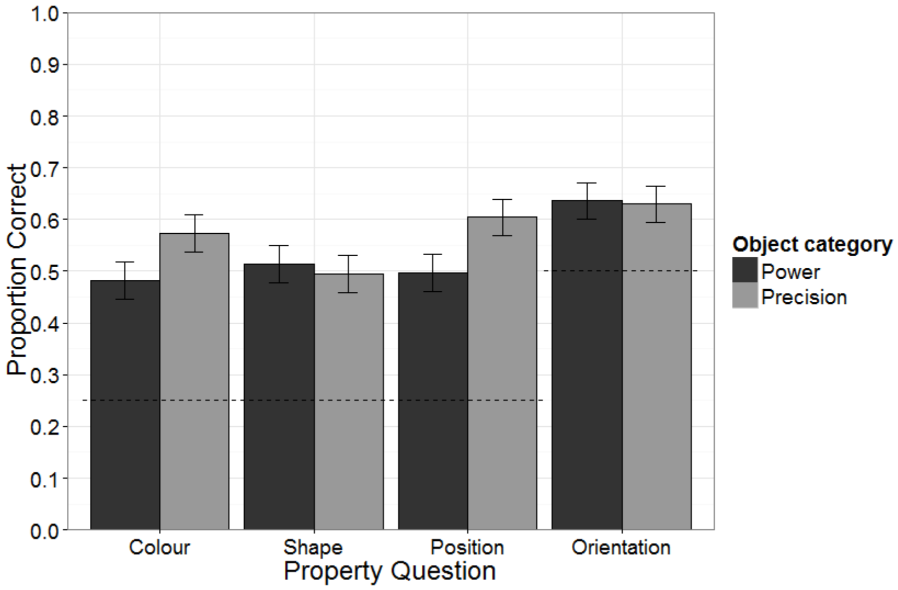


Figure 3.16. Mean proportion of correct responses to power and precision objects following precision grip at encoding

To further investigate potential effects, responses to power compatible and precision compatible objects were examined separately, using one-way ANOVAs to compare responses to the three questions. For the power grip compatible objects, no main effect of question type for power compatible objects was found (F<1). For precision grip compatible objects a marginal main effect of question type was found, F(2,22) = 3.09, p=.068. Post-hoc comparisons showed no significant differences but the trend in the data indicates a position advantage (*M*=0.61) over shape questions (*M*=0.50).

Responses on the orientation questions for power and precision compatible objects were both significantly above chance (p<0.001 for both). However, there was again found to be no significant difference between scores on power and precision objects, t(17.99)=-0.122, p=.904.

Power intention. For participants who maintained a power grip during viewing, a main effect of question type was found, F(2,22) = 4.91, p=.017, again driven by an advantage for position questions. No main effect of object grip type was found (F<1) and no interaction between the two factors was present, F(2,22)=1.94, p=.17. Post-hoc comparisons for the main effect of question type showed a significant advantage for position (*M*=0.57) over shape (*M*=0.48, p<.01).

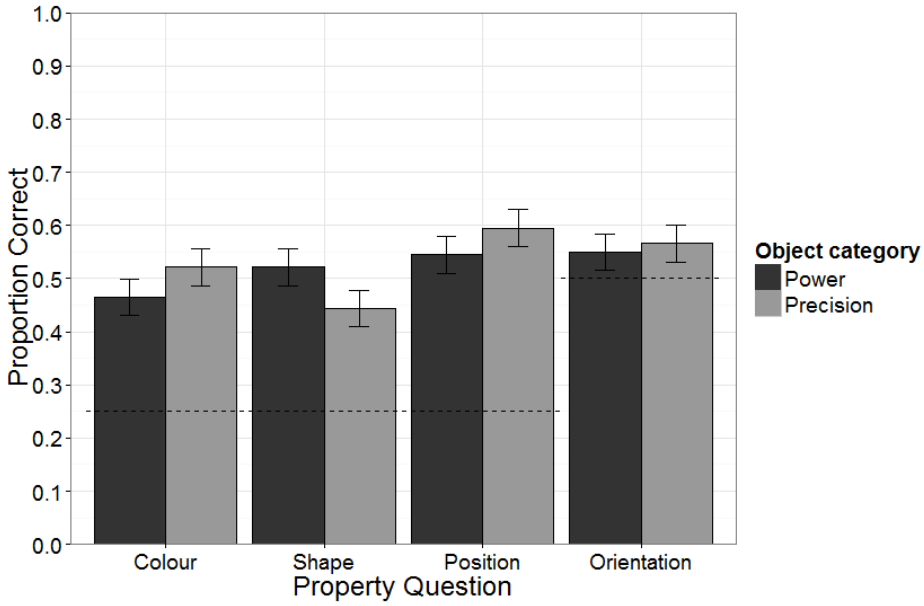


Figure 3.17. Mean proportion of correct responses to power and precision objects following power grip at encoding

The one way ANOVAs conducted on each object grip type showed no significant difference between responses to power grip objects (F<1).

For objects compatible with precision grips a significant effect of question type was found, $F(2,22) = 8.46$, $p=.002$, in which both position (*M*=0.59) and colour (*M*=0.52) questions for these objects were answered significantly better than questions about object shape (*M*=0.44, $p<.05$).

Scores for the orientation questions on precision compatible objects were only marginally above chance ($p=0.0592$), while scores for power compatible objects were no different from chance ($p=0.151$). No difference was found between scores for power and precision objects when testing orientation memory, $t(21.95)=-0.441$, $p=.664$.

In summary, it seems that participants are able to recall the position of objects well, with this information consistently being recalled better than the other properties of shape and colour. This pattern is present for participants in all of the four intention conditions. The intention condition under which the participants encoded the scenes and the grip types of the objects themselves does not appear to influence recall of the object properties. This finding is also consistent across the intention conditions.

3.8.2.3 Object position. In order to consider whether memory was different for objects located toward the left, centre or right of the scenes, mixed factorial ANOVAs were conducted on the three levels of position (left, right and centre), the four intention groups, and the four question types, with orientation questions again considered separately.

No main effect of intention or position was found, although there was a main effect of question type, $F(2,84) = 15.75$, $p<.001$. This came from the better performance on position (*M*=0.59) questions compared to both colour (*M*=0.54) and shape questions (*M*=0.51, ps<.05).

The intention group which might have the most effect relating to position was the hands, as the objects at the left or right of the screen would be those in closest proximity to the hands, and so might show an advantage for these (Reed et al., 2006). We therefore examined effects of position separately for each intention condition. Again, data from orientation questions was examined separately.

Passive observation. For participants who held no action posture during the trial, there was found to be a main effect of question, $F(2,20)= 6.78$, $p=.005$, such that position questions(*M*=0.63) were answered significantly better than shape(*M*=0.55, $p<.05$). There was no main effect of position, $F(2,20) = 1.62$, $p=0.223$, and no interaction between them ($F<1$). For orientation, there was no main effect of the object position ($F<1$) although only responses to objects on the left hand side were significantly above chance ($p<.01$).

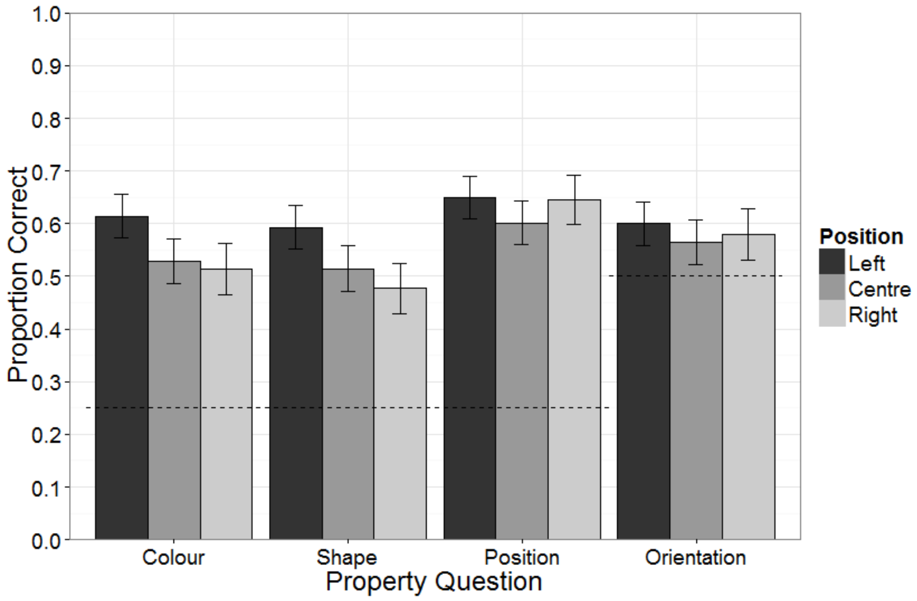


Figure 3.18. Mean proportion of correct responses to objects positioned across the scene following passive viewing at encoding

Hands intention. Participants who gripped the side of the screen during the trial also showed a significant main effect of the question type, F(2,22)= 5.91,p=.008, but again, no main effect of the object position (F<1). The effect of the question type was due to the significantly better performance on position questions (*M*=0.62) over shape (*M*=0.52, p<.05). The interaction between the factors was also not significant, F(4,44) = 1.89, p=.129. Responses to orientation questions at each position were found to be significantly above chance (all ps<.01). However, responses to orientation questions also showed no main effect of position (F<1).

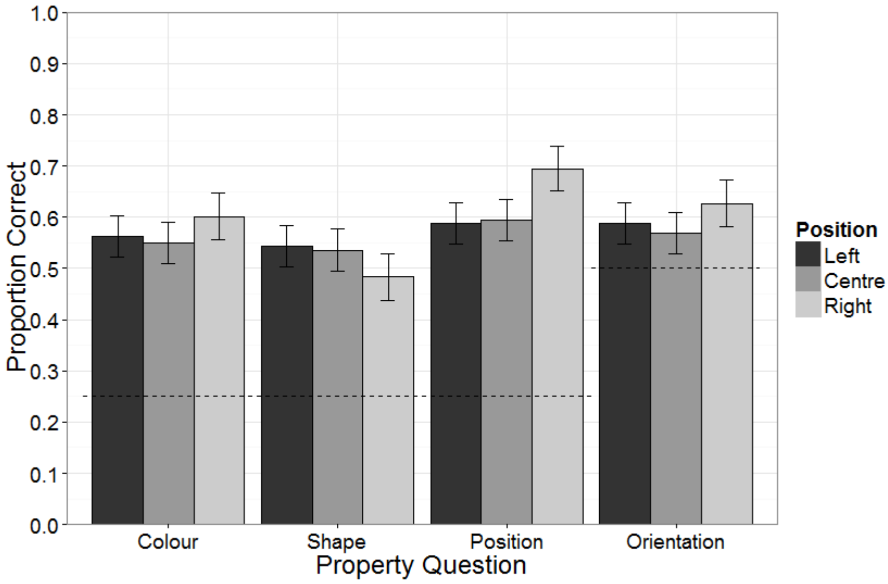


Figure 3.19. Mean proportion of correct responses to objects positioned across the scene following proximal hands at encoding

Power intention. Participants in the power grip group also showed a significant main effect for the question types, F(2,22) = 4.84,p=.018, with an advantage for the position questions (*M*=0.57) over shape(*M*=0.48) and marginally over colour (*M*=0.50, p=0.80), but no effect of object position, or interaction between then (Fs<1). For orientation questions, there was also no main effect of position, F(2,22) = 1.37, p=0.26. However, only responses to items on the right of the screen were significantly above chance (p<.05).

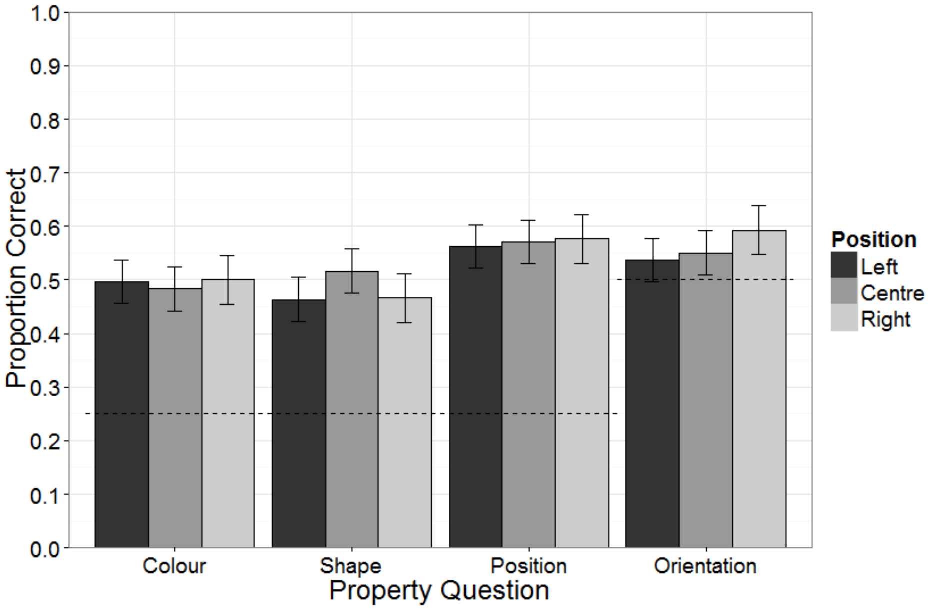


Figure 3.20. Mean proportion of correct responses to objects positioned across the scene following power conditions at encoding

Precision intention. Participants in the precision grip group showed a different pattern of performance from those in the other groups. There was found to be no main effect of the question type (F<1), but the effect of position was marginally significant, F(2,20) = 2.64, p=.096. Post-hoc comparisons did not show significant differences between responses to objects at the three positions, although the means for the precision intention group suggested higher scores on objects positioned on the left of the screen (*M*=0.58) compared to the centre (*M*=0.50) and right (*M*=0.49) regions. The interaction between them was also non-significant (F<1). For the orientation responses, all responses across the three positions were above chance (all ps<.05) but there was no main effect of the objects' positions (F<1).

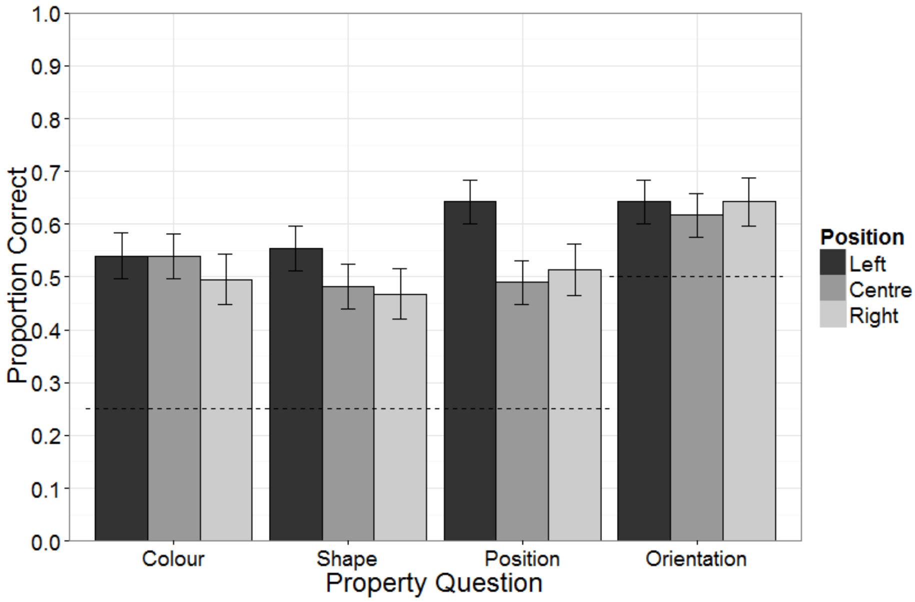


Figure 3.21. Mean proportion of correct responses to objects positioned across the scene following precision conditions at encoding

Overall, it appears that the position of the objects did not affect how participants performed on these items, with the possible exception of those in the precision intention group, who showed a weak advantage for items presented on the left hand side.

3.9 Discussion

Experiment 2.2 examined the influence of holding action postures when viewing scenes depicting a range of objects which were compatible with the action postures formed by the participants. The influence of these postures (either the presence of the hands near the screen, or a more object-specific grip posture) was examined both in terms of how it influenced aspects of inspection behaviour and object memory.

3.9.1 Influence on Inspection

3.9.1.1 Object Category. The objects presented in the stimulus displays were compatible with either a kitchen or garage background. As a result, each object was presented to participants once against a background that was compatible with its usual location, and twice against backgrounds that were incompatible. However, these backgrounds had no strong effect on the inspection behaviour. Regardless of the background scene, participants showed on average more and longer fixations on objects compatible with a garage environment, although there was a tendency to fixate the kitchen compatible objects less when in a kitchen environment. This does not fit with previous research on the effect of scene context on objects: the earlier eye tracking studies suggest that there should be more time spent fixating the inconsistent items in a scene, as these are the ones which require more processing (Friedman, 1979), or might be more informative to the viewer (Henderson, Weeks and Hollingworth, 1999). Kitchen items in a kitchen environment were fixated less than the inconsistent garage items, but this finding is consistent across all three scene types, rather than changing according to the nature of the background, as might be expected.

Garage objects were always the more fixated items, possibly because they were more unfamiliar to participants in general, rather than being noticeably out of place. Davenport (2007) notes that one reason for increased fixations to inconsistent items could be that these objects are considered more novel by the viewer, although this should still mean that the fixations to garage objects are reduced when they are in a consistent environment and thus not so unusual. A related possibility to this is that the backgrounds themselves were not as easily categorised as the intended environment. For example, participants may not have recognised the garage background as a garage, and so there would have been no advantage from the compatible background for object recognition in those scenes. This could explain why the garage items were consistently viewed as novel, and received more fixations. Indeed, if participants had difficulty with identifying the scenes, this could explain why we did not see any indication of a more typical effect of the background and foreground consistency. However, we have no measures relating to how typical the participants considered the scene, or how familiar they were with the objects, so this is largely speculation.

3.9.1.2 Object Position. We examined how the action posture manipulations affected scene inspection, both in terms of the target objects, and broader areas of the scene. Both measures of scene inspection showed similar patterns: namely, that participants had a tendency to explore the scene from left to right, after their initial fixations on the centre. However, this general pattern did seem to be affected by the action posture condition the participants were in. While those in the passive, power and precision grip conditions all showed this particular behaviour, it was much more pronounced in the two grip groups. Participants took longer to first fixate objects or the scene area on the right hand side of the screen, and spent less time on those items as a result. The hands conditions is in marked contrast to this, with objects at any position in the scene being fixated equally early in the viewing period.

The left-to-right inspection behaviour may have been encouraged by the layout of the scene used. The target objects were arranged in rough rows on the table tops, providing a structure to the scenes. Gilchrist and Harvey (2006) have previously shown that participants are influenced by the scene structure when viewing, so that more ordered arrays in scenes result in an increase in horizontal saccades, compared to scene arrays that are less structured and more random. Although the scenes in the present study were only approximately ordered, this was still enough to encourage this strategy shown by participants. This initial leftwards bias has been demonstrated in more recent investigations, during a variety of tasks including memorisation, (Nuthmann and Matthias, 2014) and in conditions where the symmetry of the image has been controlled for (Ossandón, Onat and König, 2014). This preference for the left side of a scene therefore seems to be a consistent presence in scene viewing, due to both asymmetries in the hemispheric control of attention, (as suggested by Ossandón et al., 2014) and the construction of the image (Gilchrist and Harvey, 2006). Of most importance to the present study, however, is the finding that this preference was modulated by the participant's action posture.

The presence of the grip postures may have led to participants taking more time on the objects they encountered. Measures of total fixation time indicated that participants spent more time on objects on the left hand side than those on the right, although those in the passive viewing condition show a similar pattern. Spending longer looking at the left side objects isn't unique to the grip intention conditions, but is more pronounced for them. Furthermore, objects compatible with the grips were not being prioritised when the scene locations were viewed, indicating that the presence of the grips was not enhancing this aspect of inspection.

For the hands intention group, the lack of any strong bias to a particular side is perhaps surprising, given previous studies using proximal hands that indicate a positional bias (e.g., Reed et al., 2006; Abrams et al., 2008), with distant objects receiving less of a benefit from the hands' presence. In the current study, this might have been expected to show as increased time spent on items at the left and right of the screen, over those items presented in the centre. However, these findings are not necessarily incompatible with the literature: Davoli and Brockmole (2012) found that the presence of the hands increased attention to all objects between the hands compared to items beyond the hands. This is in keeping with the more evenly distributed fixations shown by the participants here. Furthermore, Tseng and Bridgeman (2011) showed that the experimental context could influence attention distribution. In a change blindness study, where the presence of the hands was used to determine whether it increased detection of changing objects, it was found that the improvement due to the hands was largely a uniform improvement across the display screen. However, under certain conditions, change detection was best at the right hand side of the screen when the hands were present, indicating prioritisation of that region. This occurred when the presented set of objects was large, preventing participants from viewing all the items within a single saccade. As a result, while the whole region between the hands was prioritised, the right hand side was prioritised further, simply because it was examined first. The task demands in both Experiment 2.2 and Tseng and Bridgeman's (2011) study are also important; as both require participants to view the entirety of the screen in order successfully perform the task, making an equal distribution of attention across the screen the best strategy. However, the time pressures are different: while in the current study, participants had enough time to view the whole screen at least once, Tseng and Bridgeman's participants had only milliseconds. Thus, while there is evidence that the presence of the hands does lead to prioritisation of nearby locations, this emerges most strongly either when there are time and task pressures, as for Tseng and Bridgeman's study, or tasks such as Reed et al.'s (2006) orienting paradigm, where the best strategy is to prioritise a region. In the present study, the nature of the task may have encouraged the more uniform distribution of attention rather than the structured left-to-right progression; but without the time pressures, the prioritisation of a particular side did not emerge.

While the layout of the scene encourages a particular viewing strategy, following the scene structure, the findings here show that the maintenance of a grip posture can adjust this pattern. The grip postures enhance this, possibly by increasing attention to each of the objects, while the proximity of the hands reduces the effect, with a more even distribution of attention.

3.9.1.3 Object Grip Type. When examining the objects in terms of their grip compatibility, there was a tendency across all groups for the power-compatible objects to be fixated for longer than the precision objects (and for participants to first fixate the power-compatible items earlier than the precision-compatible items). However, the fixation durations and numbers were influenced by the intention condition, so that participants who maintained power grips during the inspection spent less time overall on non-compatible precision objects than participants who maintained precision grips during the encoding phase. A similar pattern of reduced fixation numbers and duration on precision compatible objects was observed for those participants who placed their hands on the monitor’s sides, compared to those maintaining a precision grip.

This finding adds to those of Symes et al. (2008); one of their experiments used eye movements to show increased fixations on grip compatible objects, in the same way that the current study shows that grip compatible objects receive longer inspection times. However, while the current study indicates a bias, it is not so straightforward. Power compatible objects were always fixated for longer than the smaller precision-compatible objects, even when participants formed a precision grip. However, when a power grip was prepared, or the hands were close to the screen, this difference in time spent fixating precision- and power-compatible objects increased. While it appears that the grip posture being held during scene inspection influenced object viewing, the effect was not as strong as might be expected. This may be due to the nature of the task. According to the instructions, all items within the scene were relevant, as participants knew they would be tested at the end of the trial. The larger size of the power-compatible objects may simply have resulted in a bias to fixate these objects in all conditions, but forming a precision grip throughout inspection seemed to reduce this bias by increasing the time spent on precision-compatible objects.

Similar results were found in the fixation durations and numbers for those participants forming power grips, and those placing their hands either side of the display screen. This may be because the ‘open palm’ gesture that participants make when they place their hands either side of the monitor is itself thought to afford a power grasp (Thomas, 2013). While the open palm is not strictly a grip posture in itself, it is a stage in the preparation and progression of postures the hand will make as it forms the end state of the power grip. The power grip is more likely to follow the earlier stage of an open palm configuration, as the stages from the open palm to end posture are simpler in the case of the power grip. Power grips are also considered to be more familiar to people (Vainio, Tucker and Ellis, 2007), further increasing the affordance between the open palm and the power grip over the precision grip. It is interesting to note that this similarity between the effects of the two postures occurs in the present study, despite the fact that they occur at different stages of the grip formation process, and are not equally proximal to the screen. These factors seem less important in biasing attention away from non-compatible objects than the fact that a power grip is afforded by these two postures.

Overall, the eye-movement data from Experiment 2.2 indicated that the presence of action postures during the encoding of object information influenced the way in which items were attended. The presence of the hands in close proximity to the monitor had an impact on the overall strategy used to examine the scenes, while both the formation of grips and the positioning of the hands influenced which objects received more or longer fixations depending on their compatibility with the grip in question.

3.9.2 Influence on Memory

3.9.2.1 Object Category. The memory findings for the influence of object category were similar to those for the inspection data. While kitchen compatible objects were recalled better than garage compatible items, performance was uniformly poor for objects in the kitchen environment. This doesn't seem to match with previous studies of object-background interactions (e.g., Davenport and Potter, 2004), from which it might be expected that compatible items would be better recalled in their correct location. Nor do the results match previous work suggesting that incompatible items would show facilitated recall in memory (Hollingworth and Henderson, 2000). As for the results found for the influence of object category on inspection, these memory findings may be due to the nature of the task, preventing participants from spending much time on the background details. Familiarity may also have had an effect: we can again speculate that kitchen items may be more familiar to the participants than garage items, aiding the responses. The poorer results from the kitchen scenes may be due to the layout of these scenes: the table-top in this environment was narrower than those in the other locations, meaning the objects were more crowded together. Participants generally reported more difficulty with this scene, and it appears that this affected all the objects, regardless of their location compatibility, again suggesting that the design of the study may have prevented a strong effect of the background on participants' memories for foreground objects.

3.9.2.2 Object Position. While an influence of intention condition was found for when and how long objects in the three areas of the scene were fixated, this did not appear to translate into an influence of on-screen position on subsequent memory for the objects, across the intention conditions. This was particularly interesting for the condition in which the hands were placed in proximity to the screen, as this meant objects could be in close proximity to the hands if positioned at the edges, or more distant if centrally positioned. As noted, there are previous studies examining the influence of proximal hands on memory, indicating the presence of the hands may improve LTM (Davoli and Brockmole, 2012), and VWM capacity (Tseng and Bridgeman, 2011). However, the present study does not show an advantage in recall for objects in particular locations, or across all locations, compared to the other conditions.

The only condition in which there was a (weak) effect of position was the condition in which participants maintained a precision grip throughout inspection. Here participants showed marginally better recall of items positioned at the left hand side. This finding can be most easily explained with reference to the eye movement recordings relating to position. While all conditions (with the exception of that where hands were placed either side of the monitor) showed a left to right exploration pattern, this was particularly strong for the precision intention condition. Thus, items on the right hand side received fewer fixations over the course of the trial in this condition, which may have led to an advantage for left side items, based on the amount of time for which they were examined. However, this advantage for the left hand side is small, and not seen for any one property type. Rather, it is a general advantage for recalling objects at that location. It is therefore unlikely that this shows a bias towards recalling relevant objects. Instead, it is more likely to be an advantage for the items that are fixated for longer. Interestingly, this finding is the only one from the current study which shows a link between the eye movements and the memory performance: otherwise, the two seem largely disconnected.

3.9.2.3 Object Grip. When examining the effect of the intention conditions on objects associated with the two grip types similar patterns for memory performance were observed in all the groups. For precision-grip-compatible objects, responses to shape questions were poor, with participants scoring higher on colour, and highest on position. There were similar patterns for power-grip-compatible objects, although these differences only emerged as significant in the hands and passive conditions. Thus it would appear that adopting an action posture with the hands does not bias memory toward particular objects (e.g., those compatible with the action posture) or toward particular object properties (e.g., more action-related properties like shape compared to less action-relevant properties like colour). This is a little unexpected, given previous work which suggests that it is the relevant properties which will be prioritised in memory by the context of the task (e.g., Triesch et al., 2003). Given that shape is consistently judged to be action-relevant (see Experiment 2.1), we might have expected it would be facilitated by the action postures at encoding. This is evidently not the case, and the possible reasons for this are considered below.

Participants showed generally poor performance on orientation questions, with scores on several conditions at chance level. It is possible that this reflects the suggestion of Derbyshire et al. (2006), that orientation is an extrinsic object property, and therefore not stored as part of the object representation. An alternative is simply that participants were not expecting to be asked about the orientation of objects, and so did not make an effort to encode this information.

The fact that preparing and maintaining action gestures during encoding did not influence subsequent memory performance may reflect a number of possible underlying explanations. The first option that must be considered is the possibility that feature weighting simply does not occur in memory. The idea that memory representations are not weighted has been suggested previously, in relation to strongly embodied views of memory. Wilson (2002) suggested that the representations we maintain of objects might be ‘purpose-neutral’. A purpose-neutral representation would contain information beyond just that which is needed for the immediate task, allowing for more flexibility when working with objects. However, while the studies of memory may be sparser, there is still evidence to suggest that such influences can occur, suggesting that the purpose-neutral representations seen in the present study may be due to the nature of the task, and its context.

Firstly, it may be that the action manipulations used were not sufficient to result in action based modulations of the resulting memory representations. The actions were only maintained for as long as the scene was being viewed, and when it disappeared, participants stopped acting, which may have indicated the end of the task, and the end of any necessity to continue priming the representations in favour of action. Earlier studies have noted that memory during tasks may sometimes be fairly sparse (see e.g., Ballard et al., 1995), perhaps to avoid memories from one part of a task interfering with the later performance. While there is no active manipulation in this present study, it may be that the lack of effects seen in the subsequent memory test are due to preventing confusion in any actions that may follow. This idea can also be applied to the memory for the individual properties displayed here. While certain properties are necessary for action over others, it may only be during perception that these are affected. At this point, the information is being gathered to inform an action which may be imminent. Once items are stored in memory, however, perhaps any such biases are not stored. The most useful information to have in memory, particularly for objects that may be acted with, is position information. Thus, spatial information may be stored preferentially while more intrinsic features are not maintained. Previous studies have noted that the spatial layout of a scene is extracted during the early stages of viewing (Tatler et al., 2003), and more recently, Kondo and Saiki (2012) demonstrated a bias towards position information in the context of a feature detection task. While shape and colour information could be excluded from the detection when the task settings made them irrelevant, location information was added to the representation regardless of the task demands. Position information therefore seems to be an important property in the formation of object representations, which may account for its preferential storage in memory.

Another possible reason relates to the stage at which the action was presented. For the power and precision grips, participants formed the gesture by holding on to a device in the appropriate posture, which again may have signalled that the task was over, as the grasp was already being formed. Thus, due to both aspects, the strength of the intention towards the pictured objects may have been reduced, so that there is no need to maintain representations that are informative for any subsequent actions. Previous studies do vary on how complete the action manipulations are: many only use the preparation of action (e.g., Symes et al., 2008; Fagioli et al., 2007), while others have participants performing the action during the task (Witt and Brockmole, 2012). While these studies have all shown influences on perception of scenes and displays, it is unknown how the different stages of action might influence the maintenance of any biases in memory. It is interesting to consider that, given the posture of the hands used in the current study can be seen as affording a power grip (Thomas, 2013), if there were a strong effect from the stage the action is at, then there might be a difference between the hands intention group, and the power grip group, where the grip in question has been completed. There is nothing in the memory results to suggest this, although there are other potential confounds in trying to make such a comparison that the current study cannot really address that possibility. It remains, however, that the stage of the action execution might have a particular influence on any memory biases, particularly if memory is used only to maintain such biases when they might be useful later.

A second important consideration is the realism of the task. In Experiment 2.2, participants did not interact with the objects presented: indeed, they could not interact with the objects. This may also relate to the strength of the action manipulation. If there is no possibility of interaction with the objects, because they are not physically present, then again, there may be no need to weight the memory representations formed. Furthermore, several of the studies that have examined how memory representations might be affected have used more realistic settings involving interactions with the objects, and found effects of the manipulation (e.g., Thomas et al., 2013; Tatler et al., 2013).

A related factor may be the nature of the task itself. Experiment 2.2 used a standard memory task, in which participants had to recall all the items that were presented, with no particular item more important than any other. This was necessary for the purposes of the study, and allowed investigation of how the presence of an action might influence memory when the task itself is fairly unrelated to the action. However, in order to show any influences of action on memory, it may be necessary for the task to involve more specific instructions regarding the stimulus objects. Studies such as those by Droll and Hayhoe, (2007) have demonstrated how the relevance of a property to the ongoing task affects the representation of that property in memory. Without a more specific task, properties in the present study were not as specifically relevant to action, and thus the representations need not have been constructed with the requirements of a particular task as a guide. As a result, the representations formed in the current task appear to have been, as suggested above, purpose neutral.

Overall, placing the hands either side of the monitor or forming a power or precision grip during scene inspection did not seem to have a strong effect on subsequent memory for object properties. There was no indication that the presence of a particular gesture led to improved recall for objects compatible with the gesture (object grip type conditions) or simply in proximity to it (hand condition). This is in contrast with our findings from the eye movements of participants, which do seem to be affected by the action conditions. The rather general nature of the task may have had some influence on this: there was no specific requirement to act with the items later, and so there was no need to store information with a bias towards action. Some support for this view comes from Tatler et al. (2013), where participants who only observed a task being carried out showed worse memory for the position of task relevant objects compared to participants who acted with them. Alternatively, memory for the intrinsic features of objects may never be affected in this way, whatever the task. Instead, the action associated with the object might need to be present at the time that the object is being recalled, when there is a possibility that it might be required shortly.

3.9.3 General conclusions

Experiment 2.1 allowed us to establish a base of usable items which had clear and confirmed associations with particular object grip types and locations. Furthermore, it provided some evidence on the way that people class properties, which seem to be largely in agreement with the way other studies have classed object properties, in terms of their action or visual relevance.

When these findings were transferred into an experimental situation in Experiment 2.2, further evidence was found to support the influence of action on perception and inspection behaviour. However, from the results so far, this does not strongly translate into the memories we form. Several possibilities have been considered for why this finding occurs, which can be grouped into two main (and related) areas for further investigation. Firstly, the action manipulation may not have been strong enough, as it was not maintained, and secondly, that the task may not have been active enough, as it involved no real interaction with the objects in a realistic task situation. Both these possibilities are addressed in the following chapters, with Experiments 3and 4 focusing on the effects of when the action postures are produced, and Experiments 5 and 6 concentrating on the influence more realistic situations might have on the outcomes for perception and memory.

Chapter Four- The influence of the potential for action at retrieval on the formation of object representations

4.1 Introduction

In Experiment 2.2, we investigated whether the presence of an action posture at the encoding stage of memory (i.e. while viewing a scene) could influence the way in which the resulting memory representations were constructed. Specifically, we looked for an indication that the representation would be biased toward or weighted in favour of objects and their features relevant to the particular action formed. However, while the preparation of an action during the encoding stage may affect the construction of the representation, in order to measure this, it is necessary for the representation to be accessed at a later stage. It is equally important to consider how the retrieval process may itself be affected by the action context at the time that the memory is accessed.

Several studies have demonstrated that, while information from a scene may be successfully extracted and stored, it is still possible that the retrieval processes can fail. In a change blindness study, Hollingworth et al. (2001) found that despite increased fixation durations on changed objects, participants could still fail to detect the change, at least in terms of explicit report. Given the relationship between fixation and the subsequent memory performance, (e.g., Hollingworth and Henderson, 2002), it was assumed that the increased fixation duration on such objects indicated that information about the change had been extracted and retained. The failure in detection was thus considered to have arisen from a problem at a later stage than that of initially constructing the representation, such as a failure in retrieving the stored information, or comparing it to the current perceptual information. Hollingworth (2003a) provided further support for this when it was demonstrated that change detection rates could be improved by including a post-cue which indicated the target object. This reduced the retrieval demands: participants only had to determine what change had occurred to that item, rather than determine if a change had occurred at all, as for the un-cued version. Thus, whatever information is incorporated into the representation at encoding, there is still the process of retrieval which can affect what information is later recalled in an explicit test.

According to theories of embodied or grounded cognition, the retrieval of conceptual information will lead to the re-activation of neural systems active at the initial formation of the event code. These neural systems involved in both the formation and storage of the information contain not only the perceptual information, but also motor and affective information, derived from prior experiences with the items, as well as learning (e.g., Hommel et al. 2001; Barsalou, 1999). Evidence for these similarities has been shown by studies that found the same phenomena are present in conceptual processing that are present when the actual items are being processed. For example, Connell and Lynott (2010) showed that the disadvantage for processing tactile information is present when the linguistic concepts are encountered (e.g., words describing a tactile modality are processed more slowly than those for visual or auditory modalities). The process of recalling the concepts rather than the real items is therefore still subject to the same constraints as the initial processing of the objects. Most importantly, there is evidence to suggest that this re-activation will be tailored to the current context and the task requirements. Louwerse and Jeuniaux (2010) investigated the influence of context on the processing of conceptual information. Both the nature of the stimuli (words or images) and the task (judgement of semantic or iconic relationship) affected performance. When the task was predominantly language based (semantic judgements on word stimuli), then linguistic factors were the better predictors of performance, but embodied factors were the better predictors when the task required iconic judgements (on pictorial stimuli). The nature of the conceptual processing is sensitive to the particular task constraints, and the context. Thus, re-activating the information in order to retrieve it at a later stage is likely to also be influenced by the situation under which the retrieval takes place.

Other studies have shown how the action context at retrieval can affect access to memory representations. Dijikstra, Kaschak and Zwaan (2007) investigated the influence of the task context on the retrieval of stored autobiographical information. When participants held body postures congruent with the autobiographical memory they were retrieving (e.g., lying on a recliner while recalling a visit to the dentist), their response times for producing the information were shorter than when they held incongruent postures. As suggested in theories such as the TEC, the representation seems to be grounded in the neural areas active at the time of the processing and formation of the representation, and are highly embodied, maintaining the posture and motor information as part of the encoded trace. Resuming the associated action improves the access and recall of the information.

Ross, Wang, Kramer, Simons and Crowell (2007) examined whether the more specific action gestures associated with the use of objects were similarly incorporated into representations, although they used novel items to investigate the learning process involved. The new objects were associated with particular actions (arbitrarily selected movements of the objects to the left or right) during a learning phase, followed by a test of their recognition of the objects at a later stage. When participants responded to the test items by repeating the movement they had associated with that item in the learning stage (i.e. moving the item to the left again to categorise it as familiar), they were faster and more accurate in recognising the object. Actions associated with objects, even arbitrarily, seem to be incorporated into the representation, where they can continue to influence further interactions with the object.

For familiar everyday objects, it would be expected that the repeated use of the items over time would also lead to the incorporation of the associated actions into the representation of that object. Thus, the power and precision grip postures used in Experiment 2.2 would form part of the encoded memory trace. Indeed, Derbyshire et al. (2006) showed that accessing the memory of objects could activate the associated grip responses and lead to faster execution of them when the object was compatible; indicating that grip posture is an important action feature of everyday objects and their representations.

The present study, Experiment 3, aims to further investigate the influence that action has when it is presented at the retrieval stage of a memory task. Given the previous findings which strongly suggest the inclusion of action information in a representation, it is expected that the presence of action will influence participants' ability to access the object's representation and extract information, with objects compatible with the grip being better recalled than those that are incompatible. As in Experiment 2.2, we will examine memory access in terms of the recall performance of different object properties which are differently relevant to the execution of action (e.g., shape may be more easily retrieved under action relevant conditions than colour). While the eye movements and inspection behaviours of participants will be recorded as well, it is not expected that there will be any influence of the action posture on these behaviours, as the action posture is only executed during the recall stage, and is never present during the viewing stage.

4.2 Method

4.2.1 Participants

Twenty-nine participants were recruited (9 males, mean age 24.3, SD = 4.5). 13 were assigned to the precision grip condition, and 16 in the power grip condition. Handedness and eye dominance were measured by self-report: the sample contained 2 left handers and 11 participants showing left eye dominance. Participants were recruited using advertisements on the University's on-line recruitment system, and received payment (£3) for their participation.

4.2.2 Stimuli, Procedure and Design

These were identical to Experiment 2.2, with the following changes. First, participants did not make action poses during scene presentation, but during the subsequent memory tests. That is, participants made action poses with their dominant hand throughout the memory questions, responding to the questions using their non-dominant hand. Second, only two intention conditions were included in Experiment 3: the power and precision grip conditions. The proximal hands were not used as an action manipulation, as participants had to makes the gesture at the same time as responding to the memory questions. Thus, keeping their hands on the sides of the monitor would have required the participants to respond another way, which could have introduced a confound into the memory measures.

The same measures of perception (average number of fixations, average duration of fixations and primacy fixation numbers) and memory (responses to multiple choice questions regarding object features) were used in Experiment 3 as in Experiment 2.2.

As a baseline, data from the 11 participants in the passive condition from Experiment 2.2 were included in the analyses that follow.

4.3 Results

4.3.1 Influence of intention on inspection

4.3.1.1 Scene inspection. The eye movement patterns were examined at the level of the scene prior to being examined at the level of the object. Experiment 2.2 showed that the presence of power and precision grips at encoding led to an influence on the scene exploration. As the grips were not maintained during encoding, it was expected that such effect would not be present in the current study, and thus conducting the scene inspection analysis allowed us to determine this.

The scenes were divided into thirds, and measures of fixation duration, number and average ordinal number of the first fixations to the areas were examined in the context of the three intention conditions. Measures of average total fixation time showed a marginal influence of the intention condition, $F(2, 33)2.73$, $p=.080$, due to participants in the power condition showing longer total fixation time across all three scene areas compared to the other intention conditions, (power *M*=6169 ms, precision *M*=5966 ms, passive *M*= 5919 ms) However, this difference did not emerge as significant in the post-hoc comparisons. A main effect of the scene area was also found, $F(2, 66)=57.10$, $p<.01$, with participants spending significantly longer on the central scene region (*M*=7845ms) compared to the left (*M*=5441ms) and right (*M*=4844ms, $ps<.001$). The difference between time spent on the left and right regions was also marginally significant ($p=.056$). The interaction between the two was non-significant, ($F<1$).

For the measures of fixation number, there was no main effect of the intention condition, $F(2, 33)=1.11$, $p=.34$, but a main effect of scene area, $F(2,66)=66.20$, $p<.001$, due to significantly more fixations made to the central region (*M*=26.4) compared to the left (*M*=17.9) and right (*M*=16.0, $ps<.001$). As for the measure of total fixation duration, the interaction between the two was not significant ($F<1$).

Due to the central bias observed, the analyses were conducted again, removing the data from fixations to the central region. In these conditions, neither fixation duration nor number measures showed a significant effect of the intention condition (both $Fs <1$), and while an influence of the location was still present, it was now marginal for both measures (fixation duration: $F(1, 33)=3.67$, $p=.064$; fixation number: $F(1, 33)= 2.92$, $p=.09$). In both cases, participants made more fixations to the left region of the scene, and the average total fixation time on this region was longer.

The average first fixation to a region was analysed, to determine if there was a difference in inspection patterns in terms of when the participants first fixated one of the scene regions. This analysis used only the data from the left and right scene regions, as due to both the central fixation bias and the central drift correction, the first fixation to each scene was always to the central region. Looking at only the left and right regions, a main effect of the location was found, F(1,33)=6.23, p=.01, with participants making their first fixation to the right hand region of the scene significantly later than the average first fixation to the left regions (left *M*=10.0, right *M*= 15.2). There was no main effect of the intention condition (F<1), and the interaction between the two was not significant, F(2, 33)=1.36, p=.273. Figure 4.1 displays the measure of average first fixation across the intention groups, showing the tendency of participants to fixate the right scene region later in the trials, across all intention conditions.

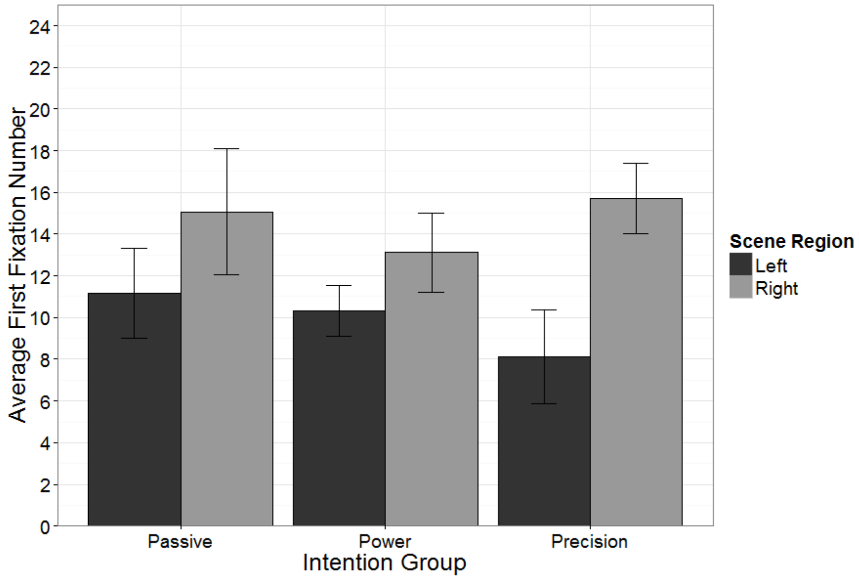


Figure 4.1. Average number for the first fixation to the left and right regions of the scene for the three intention conditions

Unlike Experiment 2.2, no influence of the participants' intention condition was found on the way in which they viewed the scenes presented.

4.3.1.2 Object Category. The influence of the object category (garage and kitchen), and the background environment (garage, kitchen and neutral) was examined, to determine if the compatibility of the objects with their backgrounds influenced the fixation numbers and durations. An analysis of the fixation numbers showed a main effect of the object category, F(2,33) = 69.19, p<.001, with more fixations made to garage compatible objects than kitchen items (garage *M*=6.32, kitchen *M*=5.18). No main effect of the scene type was found (F<1), but the interaction between the two factors was found to be significant, F(2,66) = 3.391, p=.039.

The same pattern of results was found for the measures of total fixation time: on average, more time was spent fixating garage compatible objects compared to kitchen compatible items, F(1,33)=57.25, p<.001, (garage *M*=1867ms, kitchen *M*=1574ms), but the background scenes had no significant influence on fixation durations (F<1). The interaction was significant, F(2,66)=4.36, p=.017.

Examining the interactions further showed that participants consistently made more fixations to the garage items than the kitchen items, within each of the three scene types. The difference was strongest in the kitchen scene F(1,33)=35.2, p<.001, (garage *M*=6.6, kitchen *M*=5.0). It was weakest within the garage scene, F(1,33)=13.0, p=.001, (garage *M*=6.2, kitchen *M*=5.2) and neutral scene backgrounds, F(1,33)=11.5, p=.002, (garage *M*=6.1, kitchen *M*=5.4) but still significant for both.
For the measure of fixation duration, participants showed significantly longer total fixation times to garage items over kitchen items in the kitchen, F(1,33)=36.81, p<.001, (garage *M*=2007ms, kitchen *M*=1503ms) and neutral scenes F(1,33)=8.83, p=.005, (garage *M*=1783ms, kitchen *M*=1580ms), but only a marginally significant difference in the garage scenes, F(1,33)=3.58, p=.067, (garage *M*=1812ms, kitchen *M*=1640ms).

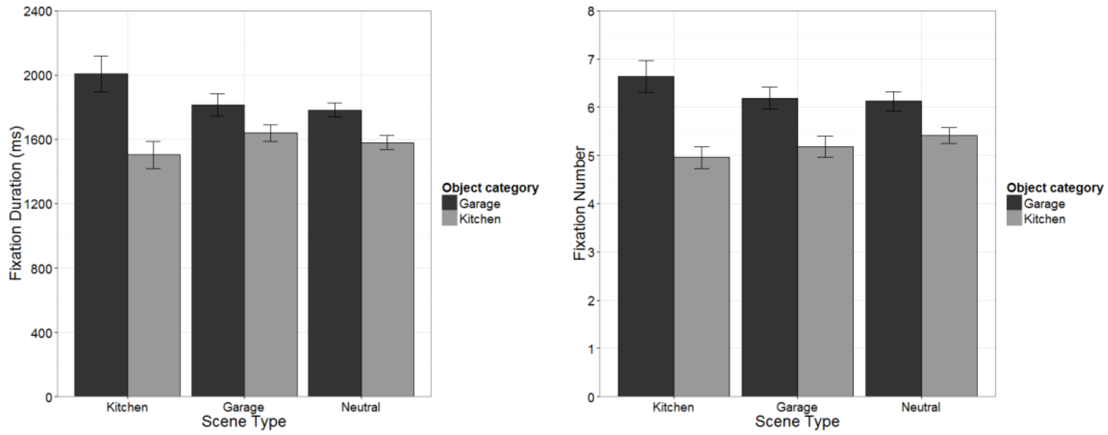


Figure 4.2. Mean fixation durations (left) and fixation numbers (right) to object types across the three scene categories

Participants showed a tendency to fixate the garage compatible items more and for longer than kitchen compatible items, although this difference was less pronounced when viewing items in the garage environment.

4.3.1.3 Object grip type. Inspection behaviour for objects related to the two grip types were examined using mixed factorial ANOVAs for the three intention groups, and two grip categories. As the grip posture maintained by the participants was not present during inspection, it was not thought that there would be a strong influence of the intention condition on the viewing of the objects presented.

For measures of total fixation duration, a main effect of grip was found, $F(1,31)=10.35$, $p=.003$, but there was no main effect from the intention group ($F<1$). For the grip conditions, participants spent significantly longer fixating items compatible with the power grip (*M*=1802ms, precision grip *M*=1630ms). The interaction between grip type and intention group was also non-significant ($F<1$).

For the measures of fixation number, a slight difference was found. There was again a main effect of grip type, $F(1,31)=52.46$,$p<.001$, such that power compatible items received more fixations(*M*=6.4, precision grip items, *M*=5.1); but there was also main effect of the intention group, $F(2,31)=4.51$, $p=.019$. Post-hoc comparisons showed participants in the passive condition made significantly more fixations to objects overall than those in the precision grip condition (passive *M*=7.00, power *M*=6.0, $p<.05$). Figure 4.3 presents the data for measures of fixation duration, while Figure 4.4 presents the data for measures of fixation number.

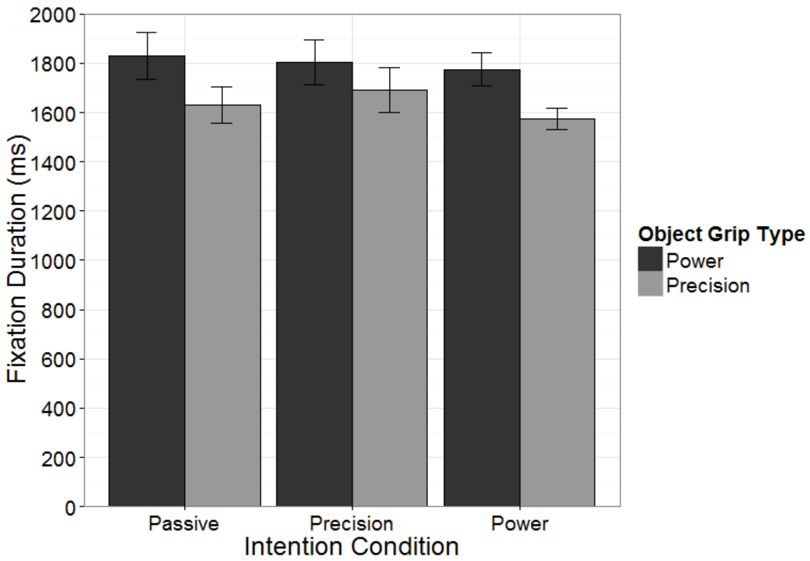


Figure 4.3. Mean fixation durations on objects by grip type across the intention conditions

Since the action manipulations took place during the retrieval stage of the experiment, it was possible that these poses might have affected the eye movements in the trials following them. Mixed factorial ANOVAs were also conducted including Trial Number as a factor, for measures of both fixation number and fixation duration. After adding this factor, the main effect of grip was maintained, for both fixation number, $F(1,31)=50.47, p<.001$ and duration, $F(1,31)=10.62, p=.003$, with more and longer fixations on power compatible items. The main effect of the intention group in the measures of fixation number was also maintained, $F(2,31)=4.44$, $p=.02$. However, there was no main effect of the trial number for measures of fixation number, $F(2,62)=1.97, p=.148$, and only a marginal effect for trial in measures of fixation duration, $F(2,62)=2.88$, $p=.06$. This was found to be due to marginally longer fixations on all objects in the second trial (M=1807ms) compared to trial 1 (M=1626ms, $p=.06$). No interactions were found to be significant, so that participants were not behaving significantly differently depending on the trial condition (all F's <1).

Participants showed a tendency to make more fixations for a longer time to objects compatible with the power grip. This did not appear to be influenced by the grip posture maintained by participants during the retrieval stage of the trials.

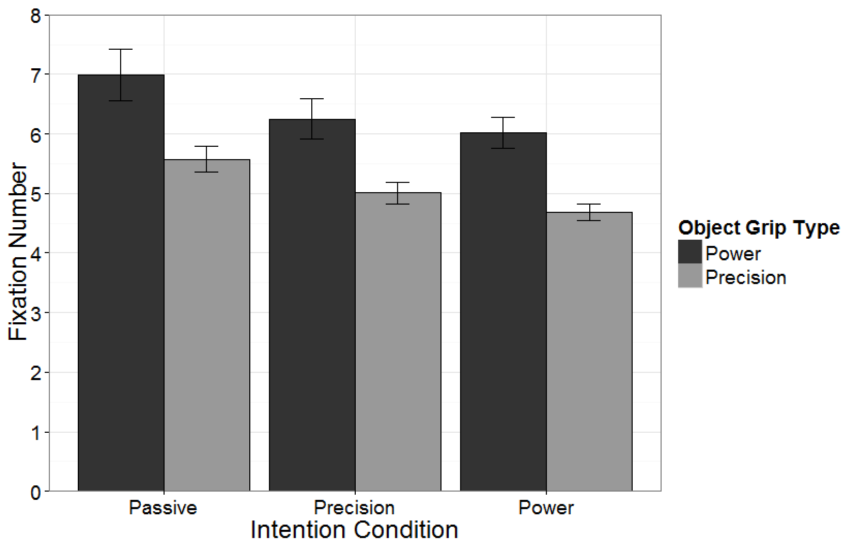
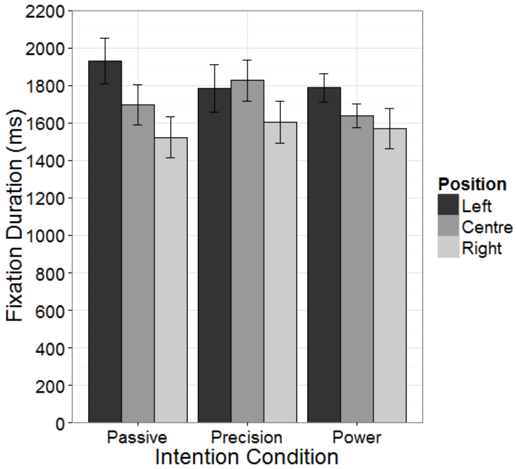


Figure 4.4. Mean fixation number on objects by grip type across the intention conditions

4.3.1.4 Object Position. The influence of the objects positions on inspection behaviour was examined across the three intention groups and object positions, for the measures of fixation number and duration, and the average first fixation to objects in each area. As when analysing the inspection of the scene, this allowed us to determine if there was any influence of the intention condition (particularly the power and precision groups) on how they viewed the objects depending on their position.

For measures of total fixation duration, a significant main effect of position was found, F(2,62)=5.10, p=.010, but no effect of the intention condition or significant interaction between them (Fs<1). Post-hoc comparisons showed significantly longer fixations occurring on objects on the left hand side (*M*=1833ms) compared to those on the right (*M*=1565ms, p<.001). Fixation number showed a similar pattern, with a significant main effect of position, F(2,62)=6.03,p=.004, due to fewer fixations on right hand side objects(*M*=5.1) compared to those positioned at the left(*M*=6.0, p<.05) and centre(*M*=6.0, p<.05). A main effect of the intention group was also found, F(2,31)=4.67,p=.017, with participants in the passive condition making more fixations to objects across all positions than those in the two grip conditions (passive *M*=6.3, precision *M*=5.6, p=.08, power *M*=5.3, p<.001). The interaction between the two factors was again not significant, (F<1). Figure 4.5 presents the data for both fixation durations and numbers.



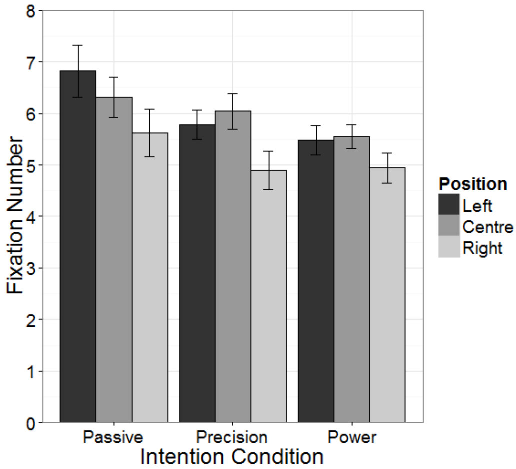


Figure 4.5. Mean fixation durations (L) and fixation numbers (R) to objects by position, across intention conditions

Using the measure of average first fixation to objects for the outcome data, it was found that while there was a main effect of position, F(2,62)= 6.59,p=.002, the effect of intention condition was non-significant, F(2,31)=1.26,p=.300, as was the interaction between them (F<1). In line with the other measures, the effect of position is due to the earlier first fixations on objects on the left hand side of the screen(*M*=16.8) compared to the right(M=21.8, p<.001). Figure 4.6 displays the data for the average first fixations on objects at the three locations, across the three intention groups

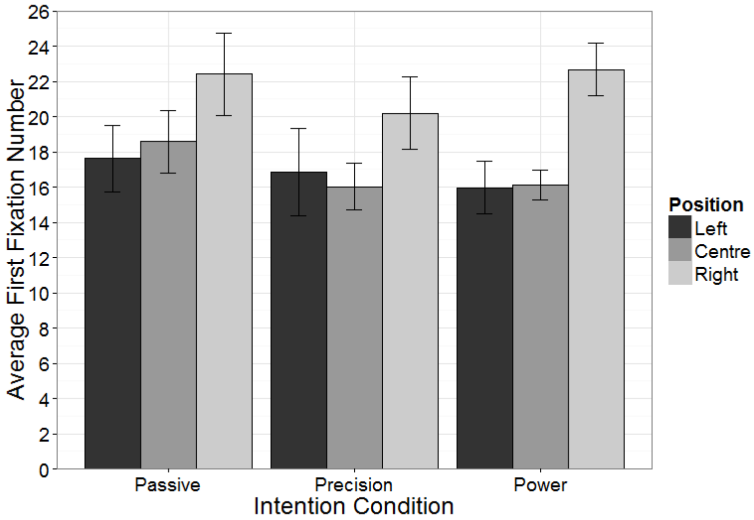


Figure 4.6. Average first fixation number across intention groups and object positions

As for the influence of grip, factorial ANOVAs were conducted including the trial number along with the position and intention condition, to further examine its influence on fixation measures. For measures of both fixation duration and fixation number, no main effect of the trial was found (fixation duration, $F(1,31)=1.91$, $p=.117$; fixation number, $F<1$). All other patterns of inspection were maintained, with both fixation measures showing main effects of the objects' positions, due to more and longer fixations on items at the left of the screen than the right (fixation duration, $F(2,62)=4.82$, $p=.011$; fixation number, $F(2,62)=6.28$, $p=.003$). Similarly, while fixation duration showed no effect of the intention condition ($F<1$), participants in the passive condition made marginally more fixations to all items than participants in the power or precision conditions, $F(2,30)=3.22$, $p=.05$. No interactions were found to be significant between the factors, (F's<1), indicating no influence of the trial on inspection performance.

A slight difference was found for the measures of the primacy fixation number. For this measure, a main effect of the trial number was found, $F(1,31)=13.76$, $p<.001$, as well as a main effect of position, $F(2,62)=7.23$, $p=.002$, from first fixations to the objects at the right being significantly later than those to the left. The average first fixation to objects was significantly later in the last trial (M=20.0) compared to the first

(*M*=15.7, p<.05). Furthermore, a significant interaction was found between the trial and the intention condition, F(2,31)=3.77, p=.034. The pattern shown in the main effect of trial was found to be significant in the eye movement measures for participants in the precision condition (Trial 1, *M*=14.6, Trial 3, *M*=20.7, p<.05). No other interactions were found to be significant (Fs <1).

All participants showed a significant tendency to fixate objects on the left hand side of the screen more, and for longer, compared to items positioned on the right. This was unaffected by the intention condition of the participants, and did not vary across the trials. Combining the factors of position and object grip type did not reveal any further effects, indicating that while there were certain viewing patterns participants followed (e.g., fixating power compatible objects and objects on the left hand side), this did not appear to be affected by the intention manipulation.

4.3.2 Influence of intention on memory

The memory data were first examined by ensuring that the responses to the property questions were above chance level. Scores were considered for each of the five property questions, across the three intention conditions. Table 4.1 presents the mean scores for these groups. (Note that the scores for the passive condition are identical to those in Experiment 2.2., as these are the same participants. These are included here for comparison.)

Table 4.1.

Mean memory scores for individual property questions across intention groups

	Question				
Intention Group	**Colour**	**Shape**	**Orientation**	**Position**	**Presence**
Passive	0.553	0.520	0.583	0.627	0.856
Precision	0.531	0.518	0.640	0.569	0.872
Power	0.520	0.585	0.628	0.625	0.864

One-sample t-tests showed that performance on the memory questions regarding objects' colour, shape, position and presence were all significantly above chance (0.25).

Performance on orientation questions was also found to be better than chance (0.50). As for Experiment 2.2, the questions regarding object presence was discarded, as it mostly measured participants' realisation that the same object types were repeated across the three trials.

4.3.2.1 Object Category. The influence of the object's category and compatibility with the background environment were examined for each of the four property questions.

Colour. For colour questions, a main effect of the scene background was found, $F(2,66)=5.08, p=.009$, with performance significantly worse when the background was the kitchen (M=0.47) than garage(M=0.57) or neutral environments(M=0.56, $p<.05$). Participants were also better at recalling the colour of kitchen compatible items, $F(1,33)=10.75$, $p=.002$, (kitchen M=0.58, garage M= 0.50) but background environment and object category did not interact ($F<1$).

Shape. Participants were significantly worse at recalling the shape of objects present in the kitchen environment than the garage or neutral environments, $F(2,66)=4.61$, $p=.013$, (kitchen M=0.49, garage M=0.58, neutral M=0.57, $p<.05$), and significantly better at recalling the shape of kitchen compatible items, $F(1,33)=29.80$, $p<.001$(kitchen M=0.62, garage M=0.47). The interaction between the factors was not significant ($F<1$).

Orientation. For the orientation questions, participants scored significantly better when items were present in a neutral or garage environment than a kitchen environment, $F(2,66)=5.03, p=.009$, (kitchen M=0.55, neutral M=0.67, garage M=0.63 , $p<.05$). No significant difference was found between correct responses to kitchen or garage compatible objects ($F<1$), and the interaction between object category and scene background was non-significant ($F<1$).

Position. For position questions, a main effect of the scene type was found, $F(2,66)=11.05$, $p<.001$, with participants scoring significantly better on objects in neutral(M=0.65) or garage scenes(M=0.66) than kitchen scenes(M=0.52, $p<.05$). Across all the scenes, participants' performed better when recalling the position of kitchen compatible items, $F(1,33)=10.90$, $p=.002$(kitchen M=0.66, garage M= 0.56). The interaction between the two was not significant, $F(2,66)=1.27, p=.30$.

All the question responses show similar patterns, with better performance on kitchen objects, but worse performance on all objects presented in the kitchen environment, which matches the pattern of data seen in Experiment 2.2. Figure 4.7 shows the memory scores for each of the property questions in the three environments for the two types of object category.

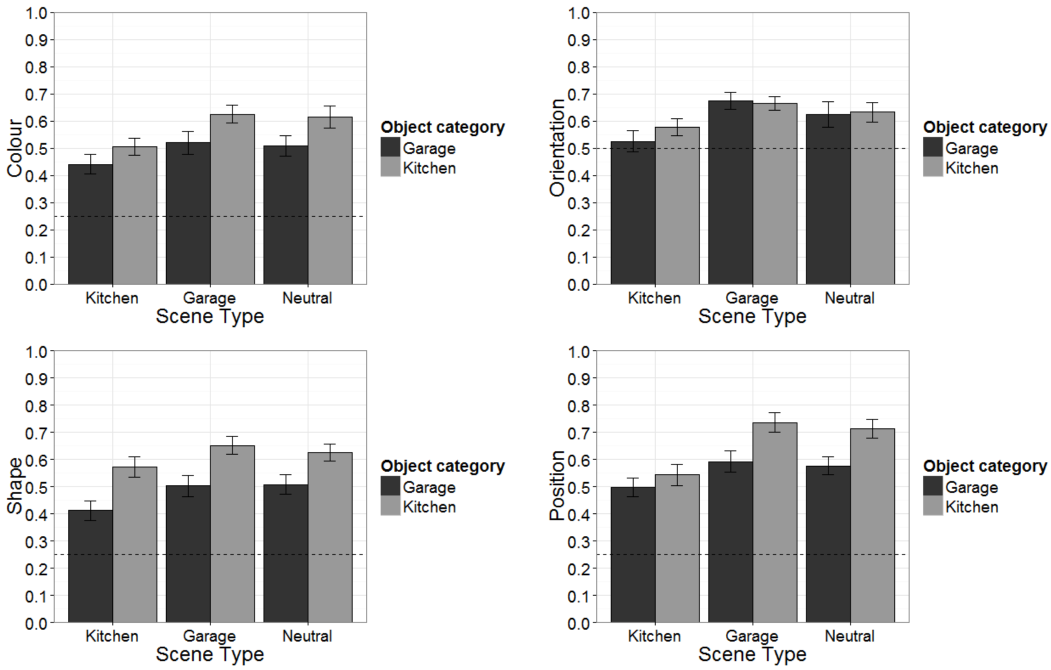


Figure 4.7. Memory scores as proportion correct for the four property questions across the three scene categories and two object categories; left to right, top to bottom: colour, orientation, shape and position

4.3.2.2 Object grip type. The influence of the intention group on the memory for grip compatible objects was considered next. For each intention group, a mixed factorial ANOVA examining the influence of object grip (power or precision), and question type (colour, shape and position) was conducted. Again, due to its different chance level, the orientation responses were considered separately within each of the intention conditions.

Passive. The same participants from Experiment 2.2 were used for this data set, so the results are the same as presented in Chapter 3. In summary, no difference was found between memory scores for power and precision items, but participants were better at recalling the position of items. Focusing only on power and precision objects showed that for both groups of objects, participants still performed better on the position questions compared to the shape property.

Precision. Participants who made a precision gesture during retrieval of the information showed no main effect of the grip condition (F<1) or the question type, F(1,10)=1.52,p=.24, and similarly, no interaction between the factors (F<1). It was decided to examine the scores for objects compatible with power and precision grips separately, as in Experiment 2.2, this method had shown differences between responses at this level. Furthermore, when examining Figure 4.8, it seemed that there was a difference between scores which might become significant when the power and precision object scores were separated. This was found to be the case. . While scores on the three property questions responding to power-compatible objects were not significantly different (F<1), an advantage for position questions emerged in the responses to precision compatible objects, F(2,20) = 4.49, p=.025. Participants were better at recalling the position of objects compatible with their grip type (*M*=0.61) compared to colour (*M*=0.54), and shape (*M*=0.52, ps <.05).

For orientation questions, scores on power and precision items were significantly above chance. However, no significant difference was found between the scores for power and precision items, t(18)=.27,p=.78.

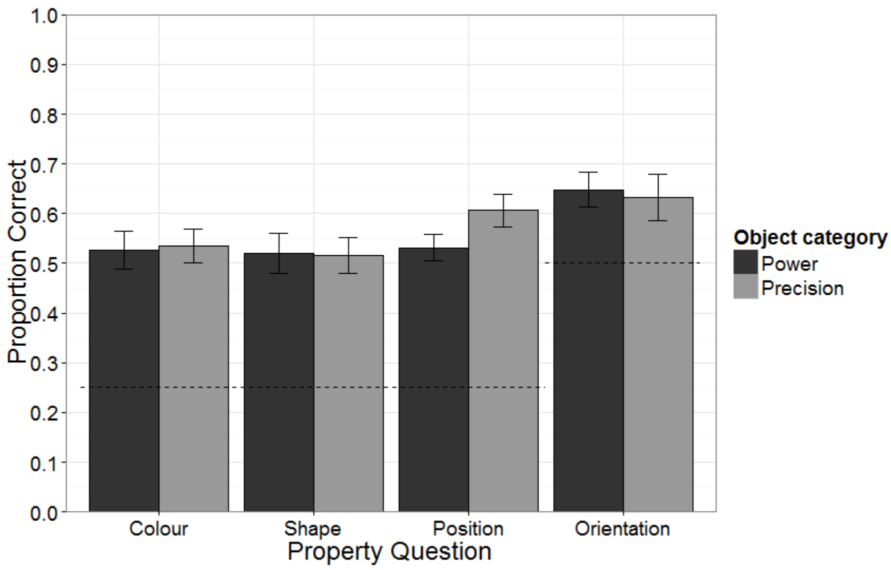


Figure 4.8. Memory scores for object properties in power and precision groups, retrieved under precision intention conditions

Power. Participants who made a power gesture during retrieval showed no difference in their scores on power and precision items (F<1), but a main effect of the question type, $F(2,22) = 4.99$, $p=.016$, with an interaction approaching significance, $F(2,22)= 2.74$, $p=.086$. Again, it was position questions that participants showed an advantage for answering (*M*=0.63) over the shape (*M*= 0.59) and colour (*M*=0.52, ps<.05). Examining the power and precision objects separately showed further results. While responses to the three questions for precision compatible objects did not significantly differ from each other (F<1), a significant difference was found between the responses to property questions for the power compatible objects, $F(2,22) = 9.20$, $p = .001$. Participants were significantly better at recalling the shape (*M*=0.61) and the position (*M*=0.65) compared to the colour (*M*=0.48) of the power compatible objects, (ps<.05).

For orientation questions, scores on power and precision items were significantly above chance. No significant difference was found between the scores for power and precision items, $t(21)=-0.196$, $p=.85$.

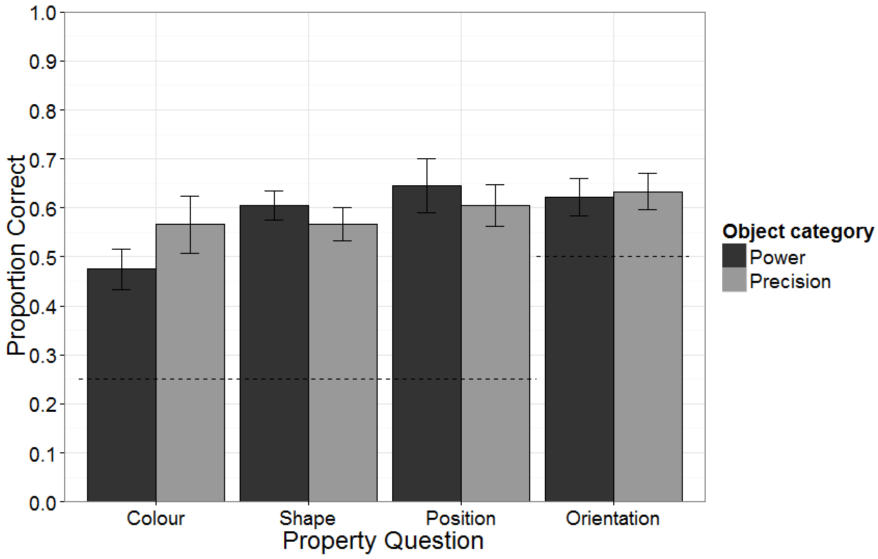


Figure 4.9. Memory scores for object properties in power and precision groups, retrieved under power intention conditions

Participants in the power and precision intention conditions did seem to show some effects of the grip posture they made during the retrieval stage. Participants who formed the power grip showed an advantage only for recalling the position of power objects (and some indication that they recalled the shape of the power objects better than their colour). Participants who formed the precision grip showed a similar advantage for recalling position information, but only for those items compatible with a precision grip.

4.3.2.3 Object Position. The objects' positions (left, centre and right of screen) were analysed to determine their influence, along with the question type, for each of the intention conditions.

Passive. The results for participants who made no action posture during the retrieval stage are the same as those reported in Experiment 2.2. In summary, participants in this condition showed a significant difference between the question scores, with better performance on position questions. However, neither the position of the objects, or the interaction between position and question showed significant effects.

Precision. Participants who made a precision gesture during the retrieval stage showed no effect of the objects positions, ($F<1$) and no significant difference between the property questions, $F(2,20)=1.80, p=.193$. The interaction between the two factors was also non-significant ($F<1$).

For the orientation questions, all responses were significantly above chance. However, no significant effect of object position on the memory scores was found ($F<1$).

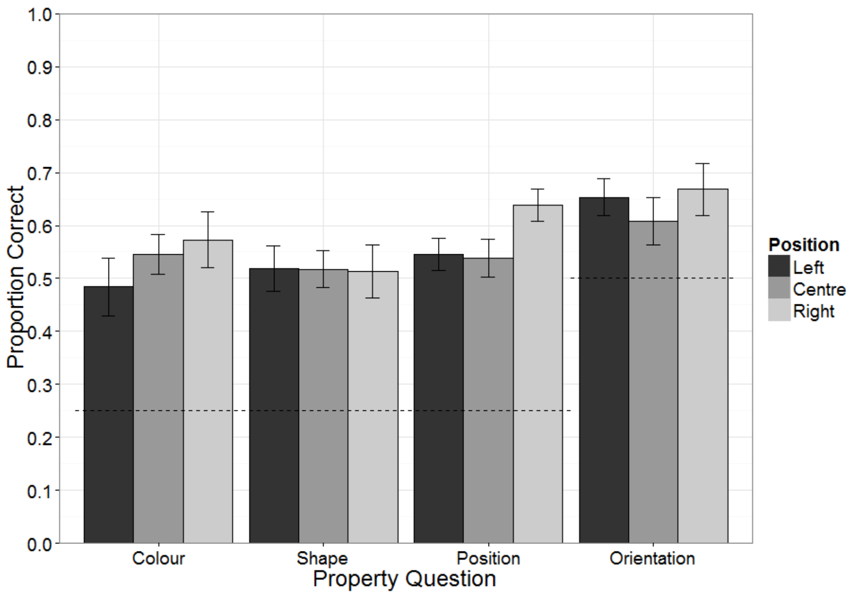


Figure 4.10. Memory scores for object properties at the three positions, retrieved under precision intention conditions

Power. Participants who formed a power posture during retrieval showed an influence of the object position, F(2,22)=4.74,p=.019, with better performance across the three property questions when responding to objects on the left hand side of the screen(*M*=0.63), compared to the centre (*M*=0.53, p<.05). Participants also performed better on position questions compared to colour items, F(2,22)=5.79,p=.009, (position *M*=0.63, colour *M*=0.51, p<.001). Furthermore, the interaction between the position and question type approached significance, F(4,44)=2.31,p=.073. Further investigation of this interaction showed that while recall of object properties for those items at the left of the screen was uniform, significant differences emerged between property recall for items at the screen centre, F(2,22)=3.86,p=.037, and the right, F(2,22)=6.05, p=.008. Post-hoc comparisons showed no significant differences between the question scores for central items, although the means indicate the standard advantage for position over the other properties (position *M*=0.46, shape *M*=0.55, colour *M*=0.59,. This difference was significant for the items at the right of the screen (position *M*=0.44, shape *M*=0.60, colour *M*=0.65, p<.05), with significantly worse recall of object colour compared to shape and position for items at this location. For orientation, no effect of the object position was found, (F<1), although responses to objects' orientation at any location was significant.

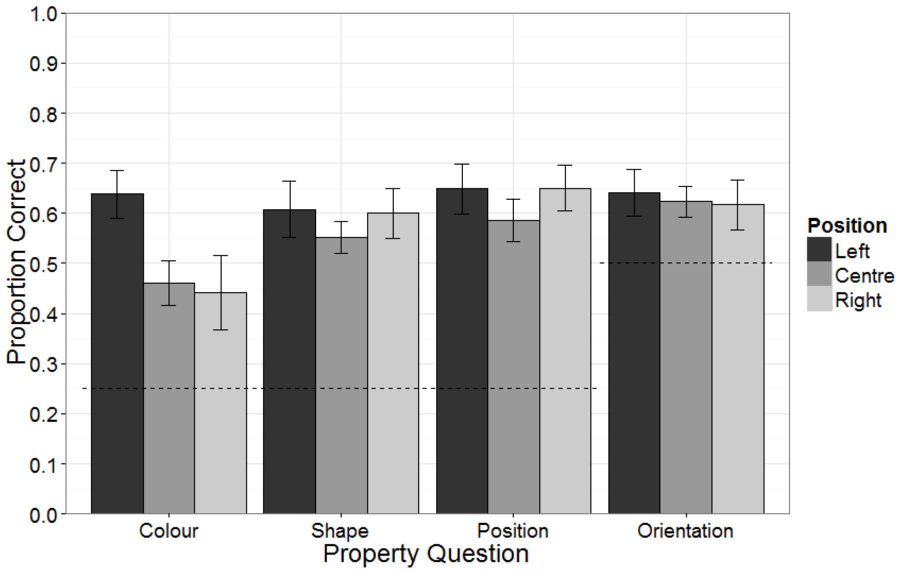


Figure 4.11. Memory scores for object properties at the three positions, under power intention conditions

In recalling objects positioned at the left, right and centre of the scenes, it was found that participants in the precision condition were not affected by the locations of the items. This was not the case for participants in the power conditions, who showed an advantage for recalling items placed on the left hand side, and differences property recall when the items were placed at the centre and right of the scene.

4.4 Discussion

Experiment 3 examined the influence of maintaining an action posture while recalling object information from previously viewed scenes. As for Experiment 2.2, the influence of the gestures was examined in terms of how it influenced both inspection and recall performance.

4.4.1 Influence on Inspection

4.4.1.1 Object category. The influence of the background environment and object category was found to be similar to that seen in Experiment 2.2. Participants spent more time fixating the garage compatible items, regardless of the background scene environment; although there were interactions indicating that when participants viewed the garage scenes, less attention was given to garage compatible objects.

As in Experiment 2.2, we can speculate that the increased fixation numbers and durations spent on garage items indicated that they were less familiar to participants, who therefore spent more time examining them in order to perform better on the later memory questions they know they will be asked. However, this can be only speculation, as we have no measure of how familiar these items really were to participants.

It is interesting that this difference is reduced for the garage environment, perhaps suggesting that participants were recognising the objects are more congruent in this setting, and so finding it easier to process the information, which would be in agreement with earlier work by Henderson et al. (1999), where consistent items were not fixated for as long as inconsistent items. Care should be taken with this interpretation, however, as even in the garage environment; it was still the kitchen items that were fixated less. The interaction arose from the fact that the difference between kitchen and garage objects in the garage scene was not as strong as in the kitchen and neutral scenes.

It is also unclear why the kitchen items did not receive more fixations from being placed in an incongruent scene, although one possibility is the difference between how ‘out-of-place’ items were. Underwood, Humphreys and Cross (2007) found that the degree of the incongruity between object and background can influence how the object is viewed, and while a saw in the kitchen may be strongly implausible, a mug or a kettle in workshop is perhaps more realistic. This, along with the increased familiarity participants may have with kitchen items, may explain why kitchen-compatible items did not receive significantly more fixations in an environment where they were technically incongruent.

Apart from the small difference in the garage scenes, it seems participants in the present study performed similarly to those in Experiment 2.2, with very little influence of the background scenes on the inspection of the objects presented.

4.4.1.1 Object Position and Object Grip. The eye movement records of inspection behaviour in terms of both position and grip were found to be very similar for each of the intention conditions. This is to be expected, as all three groups were essentially identical in this inspection phase. As the scenes were observed without any concurrent action, all participants were engaged in passive viewing. The inspection data here can therefore be seen as exhibiting the standard behaviours for inspection of these scenes.

For the object position, participants showed a similar tendency to that found in chapter 3 to inspect the scene in a left to right pattern. As for Experiment 2.2, this is likely to indicate both an effect of the scene layout, with the participants following the object rows (see Gilchrist and Harvey, 2006), and an influence of the typically asymmetric control of attention, which encourages a bias towards the left when viewing (Nuthmann and Matthias, 2014; Ossandón et al., 2014). However, the earlier finding, that participants in the power and precision condition show a more pronounced viewing pattern and take significantly longer to reach the right hand side, was not present in Experiment 3. Instead, the pattern did not differ between the three groups. This suggests that although the structure of the scene did influence inspection behaviour, the presence of the grip postures further enhanced this. Thus, it seems that in Experiment 2.2, by holding the grip posture during encoding, participants were encouraged to spend more time on the objects. We found no evidence to suggest that they prioritised one particular type of object (i.e., the one that was compatible with their grip posture), so instead this may indicate that the presence of the posture at encoding increased attention to all objects. This resulted in participants starting at the left of the screen, as a standard strategy, but then spending more time on the objects positioned there, and so reducing the time available to examine objects positioned on the right.

For object grip, the results found were similar to those shown in Chapter 3: those items compatible with a power grip were fixated more and for longer than those items compatible with a precision grip. This is very likely due to the larger power compatible items being easier to detect, and so attracting more attention during the viewing stage. Both these findings further confirm the standard inspection behaviours seen in the passive condition in Experiment 2.2, as well as confirming the interactions seen in that study are due to the presence of the action manipulations.

Another important point is that the action manipulations taking place during the retrieval stage of the study did not affect inspection behaviour in the viewing periods following these stages. This suggests that when the action posture is finished, and the participant releases the grip, then any influence the posture had on either inspection or recall of the objects is also completed. This then further supports this possible explanation for the lack of a memory influence in Experiment 2.2. While Experiment 3 showed there were some influences of the trial on inspection behaviour, these did not interact with the other conditions, and most likely reflect participants becoming more experienced with the demands of the task, and developing more of a strategy over time.

One aspect of the data for the inspection behaviour is less clear: this is the consistent finding that, in measures of fixation number, participants in the passive condition were making more fixations to objects than those in the power or precision conditions. This was only found for the fixation number measure, while no differences emerged for measures of fixation duration, suggesting that participants in the passive condition made more fixations of shorter duration. A potential explanation is that the presence of the grip postures at retrieval in the power and precision conditions was influencing the subsequent inspection behaviours in those groups, shown in fewer fixations to objects in the later trials. However, the increased fixation numbers in the passive intention condition were still present in the first trial, where no action had preceded the inspection. The increased fixation numbers by participants in the passive condition may simply reflect a particular strategy of the participants, but it is unknown why this group of participants showed it, while the other two conditions did not.

Overall, the inspection data shows that, without the concurrent grip postures being maintained during the scene viewing, the action postures had no impact on how participants viewed the scene. The only effects that remained were those which are most likely due to the structure of the scenes, which were identical for both studies. This is unsurprising, but acts as a useful contrast to the findings from the influence of action on the memory performance, considered below.

4.4.2 Influence on Memory

4.4.2.1 Object Category. All property questions showed no effect of the scene background, or the categories of the objects themselves. As in Experiment 2.2, the compatibility of the items with their background did not influence memory performance. Instead, the most influence shown came from the presentation of objects in the kitchen environment, with participants scoring lower on all questions for these scenes. For the objects themselves, participants performed better on the kitchen items than the garage items. These patterns are consistent with those seen in Experiment 2.2, and may indicate an influence of familiarity with the kitchen items over the more unusual garage items. As mentioned previously, the influence of the kitchen environment is most likely due to the more crowded layout of this scene. Again, while other studies have shown an interaction between background and foreground in the identification and recall of objects (e.g., Davenport, 2007; Lampinen et al. 2001), it is suggested that the task pressures in the present study led participants to spend more time on the task-relevant foreground objects, at the expense of studying the background, leading to the lack of influence this aspect of the scene had on memory.

4.4.2.2 Object Position. Looking at the memory scores for object properties in terms of where the objects were positioned showed some evidence of an action influence. While those in the passive and precision conditions showed no influence of position on their memory performance, participants in the power condition did show an interaction between the object position and the property recall. Items on the left hand side of the screen were recalled equally well for all properties, but for those items at the right, there was a significant difference between the recall for position and the recall for colour. It was not expected that there would be much influence of position in

Experiment 3. The proximal hands condition is more associated with influencing the location of attention, at least in the broad terms of the sides of the scene versus the centre. However, as noted in the inspection data, participants did have a tendency to view the scene in a right to left fashion, meaning they were fixating the right hand side of the scene closer to the end of the viewing period than the left hand side. It is tempting to speculate that this indicates a recency or a primacy effect. Such effects have been shown in studies of object memory previously: Körner and Gilchrist (2007) used repeated visual searches to show that by having fixated an item in the first search, finding it as the target in the second search was facilitated. This facilitation was greater if the first fixation to the object was more recent. Similar results were found by Hollingworth (2004), with memory for the form of a target found to be significantly better if it had been fixated within one to two fixations before test. In the present study, it was the items on the left that were fixated earlier, and all the object properties were recalled equally well at this location. However, for items placed at the centre and right, and therefore viewed (on average) later than other items, colour information was recalled less accurately. This may perhaps indicate that colour information is most affected by the primacy effect, and requires more time to be incorporated into the representation. However, while studies such as Tatler et al. (2005) demonstrate that object properties display different time courses for accumulation and retention, colour information was found to be retained stably (at least in photographed scenes).

It is also possible that the presence of the actions at retrieval influenced this pattern: colour is the least action-relevant property, and so the poorer recall here may indicate de-prioritisation of this information when the retrieval context emphasises the performance of action. This is more difficult to reconcile with the finding that these effects appeared to be strongest for those items associated with a precision grip, incompatible with the action actually being maintained in this condition. One suggestion for this pattern is that the precision advantage for right hand side items was a recency effect: it was a consistent pattern that participants were later to look to precision items than power items, and so precision items at the right of the screen were the last to be attended to, an influence that then showed itself in the memory performances. It is still not clear why this effect should have emerged only for the power condition, as the viewing patterns for all conditions were similar; but the effect itself was only marginal.

Similar patterns may have occurred in the other conditions, and yet not reach significance.

4.4.2.3 Object Grip. Examining the memory scores in terms of what grip action was being performed at retrieval showed perhaps the strongest evidence for an influence of the action. Participants in the two grip conditions showed better recall of the position information for items compatible with the grip they performed, while incompatible items showed no difference in recall performance for their properties. The effects were not identical for power and precision groups: only position memory was enhanced for the precision compatible items, while both shape and position were recalled more accurately than colour information for power compatible objects.

These findings are in agreement earlier studies suggesting that action information is part of an object's representation, and with the broader grounded cognition literature as a whole. Affordance studies, such as Derbyshire et al. (2006) and Ellis and Tucker (2004) have shown that the process of recalling mental images of objects is enough to activate the well-learnt and intrinsic associated gripping actions. Indeed, Ross et al. (2007) showed that this inclusion can even occur with arbitrary actions that were simply paired with objects over a short period of time.

Furthermore, it appears that the context in which the information is retrieved has an influence on what can be recalled. We suggest that Experiment 3 provides evidence that the presence of action at retrieval allowed participants to better access not only their memory representations, but particularly the features that are relevant to acting. This is in agreement with studies from the encoding-specificity literature, in particular those that use action or body posture similarities at encoding and recall to demonstrate influences on the retrieval performance (e.g., Dijikstra et al., 2007; Pine, Reeves, Howlett and Fletcher, 2013).

The current study is not, however, a true encoding-specificity study: participants did not interact with the specific objects shown in the stimuli pictures at any time, unlike the earlier work where the participants had experienced the action manipulation during the formation of the memories (e.g., actually visiting the dentist and lying on a chair, as used in Dijikstra et al.'s (2007) study). Despite this, we still demonstrated effects in our findings, perhaps due to the familiarity of the objects used. While they may not have interacted with the specific stimuli, participants would presumably have interacted with other examples of them before the study, and so incorporated the association between the object and its grasp type. This is therefore not simply a case of a match between encoding and retrieval situations, but an indication that the representations for the everyday stimulus objects contain information about the actions associated with them, which, when accessed, will aid retrieval of information about the object (as seen in Ross et al., 2007). Furthermore, this is perfectly in line with earlier studies that suggest that grip postures are a strongly intrinsic part of an object's representation (e.g., Derbyshire et al., 2006, Iachini, Borghi and Senese, 2008).

Similarly, the power and precision grips maintained by the participants were not calibrated to be specifically compatible for any particular object in the scene: there is likely to be some variation in the precision grip required for a teaspoon and the precision grip required for a clothes-peg, for example. However, it seems that the more generalised grip gesture is enough to have an effect on recall performance, and indeed, earlier studies of action preparation influencing perception have typically not made a particular attempt to exactly match stimuli and grip posture. Pine et al. (2013) used fairly general actions (clenched fist or flat palm) and found these could still increase the speed of object naming when they were congruent with the target, despite the gestures matching the actions only minimally. For Experiment 3, it is likely that these two aspects both contributed to the effect we obtained. The action gestures are well learnt, and strongly associated with the concept of the objects presented, and while they did not exactly match every object, the overlap between the represented action for an object, and the action formed appears to have been enough to lead to the observed memory benefit.

Experiment 3 extends previous work on the influence of action at retrieval by showing the memory facilitation is most effective for certain object properties, in particular, the position information for the objects. While this indicates spatial information being prioritised, rather than a more intrinsic object feature, we noted in Experiment 2.2 that there is a clear logic to this situation. Recalling an object's location is perhaps the most important factor during the execution of a task: if the actor knows where it is at the start of the task, they can quickly locate it again when it is required, without having to spend extra time conducting a more detailed search. Other features which may be important (e.g., shape or orientation) can be extracted when the object is re-fixated, but position information is necessary to get to that stage. Indeed, while studies show our representations during action have a tendency to be rather sparse, there are several findings that indicate spatial information is maintained, and remains available to the observer to rely on, if the on-line viewing should be disrupted in any way (see e.g., Aivar et al., 2005; Brouwer and Knill, 2007).

The present study does show an exception to this, however, with participants in the power-grip intention condition showing an advantage for recalling both shape and position information for the grip compatible items, while no such effect is seen for the precision-compatible items. A possible reason for this difference between the groups may relate to the nature of the grips used: perhaps the objects selected as power grip compatible were all easily matched to the grip posture that participants made during the recall phase. As a result, participants retrieved the shape information as it was likely to be useful and match their posture. In contrast, the precision posture made by participants might not match every one of the precision-compatible stimuli so exactly, and so retrieval of the shape information is less useful: the exact shape must be extracted from later re-fixation of the object, once it is located. Alternatively, the difference may be linked to the differences in fixation during the inspection phase. Participants spent more time on the larger power-compatible items whatever their intention condition. Possibly, this increased fixation combined with the power posture at recall increased the facilitated retrieval, allowing the extraction of shape information as well as position.

It is interesting to note the contrast between the findings of Experiment 3 and Experiment 2.2. While the present study found a prioritisation of position information specific to the action posture performed, Experiment 2.2 found that participants were consistently good at recalling position, regardless of the object type and their action condition. As noted, a general advantage for position memory is in accordance with other studies which have suggested that the acquisition of position information is automatic, and less affected by the particular task demands. Kondo and Saiki’s (2012) study demonstrated this by showing that participants could not ignore position information, even when the task setting made it irrelevant to performance. Similarly, Lamy and Tsal (2000) found that attention was always attracted to a cued location, regardless of whether location was task relevant or not, while features such as shape and colour were only attended when they were relevant. Studies of the formation of object files typically suggest that the spatial information for an object is used as a binding site for the item, as it is an object feature which cannot be shared by another item in the scene (see e.g., Wheeler and Treisman, 2002; Hollingworth and Rasmussen, 2010). Given this earlier work, the specific facilitation of position information shown in the current study is perhaps surprising. One possible explanation for this difference between the studies is that the presence of the action posture at retrieval leads to a position deficit for the non-compatible objects. If position information is normally well recalled in all situations, then when the conditions of retrieval suggest a specific association with particular objects, it may become necessary for position information relating to other objects to be suppressed. This will then give the appearance of facilitating only the information relating to the compatible items, as seen in the present results. While not examining exactly the same area, there are suggestions for similar findings in affordance effects: Tipper (2010) proposes that attention to specific object details may act as a boundary condition in the emergence of the affordances not only by facilitating relevant responses, but by suppressing the irrelevant ones. However it is achieved in the current study, it seems that the presence of action postures at retrieval does lead to benefits for the property of object position for those items compatible with the postures.

Experiment 3 is in line with the central proposals of theories such as the TEC (Hommel et al., 2001), and grounded cognition in general. Our representations contain both motor and featural information, gained by incorporating details of the situation present at first encoding (e.g., associated action postures) into the resulting memory trace. Later reconstruction of some aspect of the trace (in this case, the well learnt grip type) aids the process of accessing the trace. The findings presented here go further by demonstrating that this facilitation seems to target features that are particularly useful for later action performance.

In the context of this thesis, Experiment 3 provides a contrast to Experiment 2.2. Each study shows that either inspection behaviour or later recall processes can be affected by the presence of an action posture. However, these studies demonstrate the effects only when the action is presented concurrently to the stage in question, either encoding or retrieval. In order to further investigate how action may continue to influence memory, it is necessary to extend the presence of the action manipulation, so that it continues through both encoding and retrieval stages of the task. This is therefore the aim of the experiment conducted in Chapter 5.

Chapter Five- The influence of the potential for action at encoding and retrieval on the formation of object representations

5.1 Introduction

One question which arises from the findings of the previous experiments relates to how long the effects of the action preparations and postures might be expected to last. Thus far, the findings from the earlier studies suggest that the influence of the action potential is restricted to the time at which it was present. In Experiment 2.2, where the action was present alongside the viewing and encoding process, the effects were seen on the eye movements and fixation patterns of the participants. In Experiment 3, where the action postures were present at the retrieval stage, it was the recall of information that was affected, without any influence on the eye movements.

There is some previous work examining the influence of action on perception which suggests that action effects and representations are fairly short-lived, in line with the findings from Experiments 2.2 and 3. At the lowest level, there is evidence from the TEC (Hommel et al., 2001) which suggests that the integrated codes for action are more transient than those for perception. Part of the proposed system for the TEC is that, once items are bound into an event code, they are less available for subsequent events, which draw on the same features. Stoet and Hommel (1999) examined this effect when participants had to produce responses that overlapped in time, and drew on the same action features. Unexpectedly, performance on the second response was not inhibited by the amount of overlap between the two aspects as it was when perceptual stimuli overlapped. Instead, particularly at short intervals between the two responses, the second was facilitated by the amount of overlap with the first. Hommel et al. (2001) suggested that, at least for action-related codes, the bindings are short-lived, decaying more rapidly than those for object-related event codes.

While the TEC concentrates on rather more abstract event and action codes, there is also evidence from the studies conducted as part of more natural tasks, which suggest that representations constructed as part of a natural task are generally transient. Tatler (2001) examined participants' memories for the objects in an environment in which they were acting (making a cup of tea). Normal viewing during the task was disrupted unexpectedly by the lights being switched off, and participants were asked to recall what they had just been looking at. Recall for the contents of the fixation at the point of disruption was high, with large amounts of detail. However, recall for the information contained in the fixation previous to the one being made during the disruption was poor, with little detail retrieved. In some cases, where participants had recently made saccades to a new location just before their vision was disrupted, they still recalled information from the fixation previous to that, but over time, the information from the previous fixation appeared to be overwritten by that from the currently fixated location. Thus, the immediate detail received during a natural task may be very transient, and subject to rapid replacement by incoming information. Indeed, Land and Tatler (2009) note that, in the midst of a natural task, overwriting the earlier information is a necessary process. This information is obtained for a particular part of a task, and would only interfere with later sections of the task if it was maintained. For example, when driving, maintaining the information about the curvature of the previous bend in the road would be no help (and might hinder) navigation of the next bend. This is similar to the way in which the type of information maintained is that which is necessary for future processes; shown clearly in Triesch et al.'s (2003) block sorting task. Participants here would maintain the information about the size of a block only if it was a relevant property for a later stage of the task (for example, it informed the participant where the object should be set down). If there was nothing to indicate that size information would continue to be important throughout the task, it would not be maintained, and so it was more efficient for this information to be discarded.) In the same way, the length of time information is maintained is dependent on how far in the future the information will be required. Thus, when driving, information about the previous stretch of road is not maintained for a long period, as it is only relevant for a specific part of the task. In other tasks, participants may maintain information, such as the spatial location of objects that will be necessary later, over a longer period of time until they require the object (see e.g., Land et al., 1999; Pelz and Canoza, 2001).

Maintaining information therefore seems to depend on its later necessity to the task. In terms of our own studies (Experiments 2.2 and 3), participants do not receive any outright statement of how the action postures relate to the objects they see (as in all previous studies examining how the preparation of action affects perception, e.g., Fagioli et al., 2007, Symes et al., 2008). Any effects of action emerge therefore from the suggestion of the possibility, via the postures adopted by participants. While effects of the actions did emerge, these were closely linked to the period of the study at which they were performed, suggesting that ending the action ends the influence it has, as it indicates the potential for action is done.

The purpose of Experiment 4 is to therefore extend the time at which the action manipulations are present, still within the paradigm used for Experiments 2.2 and 3. Prolonging the presence of the action potential is done simply by requiring participants to maintain the posture throughout both the viewing/encoding stage, and into the recall stage. In this way, the potential for participants to act with the objects remains throughout the initial construction of the representations, and while the information is being retrieved. Such a manipulation is perhaps the least realistic variation of the paradigm we have used in Chapters 3 and 4. While we might plan an action when viewing, or recall an action when remembering an object, to maintain this action plan throughout both processes is something we might be less likely to do within an everyday setting. While this study may indicate a reduction in realism, we feel it is a reasonable next step to make, to determine if it is the physical presence of the action preparation during encoding and retrieval that will lead to influences on both the inspection and recall of objects and their properties. As a result of these manipulations, it is possible that different effects will emerge in the recall performance. Stronger patterns might indicate that by prolonging the action posture, the representations have been constructed and accessed in favour of this action, while a weaker influence in the results could suggest that the reduced realism of the situation is a factor in the study.

Another consideration is how the action postures at both encoding and retrieval will influence the way in which the representations are constructed and accessed. One possibility is that we find similar effects to those in Experiments 2.2 and 3: that is, the same patterns will be evident in the eye movements and memory results, but show no indication that they are changed by the presence of the action at the other stage as well. Such a finding would indicate support for a more purpose-neutral representation (Wilson, 2002), where the influence at encoding has no influence on the construction of the representation. The retrieval performance might continue to show effects of the action presence, but again, this would be due to the context of retrieval affecting the access to the representation, unconnected to the way in which the representation had been formed.

Alternatively, the representation may be constructed with the context of the action posture in mind, and the retrieval performance similarly influenced by this construction. Thus, rather than seeing only one property facilitated (as in Experiment 3), other properties would also show an effect in how they are recalled. In this case, it would seem that maintaining the action representation across both postures does indeed lead to the formation of a representation weighted for action, where this construction continues to affect the success of retrieval when later accessing the memory.

5.2 Method

5.2.1 Participants

Twenty-four participants were recruited, of which 2 were later removed from analysis due to poor calibration. The analysed sample consisted of 5 males, mean age 25.2, SD = 3.5. 10 were assigned to the precision grip condition, and 12 to the power grip condition. Handedness and eye dominance were measured by self-report: the sample contained no left handers and 8 participants showing left eye dominance. Participants were recruited using advertisements on the University's on-line recruitment system, and received payment (£3) for their participation.

5.2.2 Stimuli, Procedure and Design

These were identical to Experiment 3, with one change. Participants in Experiment 4 performed the action pose they were assigned to during both the viewing stage of the study, and the retrieval stage. Participants began these poses before the presentation of the first stimulus scene, and maintained them throughout the three trials, until after the last memory question of the third trial had been asked. Poses were again maintained in the participants' dominant hand, while their non-dominant hand made the responses on the computer keyboard.

The same measures of perception (average number of fixations, average duration of fixations and primacy fixation numbers) and memory (responses to multiple choice questions regarding object features) were used in Experiment 4 as in Experiment 2.2.

As for Experiment 3, the measures from the 11 participants in the passive condition collected in Experiment 2.2 were used as a baseline in the following analyses.

5.3 Results

5.3.1 Influence on Perception

5.3.1.1 Scene inspection. As for Experiments 2.2 and 3, participants' eye movements were examined in terms of how their viewing condition affected viewing of the overall scene. The regions of interest for analysis were the scene thirds, that is, the left, central and right regions of the scene stimuli. Measures of average total fixation number, average total fixation time and the average ordinal number of the first fixation to a region were examined for influences of the participants' intention condition and the scene location fixated.

Using the measure of fixation number, participants showed a significant influence of the intention condition, $F(2,29)=3.62$, $p=.040$. Pairwise comparisons showed that this came from participants in the power condition making fewer fixations to the scene ($M=19.4$), across all the locations compared to the passive ($M=21.1$) and precision ($M=22.0$) conditions (although post-hoc comparisons did not show significant differences here, $ps>.05$).

A significant effect of the scene area was also found, $F(2,58) = 47.56$, $p<.001$. Participants showed significant differences between all three locations, with significantly more fixations made to the central region than the two edge regions ($M= 26.3$, both $ps <.001$), and significantly more fixations made to items on the left ($M=19.3$) than the right ($M=16.6$, $p<.05$). No interaction emerged between the intention condition and the scene location ($F<1$).

The measure of total fixation time showed a slightly different pattern. Across the three intention conditions, participants did not differ in the time spent fixating the scenes ($F<1$). However, a main effect of the scene location did emerge, $F(2,58)=41.81$, $p<.001$. Again, significant differences were found between all three regions, with participants spending the most time fixating the central region (M=7500ms), compared to both left (M=5506ms) and right (M=4853ms) locations ($ps <.001$), and significantly more time on the left scene region compared to the right ($p=.033$). No significant interaction was found between the scene region and the intention condition for this measure ($F<1$).

For both fixation number and duration measures, there was a strong influence of the central scene region. As for the previous studies, this is most likely due to the drift correct presented prior to the scene during the experiment. This might bias participants to spend more time in this area, skewing the results. In order to investigate, the analyses for fixation number and duration were re-run without the data from the central region.

This change had a slight effect on the outcome for both measures. For fixation number, the main effect of intention was still present, but was now only marginally significant, F(2,29)=2.99, p=.06. This was still due to participants in the power condition making fewer fixations on the scene overall (*M*=16.7), compared to passive (*M*=18.4) or precision conditions (*M*=18.9), although post-hoc comparisons remained non-significant (ps>.05). Similarly, the influence of location was still present, though no longer as strong, F(1,29)=5.77, p=.023. The left region of the scenes (*M*=19.3) received more fixations than the right hand region (*M*=16.6) across all groups. No interaction was found between the two factors (F<1).

Similarly, for the measure of fixation duration, the removal of the data for the central region changed the strength of the effects, but not the pattern of inspection. No main effect was found for the intention condition for this measure (F<1), and the influence of scene region was also weaker, as it now emerged as only marginally significant, F(1,29)=3.38, p=.077. As before, participants spent longer fixating the left region (*M*=5506ms) compared to the right (*M*=4853ms).

Finally, the scene inspection data were examined in terms of the number of the average first fixation made to the scene regions. Due to the fact that all first fixations to a scene were made in the centre because of the drift correct, the central region was again removed from this analysis, and only the average first fixations for left and right scene regions were examined. For this measure, no influence of the intention group was found (F<1). The scene region did have a significant influence, F(1,29)=18.05, p<.001, with participants first fixating the left of the scene (*M*=9.0) earlier than the right (*M*=17.5). The interaction between these two factors did not emerge as significant, F(2,29)=1.56, p=.226. Figure 5.1 displays the results for the average first fixations to scene regions, across the three intention conditions.

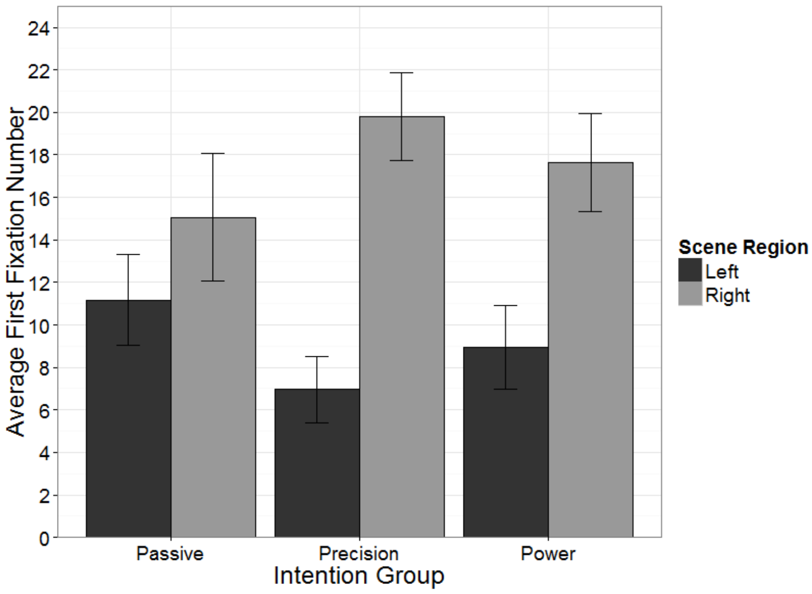


Figure 5.1. Measure of average first fixation to scene regions in the three intention conditions

5.3.1.2 Object Category. As for the previous studies, analyses were carried out to determine whether each object's associated category and the background of the scene had any influence on the way in which the scenes were inspected. Both fixation duration and fixation number were used as the outcome measures.

For the measures of fixation number, no influence of the scene type was found (F<1). However, a difference emerged for the object category, such that items associated with a garage received more fixations than those compatible with a kitchen, F(1, 32) = 62.015, p<.001 (garage *M*=6.6; kitchen *M*=5.4). Furthermore, the interaction between object category and scene type was significant, F(2, 64) = 6.00, p=.004. Breaking down the interactions showed that this difference between object types was at its strongest in the kitchen environments (p<.001), (garage *M*=7.0; kitchen *M*=4.9), although the differences for neutral (garage *M*=6.5; kitchen *M*=5.8) and garage (garage *M*=6.3; kitchen *M*=5.4) environments were also significant (ps <.05).

A similar pattern was found for the measures of fixation duration. Again, no significant difference was found between the three scene types (F<1), but the garage compatible objects were fixated for a longer average time, F(1, 32) = 48.61, p<.001, (garage *M*=1853ms; kitchen *M*=1562ms). The interaction between object category and scene type was also significant, F(2, 64) = 11.14, p<.001, and this was once again driven by the garage items in the kitchen environment being fixated for significantly longer than kitchen items (p<.001, garage *M*=2207ms; kitchen *M*=1445ms). However, for the fixation duration measure, this difference was not significant for the items in the garage scene (p=.19), and only marginally so for items in the neutral scenes (p=.053, garage *M*=1744ms; kitchen *M*=1600ms).

Figure 5.2. shows both the results for measures of fixation number and fixation duration.

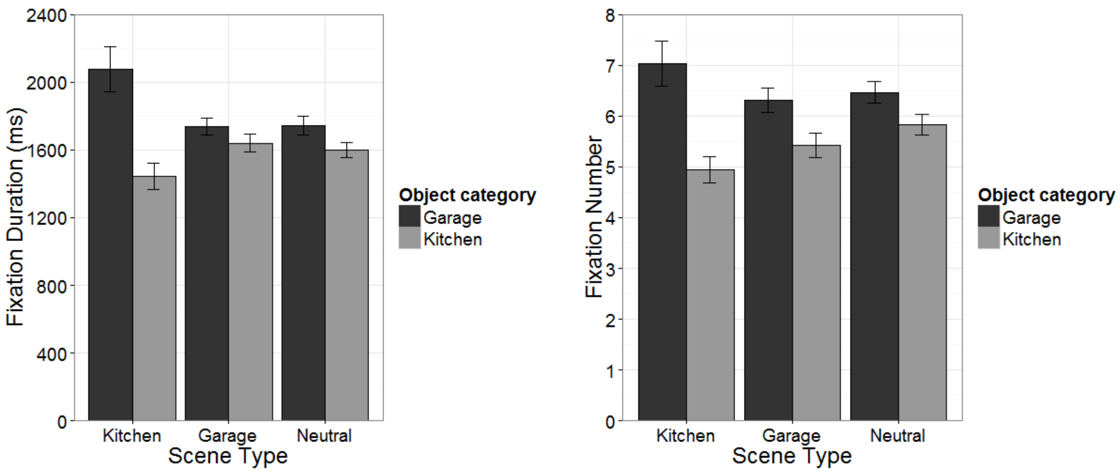


Figure 5.2. Graphs for (L) fixation duration and (R) fixation numbers on garage and kitchen compatible objects, across the three scene types

5.3.1.3 Object Grip. The influence of the objects grip compatibility on inspection behaviour was compared across the three intention conditions.

Fixation duration. For the measure of fixation duration, an effect of the object's grip type was found, $F(1, 30) = 23.80$, $p<.001$, with significantly longer fixations to objects compatible with a power grip (*M*=6.7) than precision grip (*M*=5.3). No effect of the intention condition was found, and the interaction between the two factors was similarly non-significant (both Fs <1). Figure 5.3 shows the data for the fixation durations.

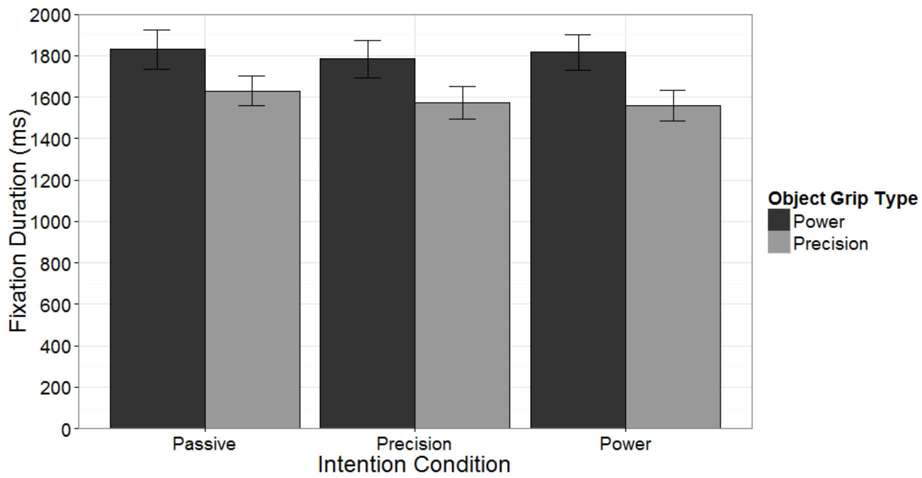


Figure 5.3. Average fixation durations to power and precision compatible objects, across the three intention conditions

Fixation number. The pattern found for the measure of fixation numbers was very similar to that for fixation duration. Again, an effect of the object's grip type was found, with significantly more fixations to power items (*M*=1811ms) than precision (*M*=1588ms), $F(1, 30)=70.33$, $p<.001$. However, this effect did not differ across the intention conditions ($F(2, 30)=2.28$, $p=.12$) and no interactions were found($F<1$).

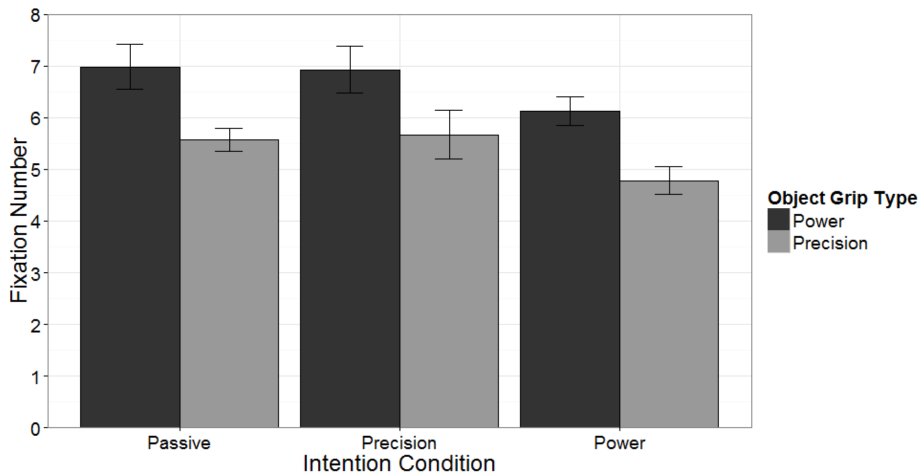


Figure 5.4. Average number of fixations to power and precision compatible objects, across the three intention conditions

5.3.1.4 Object Position. Mixed factorial ANOVAs were run to examine the influence of an object's position in the scene on inspection behaviour, firstly across the three intention conditions, and then examining each separately. Measures of fixation duration, number, and average first fixation to objects were analysed.

Fixation duration. For this measure an effect of position was found, F(2, 60) = 3.62, p=.032, due to participants spending significantly longer on objects at the left (*M*=1815ms) than the right (*M*=1593ms, p<.05). However, no difference was found between the intention conditions, (F<1) and no interaction between the two factors (F<1).

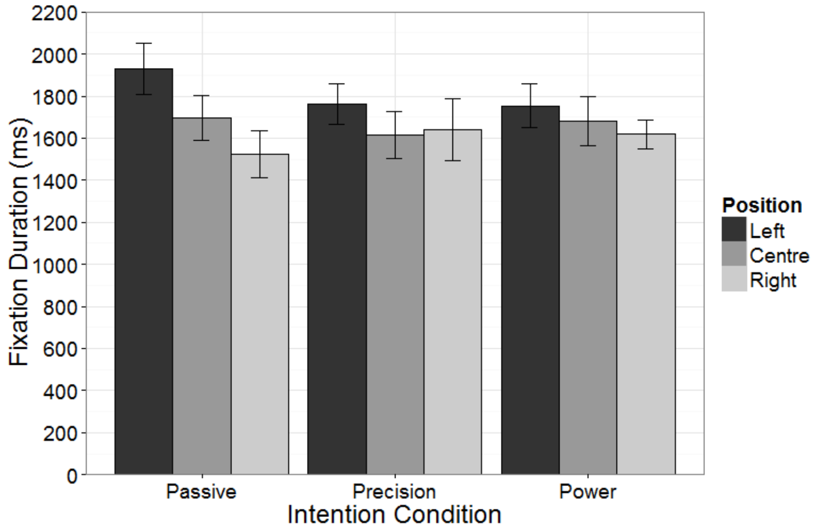


Figure 5.5. Average fixation durations on objects positioned across the scene for the three intention conditions

As before, the participants in the passive condition were the same as in previous studies. Their results are therefore the same as previously reported, with participants spending significantly longer on the left side objects than those on the right. However, for both the power and precision intention conditions, participants showed no influence of the position on their fixation durations (both F's <1).

Fixation number. A similar pattern was found, with a significant effect of position, F(2,60)=5.35,p=.007, due to participants making more fixations to objects on the left (*M*=6.4) than the right(*M*=5.4, p<.05).Once again, the three intention conditions did not differ, F(2,30)=2.13, p=.136 and no interaction was found between the factors(F<1).

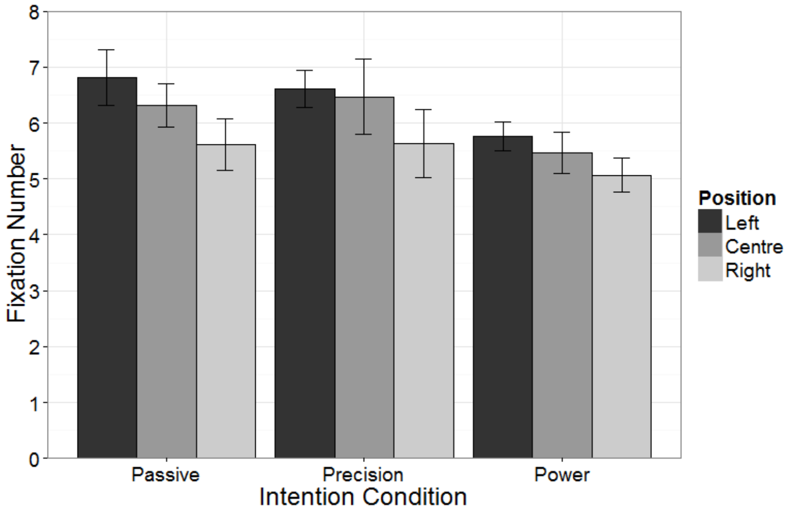


Figure 5.6. Average number of fixations to objects positioned across the scene for the three intention conditions

Examining the responses from the power and precision intention conditions separately, participants in neither the precision, $F(2, 18) = 1.69$, $p=.212$ nor power, $F(2,22) = 1.80$, $p=.189$ conditions showed a significant influence of the object's position on their inspection behaviour (Figure 5.6).

Average first fixation number. A similar pattern emerged, with an effect of the object position, $F(2, 60)=13.45$, $p<.001$, due to later first fixations to right hand (M=23.8) items than those on the left hand side (M=16.5, $p<.001$) or at the centre (M=16.9, $p<.001$). The intention condition continued to have no influence ($F<1$) and no significant interaction was found, $F(2,60)=1.33$, $p=.269$.

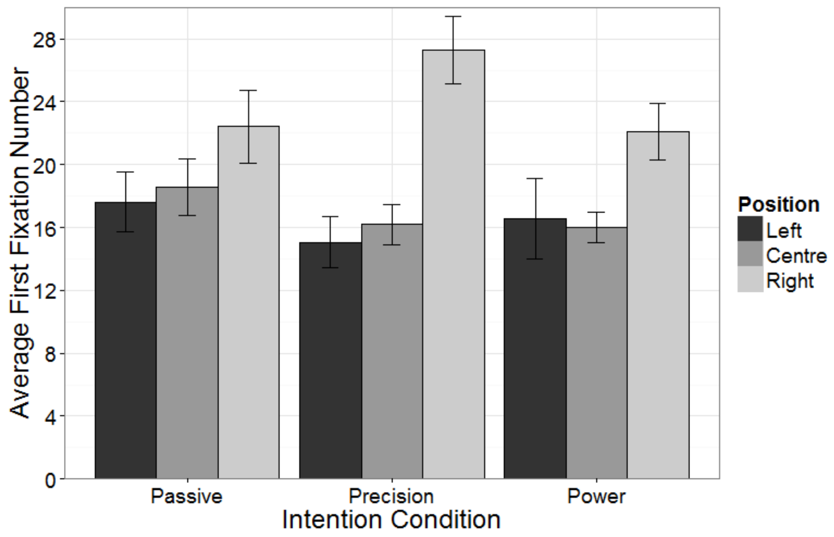


Figure 5.7. Average first fixation to objects positioned across the scene for the three intention conditions

Examining the power and precision intention conditions, however, did show significant differences emerging (Figure 5.7). Unlike participants in the passive intention condition, where no significant difference was found between the average first fixations to objects at the three positions, the two grip conditions did show a significant effect of position. Both participants in the precision condition, $F(2,18) = 15.33$, $p<.001$ and the power condition, $F(2,22) = 3.62$, $p=.045$ showed that they were later in first fixating items present at the right of the screen (power *M*=22.0, precision *M*=27.3) than those at the left (power *M*=16.5, precision *M*= 15.1) and centre (power *M*=16.0, precision *M*=16.2). This is strongest for the precision intention condition ($p<.001$), while for the power intention condition, the effect is solely between the centre and right objects, and only approaches significance ($p=.087$).

5.3.2 Influence on Memory

Table 5.1 shows the proportion of correct responses for each property question, within the three intention conditions. (As before, the results for participants in the passive condition are the same as those presented in Experiments 2.2 and 3, and are included here as a baseline.)

Table 5.1.

Proportion of correct responses to property questions across the intention conditions

	Question				
Intention Group	**Colour**	**Shape**	**Orientation**	**Position**	**Presence**
Passive	0.553	0.520	0.583	0.627	0.856
Precision	0.549	0.473	0.552	0.535	0.800
Power	0.532	0.496	0.565	0.554	0.832

These scores were checked to ensure they were above the appropriate chance level, using one-sample t-tests. All responses to the Colour, Shape, Position and Presence questions were significantly above the chance level of 0.25 (all ps <.01); while responses to the Orientation questions were significantly above the chance level of 0.5 (all ps <.05). As for the previous studies, the responses to the Presence questions were not included in further analysis, due to the artificially high score. Orientation responses were analysed separately from the other questions due to the different level of chance.

5.3.2.1 Object Category. The influence of the scene type (kitchen, garage or neutral) and object type (garage or kitchen) was examined for each of the four analysed property questions.

Colour. *A* main effect of the scene type was found, F(2, 64)=7.57, p=.001, with participants significantly better at recalling object colours in the garage environment (*M*=0.61) than the kitchen (*M*=0.48, p=.003). An effect of the object category was also found, F(1,32)=10.90, p=.002 showing participants to be better at recalling the colour of kitchen compatible items (*M*=0.59) compared to garage compatible items (*M*=0.50), but the interaction between the two factors was non-significant (F<1).

Shape. For the recall of shape information, an effect of the scene type was again found, F(2, 64)=5.06, p=.009, with participants marginally better at objects in the garage environment (*M*=0.53) and significantly better in the neutral environment (*M*=0.54) than the kitchen environment (*M*=0.44, p=.070; p<.05 respectively). Better recall was also found for kitchen compatible items (*M*=0.55) over garage items

(*M*=0.46), F(1,32)=12.71, p=.001, but again, no interaction between the two factors (F<1).

Orientation. For the recall of orientation information, it was found that there was no significant effect of any factor. Participants did not perform differently when recalling the information from different scene types, F(2, 64)=1.28, p=.29 or categories of the objects, F(1,32)=1.56, p=.22 and the interaction was also non-significant (F<1).

Position. When recalling the position of objects, an effect of the scene type was found, F(2, 64)=8.82, p<.001, with participants significantly better at recalling items in the garage (*M*=0.64) and neutral environment (*M*=0.59) than those in the kitchen (*M*=0.50; p=.001; p=.070 respectively). As for the other property questions, participants recalled the position of kitchen items (*M*=0.61) significantly better than garage items (*M*=0.54), F(1,32)=5.43, p=.026. Again, no interaction was found between the factors, F(2, 64)=1.72, p=.187.

Figure 5.8 displays the scores for object categories within the scene types, for each of the four property questions analysed here.

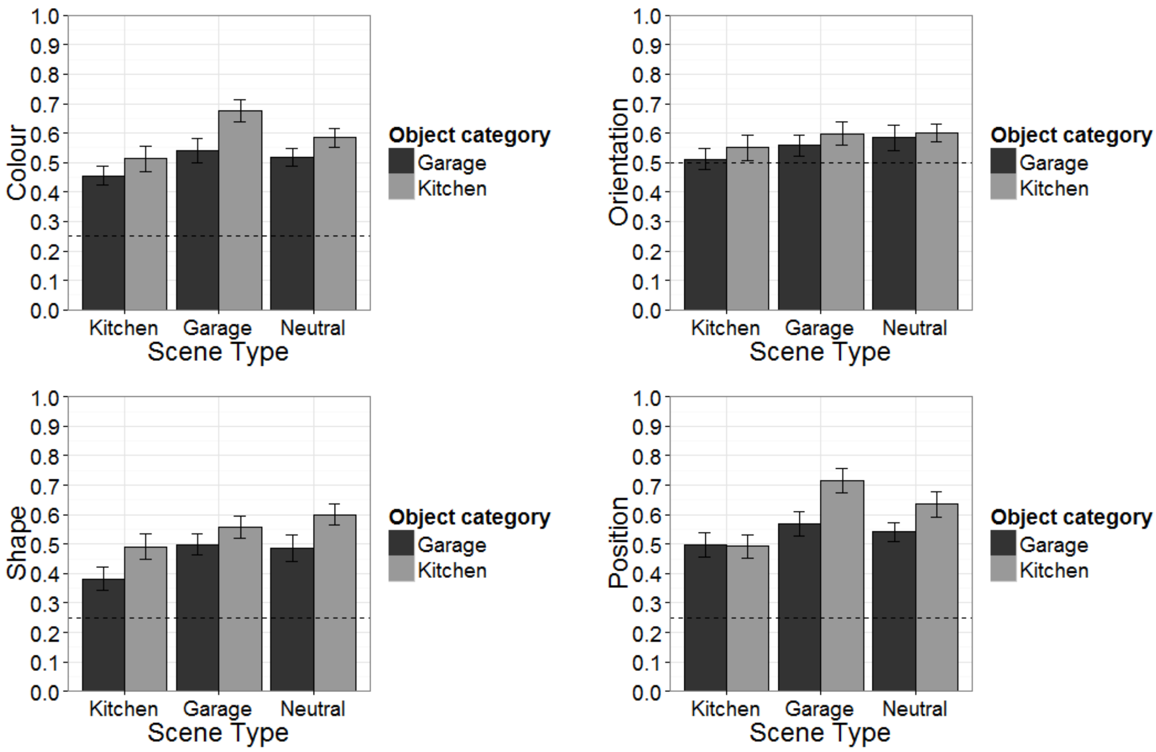


Figure 5.8. Scores for object categories within the three scene types; top left to bottom right: Colour, Orientation, Shape, Position

5.3.2.2 Object Grip Type. Investigating the effect of the objects grip type on recall, a mixed factorial ANOVA was conducted including all the intention conditions. In this analysis, no significant difference was found between the scores for the intention conditions, $F(2, 30)=1.12$, $p=.34$, or the grip type of the object ($F<1$). However, a main effect of question type was found, $F(2,60)=8.32$, $p<.001$, with higher scores for position questions (*M*=0.57) than shape (*M*=0.50) or colour (*M*=0.54) (although a post-hoc comparison did not reveal a significant difference between scores).
Examining the interactions showed that most were non-significant ($F<1$). However, the interaction between the grip type and the question type was significant, $F(2,4)=4.94$, $p=.010$. Closer examination of this interaction showed that precision items displayed a strong difference between the scores for the three question types, $F(2,64)=10.84$, $p<.001$, with participants successfully recalling the colour (*M*=0.55) and position (*M*=0.53) of these objects better than their shape (*M*=0.47, ps<.05.). Examining the orientation measure separately showed no difference between the three intention conditions ($F<1$) or the object grip type, $F(1,30)=1.04$, $p=.32$. The interaction between the two was also not significant, $F(2,30)=1.94$, $p=.16$.

The three intention groups were next examined separately, in order to determine whether any further effects were present.

Passive. Participants in the passive condition are the same as those in Experiment 2.2 were used for this data set, so the results are identical to those presented in Chapter 3. In summary, no difference was found between memory scores for power and precision items, but participants were better at recalling the position of items. Focusing only on power and precision objects showed that for both groups of objects, participants still performed better on the position questions compared to the shape property.

Precision. Participants in the precision intention condition were unaffected by the type of grip the objects were compatible with ($F<1$), but did show an effect of the question type, $F(2, 18) = 5.08$, $p = .018$. Recall of shape information (*M*=0.47) was worse than that for recall of the position (*M*=0.53) and colour (*M*=0.55) information, although comparisons run with Bonferroni-corrections were too conservative to show a significant difference between the scores. The interaction between the two was non-significant, $F(2, 18) = 1.053$, $p=.369$.

Responses to the orientation questions were examined separately, as before. The mean scores for the power and precision questions were rather close to the chance level for this question type (0.50), and so one-sample t-tests were conducted to determine whether responses were any different from chance. The scores for recalling the orientation of precision compatible objects did not significantly differ from chance (p=.765), although recall of power objects' orientation states were significantly better than chance (p=.013). Comparing the orientation scores for recall of power and precision items showed that the difference approached significance, F(1,9)=3.64, p=.089, with participants showing marginally better recall for the power objects' orientations (*M*=0.59) compared to precision items (*M*=0.51).

Figure 5.9 shows the proportion of correct responses to the object properties for participants in the precision condition.

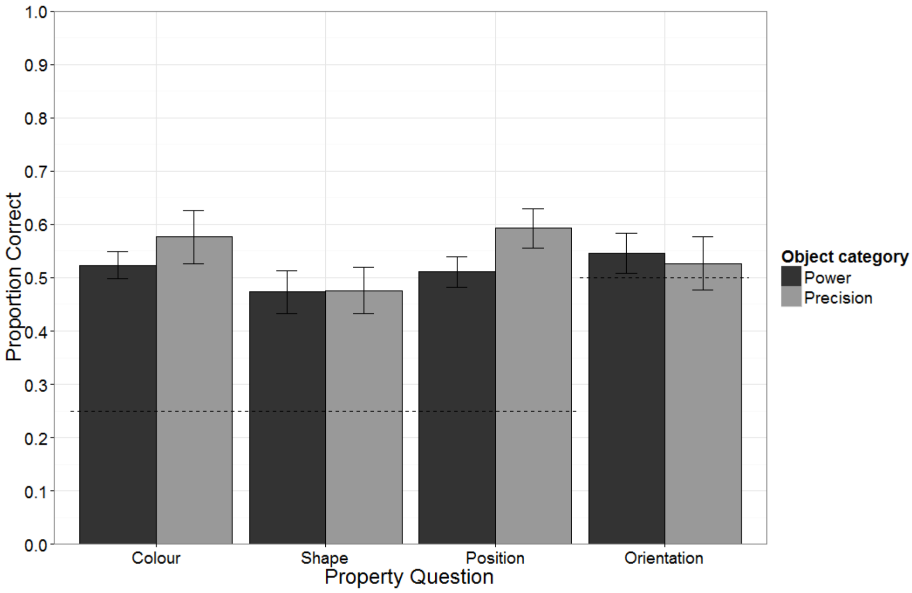


Figure 5.9. Proportion of correct responses to property questions encoded and retrieved under precision conditions

Power. Participants in the power intention condition showed no effect of the object grip category (F<1), or the question type, F(2, 22) = 1.280, p =.298. Furthermore, the interaction between the two was non-significant, F(2, 22) = 1.592, p=.226. The scores for the orientation responses were again considered to be close to chance, so each grip type response was analysed with a one-sample t-test. For both power and precision objects, recall of the orientation information was above chance, significantly so for power, (*M*= 0.58, p<.05), and approaching significance for precision, (*M*=0.54, p=.075). However, no significant difference was found between the orientation recall for precision and power items (F<1).

Figure 5.10 displays the response scores for participants in the power grip condition.

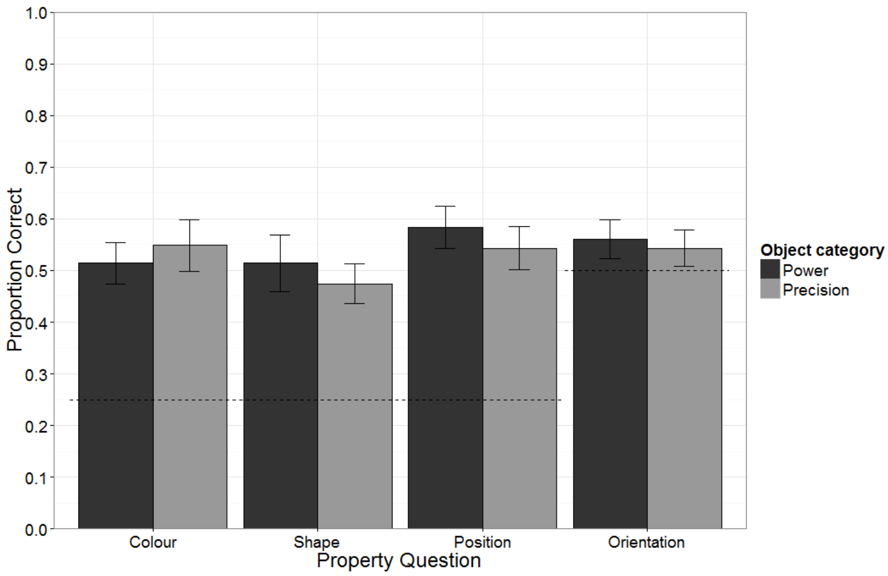


Figure 5.10. Proportion of correct responses to property questions encoded and retrieved under power conditions

5.3.2.3 Object Position. Examining the influence of the object's position as part of the scene across all three intention conditions, it was found that the three groups did not appear to differ in their responses, F(2,30)=1.04, p=.367. However, effects of position, F(2,60)=4.56,p=.014 and question type, F(3,90)=8.34,p<.001 did emerge, showing a tendency for participants to recall items on the left (*M*=0.57) better than those in the centre (*M*=0.50, p<.001) and an advantage for position information(*M*=0.57) over shape (*M*=0.50, p<.05).

Splitting the data set into the three intention conditions allowed us to look more closely at the effects within each group.

Passive. The findings for the passive intention group are as reported in more detail for Experiment 2.2. In summary, these participants were better at recalling the position of items, but showed no effect of the general object position within a scene, and no interaction between the effects.

Precision. Participants in the precision condition showed a significant influence of the position of the objects in the scene, $F(2, 18) = 4.68$, $p= .023$, with centre items(M=0.46) recalled worse than items at the left (M=0.55, p=.064) and right (M=0.56, p=.030). There was also a significant effect of the question type $F(2, 18) = 5.64$, p=.012. Examination of the means showed better performance on position questions (M=0.54) than shape questions (M=0.47) although this effect was not strong enough to remain in a post-hoc tests (p=.28). The interaction between the two factors was also non-significant ($F<1$).

The mean scores for the responses to orientation questions were found to be close to chance for objects at the three positions. One sample t-tests showed that participants recalled the orientation of objects at the left hand side significantly better than chance (M=0.62, p=.051), but objects at the centre and right of the screen were recalled no differently from chance (M=0.52, p=.331 and M=0.50, p=.691, respectively). No significant difference was found between the recall of the orientation information for objects positioned at the three locations, $F(2,18)=2.25$, p=.13.

Figure 5.11 shows the proportion of correct response to each property question at the three scene locations for these participants.

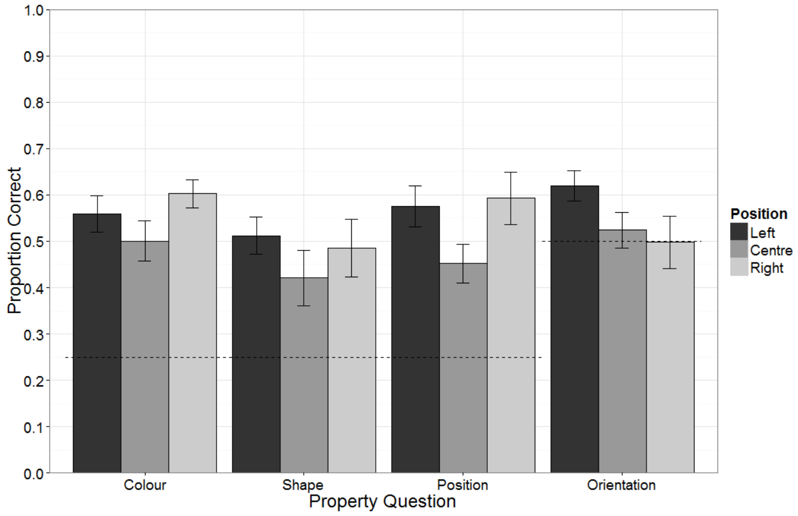


Figure 5.11. Proportion of correct responses to the property questions for objects across the three positions encoded and retrieved under precision conditions

Power. For the participants in the power condition, no significant effects were found. All types of property were recalled equally, $F(2, 22) = 1.13$, p=.341, at all three positions (F<1), and the interaction between the two factors was not significant, $F(4, 44) = 1.302$, $p=.284$. Mean scores for the responses to the orientation questions were again found to be close to chance. One-sample t-tests showed that the objects on the right and left hand side were recalled at a level no different to chance ($M=0.55$, $p=.235$ and $M=0.55$, $p=.105$, respectively), while the objects at the centre were recalled marginally better than chance ($M=0.57$, $p=.074$). No significant difference was found between the three locations when comparing scores for orientation recall (F<1).

Figure 5.12 shows the proportion of correct responses to each property questions at the three scene locations for the power condition participants.

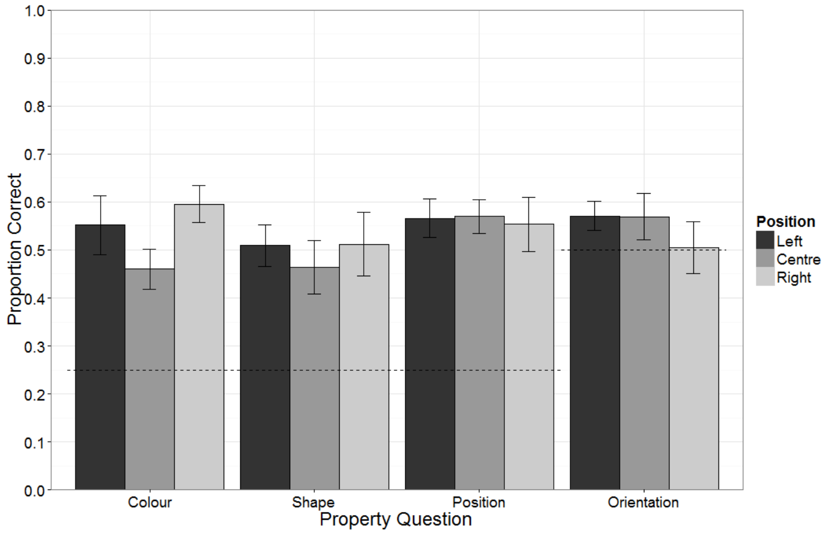


Figure 5.12. Proportion of correct responses to the property questions for objects across the three positions encoded and retrieved under power conditions

5.3.3 Comparisons with previous experiments

The data from Experiment 4 appear to show no strong similarities to the findings from the previous Experiments 2.2 and 3, at least in terms of the influence the action postures have on inspection and recall, despite the strong similarity between the designs. Other effects that seem to reflect the general means by which participants go about the task are the same (e.g., the tendency for early fixations to the left region of a scene when examining it). However, the differences in the designs may have had an effect on the outcomes.

Comparing the retrieval stage of Experiment 4 to the earlier two designs shows that this phase is different from the preceding studies. In Experiment 2.2, participants do nothing during the retrieval phase, but this is preceded by an action manipulation at the encoding stage. For Experiment 3, the action takes place at retrieval, but this is never preceded by action at encoding. In Experiment 4, action at retrieval is always preceded by action at encoding. These differences make it more difficult for us to make direct comparisons between the retrieval stages of the current and preceding studies.

For the encoding phase of Experiment 4, Trials 2 and 3 are also not comparable to Experiments 2.2 or 3.1, as there is an action posture at both the encoding stage, and the preceding retrieval stage for both. However, the encoding stage of Trial 1 from Experiment 4 is comparable to the encoding stage of Experiment 2.2., as action occurs during both, but is not preceded by any earlier action postures. As a result, extra analyses were carried out on the data from Experiment 4, comparing the results from the study across the three trials. The trial number was included as a factor in the analyses of Experiment 4, re-examining the eye movement data only.

5.3.3.1 Grip. A 3x2x3 mixed factorial ANOVA was conducted on the fixation duration and number. The effects of the object grip type (power or precision), the trial number (first, second or third) and the intention condition were examined (passive, precision and power).

Fixation duration. No difference was found between the three intention conditions ($F<1$). A marginal effect of the trial number was found, $F(2, 60)=2.95$, $p=.06$, as was a significant effect of the grip condition, $F(1,30)=22.84$, $p<.001$. Significantly longer fixations were made to power-grip compatible items (*M*=1770ms) over precision compatible items (*M*=1573ms), and participants showed marginally shorter fixations in Trial 1 (*M*=1602ms) compared to those made in Trial 3 (*M*=1767ms, $p=.06$).

A marginally significant interaction between the trial and the intention condition was also found, $F(4, 60)=2.53$, $p=.05$, and a significant interaction between the trial number and the grip type, $F(2, 60)=3.52$, $p=.036$. The interactions between grip and intention, and between grip, trial and intention were not significant, (all $Fs <1$).

Further investigation of the interactions showed that the effects came only from the power condition, where an effect of the trial was significant, $F(2,22)=4.65$, $p=.021$. Participants spent longer fixating objects in the third trial (*M*=1890ms) compared to the first (*M*=1565ms, p<.05) and marginally compared to the second (*M*=1614ms, p=.08). The other intention conditions showed no such effect of the trial (Fs <1).

Fixation number. For this measure, no main effect of intention condition was found, F(2,30)=2.30, p=.117. However, a significant effect of the trial number emerged, F(2, 60)=3.27, p=.044. This was due to fewer fixations to objects in the first trial (*M*=5.72) than the second (*M*=5.83) and third (*M*=6.18), although this difference did not emerge as significant when tested using the Bonferroni correction. A significant effect of the grip condition was also found, with more fixations made to power compatible items (*M*=6.54) than precision (*M*=5.28), F(1,30)=69.00, p<.001.
Examining the interactions showed a significant interaction between the trial and the intention condition, F(4, 60)=2.62, p=.044, and a significant interaction between the trial number and the grip type, F(2, 60)=3.32, p=.043. All other interactions were non-significant (F<1).

As for the measure of total fixation time, the interaction between trial and intention group was due to the power intention condition, where the main effect of trial was seen, F(2,22)=6.68, p=.005. This was due to fewer fixations made to items in the first trial (*M*=5.1) compared to the third (*M*=6.1, p<.05). The other intention conditions showed no differences in the trials (Fs<1).

Primacy fixation number. Using the first fixation to objects as a measure showed strong effects of both trial, F(2,60)=10.05, p<.001 and grip type, F(1,30)=57.36, p<.001, although no difference was found between the intention conditions (F<1), and the interactions were similarly non-significant (all Fs <1). Participants looked significantly earlier to the power compatible objects (*M*=16.7) than the precision compatible objects (*M*=21.1). Participants also looked earlier at items in the first trial (*M*=16.0) compared to those in the second (*M*=20.8) and third trial (*M*=20, ps<.001).

5.3.3.2 Position. Mixed factorial ANOVAs were conducted on the measures of total fixation time and number. The effects of the object location (left, centre or right), the trial number (first, second or third) and the intention condition (passive, precision and power) were examined.

Fixation duration. Examining the influence of objects' positions across the trials on fixation duration showed a main effect of the trial number, F(2,56)=3.44,p=.039, with means indicating, shorter fixations made to objects in Trial 1 (*M*=1596ms), compared to Trials 2 (*M*=1656ms) and 3 (*M*=1753ms), but no significant difference emerging in post-hoc tests. A marginal effect was also found for position, F(2,56)=2.90, p=.063, with a shorter time spent on all objects placed at the right hand side (*M*=1598ms), compared to those at the left (*M*=1785ms, p=.08) but no different from those objects at the centre (*M*=1623ms, p=0.76). No difference emerged for the intention groups (F<1), or for any interactions between the factors (all Fs <1).

*Fixation number***.** For the measure of fixation number, no difference was found across the three trials, F(2,56)=2.30, p=.12, or the intention groups (F<1). A main effect of position was found, F(2, 56) = 4.76, p=.012, with significantly fewer fixations made to objects at the right hand side(*M*=5.4) than to the left, (*M*=6.3, p=.01). No interactions were found to be significant (all Fs <1).

*Primacy fixation number***.** Examining the influence of trial number and position on the primacy fixation number showed a strong main effect of trial, F(2,56)=8.61, p<.001, with participants showing significantly earlier first fixations to items in trial 1 (*M*=15.9), compared to trials 2 (*M*=20.9, p<.01) and 3 (*M*=20.3, p<.01). A main effect of position was also found, F(2, 56)=14.80, p<.001, with participants examining items on the right of the screen for the first time (*M*=24.0) significantly later than those at the left (*M*=16.3) or centre (*M*=16.8, both ps <.001). No difference was found between the intention conditions (F<1). The interactions between the factors were also non-significant (all F's <1), with the exception of the interaction between trial and position, where the effect approached significance, F(4,112)=2.18, p=.076. Further investigation of this interaction in the individual groups did not reveal any significant effects.

Looking at the performance of participants in Experiment 4 across the three trials shows the standard effects associated with the object grip types and positions persists across the trials. Participants still fixated more and earlier on the objects at the left hand side, and on items compatible with a power grip. There appears to be no consistent pattern to any differences that emerged across the trials, and no indication that influences of the action posture were emerging in the first trial only.

5.3.4 Comparison with Experiment 2.2

As noted above, the encoding stage of Trial 1 of Experiment 2.2 is the only part of the previous experiments that is directly comparable with Experiment 4. The eye-tracking results from Experiment 2.2 were therefore re-run, including Trial as a factor as well. This allowed for the emergence of effects in different trials for this earlier study to be examined, in order to determine if the patterns produced within each trial (particularly the first) were similar or different to those found in the trial analyses for Experiment 4. The hands intention group were excluded from this analysis, as this condition was not used in Experiment 4.

5.3.4.1 Grip. Mixed factorial ANOVAs were conducted on the measures of total fixation duration and number for the data from Experiment 2.2. The effects of the object grip type (power or precision), the trial number (first, second or third) and the intention condition were examined (passive, precision and power).

Fixation duration. For the measure of total fixation duration, significant influences of both the grip condition, $F(1,31)=28.19$, $p<.001$, and the trial number, $F(2,62)=3.06$, $p=.054$, were found. Participants spent longer on objects compatible with a power grip (M=1829ms) than precision compatible (M=1535ms), and made spent longer fixating objects presented in Trial 2 (M=1764ms), compared to those in 1 (M=1563ms, $p<.01$) and 3 (M=1721ms, $p<.05$), (post-hoc comparisons, $p<.05$). There was no main effect of the intention condition ($F<1$).

One interaction emerged as significant, between Trial and grip type, $F(2,62)=3.32$, $p=.043$. Further investigation of this pattern showed that only Trial 2 showed a significant difference between power(M=2114ms) and precision items(M=1709ms) $F(1,31)=23.28$, $p<.001$, while Trial 1 showed only a marginal difference(power M=1745ms; precision M=1543ms), $F(1,31)=3.64$, $p=.066$, and Trial 3 showed no difference at all, $F(1,31)=1.92$, $p=.176$.

Fixation number. For measures of fixation number, the pattern was similar, with significant effects of both Trial, $F(2,62)=3.96$, $p=.024$, and grip type, $F(1,31)=60.78$, $p<.001$. Again, power compatible objects received significantly more of the fixations (M=6.6) than precision compatible items (M=5.1), and objects in Trial 2 (M=6.0) were fixated more than those in Trials 1 (M=5.4, $p<.05$) or 3 (M=6.0, $p=.06$). A marginal effect of the intention group was also found, F(2,31)=2.58, p=.092, with participants in the precision intention condition (*M*=5.4) making fewer fixations to objects that the power (*M*=6.1, p=.08) and passive (*M*=6.3, p<.01) intention groups.

As for fixation duration, only the interaction between trial and grip type approached significance, F(2,62)=2.67, p=.077. Examining each trial separately showed that all three showed significant differences in the number of fixations made to power and precision items, with power items consistently receiving more (Trial 1: F(1,31)=16.12, p<.001; Trial 2: F(1,31)=38.20, p<.001; Trial 3: F(1,31)=13.35, p<.001).

Primary fixation number. For the measure of average first fixation to objects, a significant effect of trial was found, F(2,62)=15.90, p<.001, as participants were earlier in making their first fixations to objects in Trial 1 (*M*=16.3), compared to Trials 2 (*M*=20.3) and 3, (*M*=20.6, ps<.001). A main effect of grip type was found, F(1,31)=47.66, p<.001. They were also significantly later to first fixate precision objects (*M*=21.1) compared to power items (*M*=17.0).
No other main effects or interactions were found to be significant for this measure (all F's <1).

With regards to how the influence of object grip type differed across the three trials of Experiment 2.2, it seems that the pattern of a preference for the power compatible items persisted across all trials. However, the previously reported interaction between intention condition and object grip type did not emerge within the individual trials, indicating that it was a cumulative effect.

5.3.4.2 Position. Mixed-factorial ANOVAs were conducted on the three levels of position (left, right and centre), intention conditions (passive, precision and power) and the three trials.

Fixation duration. The measure of fixation duration showed a significant main effect for Trial, F(2,82)=8.10, p<.001 and a marginally significant effect for position, F(2,82)=2.60, p=.080. Participants were making significantly longer fixations to objects in Trial 2, (*M*=1737ms) than Trials 1 (*M*=1553ms, p<.05) and 3 (*M*=1740ms, p=.06). They also made marginally longer fixations to objects on the left hand side (*M*=1770ms), compared to those on the right, (*M*=1740ms, p=.062).
No other main effects or interactions were found to differ significantly (all F's <1).

Fixation number. For the measure of fixation number, significant effects of both Trial and position were again found. As before, participants made more fixations to items in Trial 2, $F(2,82)=6.90$, $p=.002$ (*M*= 6.0) than Trial 1, (*M*=5.4, $p<.05$), and more fixations to objects on the left side of the screen, $F(2,82)=8.01$, $p<.001$(*M*=6.1) than the centre (*M*=6.0, $p<.01$) or right (*M*=5.2, $p<.01$).

One interaction emerged as marginally significant, between the intention condition and the trial number, $F(6,82)=1.94$, $p=.084$. Investigating this further showed that the difference in trials emerged as significant only in the group of precision intention participants, $F(2,20)=4.44$, $p=.025$. Here, participants made significantly more fixations to objects in Trial 2 (*M*=6.5) than Trial 1 (*M*=5.4, $p<.01$) and Trial 3 (*M*=6.0, $p<.05$).

Primary fixation number. For the measure of average first fixation number made to the objects, both Trial, $F(2,82)=8.28$, $p<.001$, and position, $F(2,82)=16.37$, $p<.001$, were significant main effects. Participants were significantly earlier to first fixate items in Trial 1 (*M*=16.8), than 2 (*M*=20.7, $p<.01$) or 3 (*M*=20.9, $p<.01$) and significantly later to first fixate items presented on the right side of the screen (*M*=24.1) than the left (*M*=16.5, $p<.001$) or centre (*M*=17.7, $p<.001$). No significant effect of intention condition was found ($F<1$).

The only significant interaction to emerge was between position and intention condition, $F(6,82)=2.55$, $p=.026$. Further investigation showed that this was due to participants in the power and precision conditions first fixating right side objects (power *M*=24.3, precision *M*=29.1) significantly later than those on the left (power *M*=13.8, precision *M*=14.3, ps<.001), while the passive condition showed no such difference.

Examining the effect of object position across the trials for participants in Experiment 2.2 showed that the finding of a leftwards bias when examining the scenes was consistent over all trials. The finding first reported in Experiment 2.2 (that participants in the power and precision intention conditions take significantly longer to first fixate objects on the right hand side) were thus maintained across all three trials.

Participants in Experiment 2.2 seemed to show that some effects (such as that of intention group on viewing object grip types) were not seen within every trial, but were a cumulative effect, found when all trials were analysed together. The influence of intention group on examining objects located at the different positions, however, was maintained across the trials, suggesting that this was a stronger effect.

5.4 Discussion

Experiment 4 replicated the design of Experiments 2.2 and 3, but extended them by increasing the time during which the grip posture was maintained. Rather than restrict the posture to only one stage, participants maintained their action throughout both encoding and retrieval, in an attempt to maintain the relevance of action throughout both stages of the memory process.. Patterns of effects observed in previous studies remained present in Experiment 4. For inspection behaviour, participants still showed a tendency to inspect the left of the screen earlier than the right, and spent more time fixating power compatible objects over precision compatible items. For memory performance, participants showed a general advantage for recalling the position of the objects over the other tested properties. The action effects reported in Experiments 2.2 and 3 did not persist, however, with the exception of the influence of the power and precision grips on the participants' inspection of the scenes.

5.4.1 Influence on Inspection and Memory

For both inspection and recall behaviours, the set of participants used for this study responded to the stimuli in very similar ways to those in the earlier studies. So, for object category, participants spent more time fixating the garage compatible objects, particularly when they were presented in the kitchen background. As in the previous studies, this suggests that the unfamiliar or incongruent items attracted more attention, particularly when they were placed in an environment in which they were particularly incongruous (see e.g., Gareze and Findlay, 2007).

The structure of the scene layout is most likely responsible for the left-to-right progression of fixations shown by participants (Gilchrist and Harvey, 2006), in conjunction with the asymmetric biases in attentional processing that has been found to influence viewers into showing a leftwards bias (e.g., Nuthmann and Matthias, 2014). The linear arrangement of objects in our stimuli encourages a similar 'reading' of the scene in the eye movements.

Finally, when examining the influence of the object's grip type, the larger, power-compatible items received more fixations and were examined for a longer time than the smaller precision items, due to attracting more attention during the encoding phase.

Similar patterns were seen for memory performance. For all properties, participants showed better recall for the more familiar kitchen items, but an overall worse performance in the kitchen environment itself, considered to be due to the construction of the scene. While no influence of object grip or object position within the scene was found on the memory performance, participants continued to show an advantage for recalling the position of objects, regardless of their grip type, and shape information in particular was poorly recalled. Again, this is very much what was found in both the earlier studies of this thesis, and work by others. Participants seem to always do well at recalling position, possibly because this is an important property for the construction of object representations (Hollingworth and Rasmussen, 2010), and extracted early from a scene (Tatler et al., 2003). Shape is also often the poorest recalled, possibly due to the use of outline drawings at the test phase. Other studies which have used the same approach also report that participants find this difficult to match to the correct objects (e.g., Tatler et al., 2005).

These patterns have been found in all our experiments which use this particular paradigm, and are all most likely due to the stimuli used, and the way in which the stimulus displays were constructed. Thus, the fact that we continued to find these patterns in Experiment 4 indicates that it was not completely different to the previous versions of the study. As a result, the absence of effects linked to the participants' intention conditions and action postures can be more reliably attributed to the new manipulation (maintaining the action postures throughout encoding and retrieval), rather than differences in the participants, or the overall construction of the paradigm.

Both Experiment 4 and Experiment 2.2 were examined by trial, to determine if the differences between them could be more specifically linked to the different action manipulations. In particular, it was the encoding stage of Trial 1 for the studies that we were interested in, as this trial was equivalent for both versions: an action posture was present during the initial viewing of the scene. It was hoped that the action effects expected (e.g., the de-prioritisation of fixating on precision items by participants in the power grip condition) would be seen in the data for Trial 1 in Experiment 2.2, indicating that this was a strong effect that would presumably be present in all trials; and in the

Trial 1 data for Experiment 4, indicating that the effect was initially present, but that the continued presence of the action postures led to a different effect in the later trials, so that when they were examined together, the influence of the action posture on fixations did not emerge.

However, when Experiment 2.2 was examined by trial, it was apparent that no one trial was responsible for the effects seen in that experiment. We did not find the influence of grip on power and precision object inspection in each trial, but only as a cumulative effect when all trials were combined in analysis. Furthermore, no indication of an action posture influence was found in Trial 1 of Experiment 4.

As both experiments did not show the intention condition and object grip type interaction within a single trial, it is much more difficult to draw conclusions from these null effects. It may be correct that, for the current study, the differences in Trials 2 and 3 override any emerging effect in Trial 1, so that nothing is detected when the analysis is conducted over all trials. Alternatively, there may simply not be enough data points for a significant effect to be obtained.

Only one exception to the absence of action effects was found in the data from Experiment 4: in the measure of average first fixation number for the position of objects. Here, a significant interaction was found between the intention group and the position, with both the power and precision participants taking significantly longer to progress from the left hand side of the screen, and first fixate objects on the right. This is a similar pattern to that in Experiment 2.2 (and was absent from Experiment 3, when the action postures were not present). As in Experiment 2.2, it seems that the presence of the action postures enhanced the standard left-to-right pattern, with participants giving more attention to items, so that they were slower to reach the right hand side items in the time available.

Given that participants respond in the same way to the stimuli as those in the earlier studies, it appears that the way in which this study was constructed was in some way affecting the emergence of action effects on inspection and memory. The most likely explanation for the lack of effects in both recall and inspection is that of a form of adaptation. That is, as participants were maintaining the grip throughout all the stages, they became accustomed to it, and perhaps stopped associating it, as an action, with the scenes in front of them. Indeed, as they continued to maintain it across the trials and the changing scenes, participants may no longer have been making a clear association between the grip, and the set of objects presented to them. In Experiments 2.2 and 3, and in previous studies of the influence of action on perception (e.g., Bekkering and Neggers, 2002; Symes et al., 2008), the action is completed and then remade with the end and beginning of each trial. This ensures that the action is always associated with that set of items. This explanation would suggest that such action effects seen in the earlier studies are rather transitory, with a tendency to decay.

This action decay can be linked to the importance of intention in preparing and forming an action, and observing effects of this action. In particular, studies by Witt and colleagues have demonstrated how the absence of an intention to act can prevent the effects from occurring. Witt, Profitt and Epstein (2005) found that, while holding a tool could influence perception of the distance to a target, this only worked if the participants had the intention to reach with the tool. This was found to occur both when the participants made the judgement holding the tool, or before they had picked it up (Witt and Profitt, 2008)**.** This emphasis on intention also links very clearly to the TEC (Hommel et al., 2001), and the idea of intentional weighting as the process that primes event codes for an action. The previous studies presented here, and several earlier investigations (e.g., Fagioli et al., 2007; Fagioli, Ferlazzo et al., 2007) showed that the intention to act does not have to be explicitly expressed: the act of forming or planning a posture seems to be enough. However, it may be this which is contributing to the more transient effects. Without an explicit instruction or plan to make the action and execute it, the effects will decay. This is largely speculation on our part at this stage: currently, there is no research which explicitly compares how long different types of intentional cues might last. However, turning to the literature on prospective memory (the requirement to remember to do something in the future), there is some indication here that the strength of intention can influence an actor's ability to remember to perform a future action. Ellis (1996) describes how the intentional status of a plan can vary in terms of how 'ready to act' the performer is, and the rewards that will be gained if the intention is completed. By increasing the importance and prominence of the future action, via incentives or other means, prospective remembering was also increased (e.g., Kliegl, Martin, McDaniel and Einstein, 2001).

Of course, this is not direct support of our own findings: in such prospective memory tasks, participants are instructed to perform a particular action (posting a series of cards, or making phone calls) at particular times. In the present studies, participants intentions are formed in a much more oblique manner, hinted at by the formation of the postures. However, if the strength of the intention is as important to the context of the influence of action as it is for the success of prospective memory, then our method of creating the intention would certainly be considered to be a weaker method than explicit instructions with varying incentives. As a result, the intention we create here may be only transitory, and prone to decay if it is maintained over a long period of time. Further research is clearly necessary in order to determine what kind of time course these effects may take.

Experiment 4 showed that, when the action postures were maintained across several stages, the influences of action did not emerge. This study may therefore indicate the limits of this lab-based paradigm, and suggests it is necessary to transfer the research into a more realistic setting. In particular, there are two aspects which need to be addressed: the participant's potential ability to act with the objects, and the instructions they are given to act with the objects. The final two studies in this thesis will examine these two potential influences separately. Firstly, Experiment 5 will present a situation in which there is no explicit instruction given to the participants to act with the objects, but the objects are physically present in the same environment as the participant: thus, it would be possible for participants to act with them if they wished. Finally, Experiment 6 will involve a task in which participants are given instructions to act with objects in a particular way, in order to achieve a stated goal.

Chapter Six- The influence of the potential for action in real-world environments

6.1 Introduction

The previous studies have considered how aspects of scene inspection and memory are influenced by the presence of an action posture during encoding (Chapter 3), during memory retrieval (Chapter 4) or during both encoding and retrieval (Chapter 5). However, all three studies took place in the context of a laboratory, in which the target objects were presented as photographs on a screen.

When considering the influence that action might have, both on our initial exploration and later memory representations, it is likely that the ecological validity of the scene is an important factor. The main concern of the present study is the participants' potential to act with the objects presented to them. Clearly, when the items were only represented in photographs in the previous studies, then interaction was not possible. In contrast, when both participants and objects are in the same environment, then the participant would have the potential to pick up and interact with one of the items.

However, this is not the only difference between real scenes and photographs of them. Other factors distinguish the two types of environment, and these too may have an influence on participants' memory performance. Alongside the potential for object manipulation, there is the fact that the quality of the information received from a real world scene may be different to that from a computer presented photo. Furthermore, the scale at which we experience a real scene will be veridical, but a photo may compress larger environments into a smaller display size, confusing the perception of objects within the scene. Finally, there is the question of movement through a scene, and how the changes this would make to an observers view point (and thus their view of the objects) might affect the representations they form.

When viewing a real world scene compared to a photograph, there are obvious differences in terms of the information we receive. In a photograph, there is no true depth to the environment, as it is presented as part of a 2D plane. While there are cues to depth, these are all monocular in nature, such as linear perspective, or interposition, due to closer objects hiding parts of distant objects. In real scenes, the scene depth is perceived via binocular cues as well (such as stereopsis, due to differences in the images projected on to the viewer's two retinas), which are not present in a photographic image. There is also a wider field of view to consider: in our previous studies, where participants kept their heads stationary and examined photographs, the field of view was roughly 30x40 degrees. In the real world, we have a field of view which extends 180 degrees horizontally and 135 degrees vertically (Howard and Rogers, 1995) when the head and eyes remain stationary, while movement of the eyes and head allows us to inspect a still larger field. The range of brightness values present in a real world scene compared to a photograph is also likely to be greater. These differences are likely to influence the way in which a scene is explored, as well as potentially the resulting memory.

The differences in eye movements was examined by t'Hart et al. (2009), comparing free exploration of a real scene with free viewing of both continuous videos, and single static frames of the videos. The viewing patterns in these scene types varied accordingly: for example, while a spatial bias to the centre of a scene was found in the video viewing, particularly the static scenes, the bias was only weakly present (and not particularly central) in the free exploration of a scene. Instead, participants showed a bias towards paths they might be asked to walk in the real world, something that would not be possible when viewing a video or static scene. Thus, it seems that the possibilities offered by the real world environments may be influences on the way in which they are viewed, even in the absence of a specific task.

Differences in both eye movements and the resulting representations were found in Tatler et al.'s (2005) study, examining the accumulation and retention of object property information over time. Participants performed the encoding stage of the trial either by viewing the scene on a computer monitor, or by standing in the doorway of a room in which the scene was recreated. While memory performances were largely the same for both conditions, Tatler et al. (2005) found that changes still emerged for the items recalled, and the eye movements made between the two environments. In the real world condition, participants showed a tendency to make longer fixations to the objects, and larger saccade amplitudes, most likely due to the larger scale of the real world scenes compared to the more restricted computer screens. Tatler et al. (2005) noted that the encoding strategies in the two conditions appeared to be similar, with the same patterns shown for the uptake of information in both. Information retention, however, did show a change: while colour information was maintained only transiently in the real world setting, it was stably maintained under lab conditions. The reverse was found for position information, with recall performance showing participants maintained the property transiently in the photograph condition, but stably in the real world environment. Finally, it was generally found that the effect sizes in the real world condition were larger than those in the lab, suggesting that weaker effects might be more easily detected in a real world setting, due to enhanced detail that participants may extract from a real world scene. Thus, our previous studies may have missed subtler effects of the action postures that the use of a real world setting would reveal more clearly.

The scale of a scene is particularly difficult to reproduce with a photograph. According to Montello (1993) space is represented at different scales, when dealing with real world environments. The smallest scale is figural space, for items smaller than the body. Vista space is that which is larger than the body, but restricted to what can be seen by the viewer from a single position: for example, the environment of a room. Environmental space comprises a space larger than vista space: i.e. not all of it can be seen from a single point; but an observer could still view all of it if allowed to move around, e.g., a building complex. Finally, geographical space encompasses the largest spaces, such as a country, which could not be easily explored by a single observer. These levels of spatial representation can become somewhat confused when dealing with a photograph of an environment. The scene within the photo could be classed as vista space, as it shows an environment viewed from a single point. However, the size of the photo itself places it in the context of figural space, as it is smaller than the body of the participant viewing it, and indeed the scene is contained within a monitor that itself occupies a place in a real environment (the lab) which is itself an environmental space (a vista) for the observer. Not only is space represented differently, but this confusion in the levels of representation may have an effect on the effects of action. Objects presented in the images are now reduced to a size smaller than could be interacted with usefully in a normal context, which might change the way in which they are represented, and how action preparation might inform inspection and memory. Therefore, when participants are present in the same environment as the objects, they will be experiencing the objects at the size in which they would normally interact with them. This change may allow us to find a greater (or different) influence for the presence of action during encoding.

Another difference from real world scenes is that we typically do not remain stationary within them. When conducting a task, it is often necessary to move around to gather what objects we need from their different locations. Even if we do not need to touch the items, we may move in order to inspect them from a different angle or distance, resulting in several viewpoints being acquired which may affect the eventual representation. Several studies have investigated that dynamic movement within an environment can affect our perception of and memory for objects within a scene.

Some have shown that participants in a dynamic, moving environment are often poor at detecting changes (e.g., Levin and Simons, 1997). However, later studies clarified the nature of the movement by comparing change detection and scene recognition performance when participants moved by themselves, or had items moved around them. Simons and Wang (1998) found that when participants changed their position by walking between two different viewing positions around a table, they were better at detecting changes to the object array than when they remained stationary, but the table was rotated to produce a change in retinal projection for the objects in the scene that was equivalent to the change produced by their free movement. Further investigation showed that participants were required to move by their own agency between the viewing points: if they were wheeled between the two locations by being pushed on a chair, they performed similarly to the condition in which the scene moved around them. When we navigate through an environment, it seems we are able to maintain and update a viewer-centred representation of our surroundings, which allows us to detect changes. Other studies have examined how receiving multiple views of a static scene (as when walking through an environment) affects recognition performance. While participants find it difficult to recognise a scene from a novel viewpoint (Diwadkar and McNamara, 1997; Shelton and McNamara, 1997), experiencing multiple novel views of a scene leads to multiple, viewpoint-dependent representations being formed. As more views are experienced, it seems that a flexible, schematic representation of the environment is created, which will aid recognition based on novel views. When participants are able to move naturally about a scene, therefore, it seems that they are able to adapt to the changing viewpoints, and should be able to continue to recognise the presented objects. However, it is not clear how receiving multiple views of an object may affect memory for its properties. In particular, a property such as orientation may suffer if participants are unable to reconcile the different views they receive.

The present study aims to extend the previous studies into a real world environment. This will allow us to investigate how such differences between a photographic scene and an immersive environment might affect the participants' memories of the presented objects, and how action effects via the preparation of action posture may also be affected. However, while it has been mentioned that actual interaction with the objects may be an important factor to consider in this setting, the present study will not include instructions to the participants to manipulate the stimulus objects. As outlined above, there are several other differences between a real world and photographed scene which may influence the formation of representations for objects, and any and all of these differences could themselves influence the effects of action on memory that we wish to investigate. The present study allows us to investigate these factors, by using the paradigm of the previous studies in a real world environment. By continuing to prevent interaction in the present study, we can determine if any effects emerge simply as a result of placing both participants and objects in the same (real) environment, where it would at least be possible to interact with the objects even if there is no instruction to do so yet.

The present study aims to investigate how the preparation for action influences the encoding of objects and their properties into a memory representation in a real world, rather than laboratory environment. Experiment 5 is a replication of Experiment 2.2, with similar action manipulations during the encoding process. This will allow us to determine if the results shown by Experiment 2.2 will generalise from the laboratory to the real world, and if further effects (such as the influence on memory which was absent in Experiment 2.2) will now emerge, due to the introduction of a potential for action, and the differences that exist between a real and photographic environment. If the results obtained from Experiment 5 show an effect of the action posture at encoding, then this will indicate that the earlier studies were perhaps not powerful enough to allow us to see memory differences, or that there must be some possibility for interaction to occur with the stimuli to allow effects on memory to emerge.

Alternatively, we may find that the encoding manipulation continues to have no influence on the construction of the objects' representations. Such a finding would be more supportive of our arguments in the previous studies and indicate that the representations formed in memory are largely purpose-neutral, despite the presence of action at the encoding stage. Another related possibility is that manipulation of the objects is necessary in order for memory effects to persist, and so emerge as a measurable result of manipulations at the encoding stage.

6.2 Method

6.2.1 Participants

Participants were 32 undergraduate students (average age 25.8, SD 3.1). 15 of the sample were male, and all participants had normal or corrected-to-normal vision. Handedness was measured by self-report as part of the experiment: the sample contained 3 left handers. 10 participants were assigned to the passive intention condition, 11 to the precision condition, and 11 to the power condition. Participants were recruited via on-line advertisements. They received course credits or payment (£3) for their participation in the study.

6.2.2 Stimulus

The stimuli used were the same 36 objects (divided into three groups of 12) as those employed in the three previous intention experiments. Each set was placed on a table-top, positioned in the same way as the sets in Experiments 2.2-4. This allowed object position and orientation to be counterbalanced across the scenes. As the environment for the study was a lab in the department, all objects were effectively neutral with regards to the background.

Figure 6.1 shows the three table-top displays used in the study.

Figure 6.1 Table-top displays of the three stimulus groups.

The questions used to test memory for the stimuli were identical to those used in Experiments 2.2-4 (with the exception of the position questions, where the line drawings of the backgrounds were re-drawn so that they matched the new environment). Question presentation and response collection was controlled by scripts written in MatLab using the PsychToolBox extension (Brainard, 1997; Pelli, 1997). The questions were presented to participants on the display monitor of a Macintosh computer, at a resolution of 1024 x 768.

6.2.2 Procedure

Participants were instructed that they should view the objects presented on each table, and attempt to memorise the display. As all three object sets were kept in the same room, each was covered with a sheet, which allowed the viewing to be restricted to one set of objects during each trial. Participants were asked to close their eyes when the sheets were taken off the tables, and open them when instructed. They then viewed the table top for a period of 20 seconds. During this time, they were told they could walk around the three sides of the table (all tables were positioned against a wall, so that participants could not walk directly behind them and view objects in a completely switched orientation). However, they were instructed not to pick up, or touch the objects. As in the previous studies, participants in the passive condition viewed the table without any further manipulation; while those in the power and precision conditions held the device used in Experiments 2.2-4, to form whichever grip was required. After the 20 seconds had elapsed, participants were instructed to close their eyes again, while the table was re-covered. If they were holding the grip device, they returned it at this point, and were taken to the computer in the lab. This was positioned behind a screen, blocking the view of the tables, so that participants were not able to look at the covered tables and use this to make guesses about the position of objects.

Participants responded to the questions using the keyboard, and the number keys 1-4 (re-labelled A-D). When they had finished the set questions for that table top, they were instructed to go to the next table, and the previous procedure was repeated for the remaining two object groups.

6.2.3 Design

As for the previous experiments (2.2-4) there was one between-subjects independent variable of viewing condition consisting of three levels, passive viewing (baseline), and viewing whilst making a grip gesture, (power or precision) The dependent variables of the study were the participant's memory for the displayed objects, and their properties (colour, shape, position and orientation). No eye movement data was recorded for this study.

6.3 Results

6.3.1 Influence on Memory

Table 6.1 displays the proportion of correct responses given to each of the five property questions, across the three intention conditions.

Table 6.1.

Proportion of correct responses for each property question and each intention group

	Question				
Intention Group	**Colour**	**Shape**	**Orientation**	**Position**	**Presence**
Passive	0.636	0.606	0.647	0.627	0.922
Precision	0.707	0.646	0.657	0.659	0.941
Power	0.646	0.644	0.604	0.629	0.896

One sample t-tests were conducted to ensure that all scores were significantly above chance. For each group, it was found that participants were better than chance (0.25) at recalling colour, shape, position and presence (all ps $<.01$) and better than chance (0.50) at recalling orientation (all ps $<.01$). As before, the questions regarding object presence were not further analysed, due to the repetition of the same object types possibly influencing recall performance for this question. Orientation responses were analysed separately from the other conditions, due to the different levels of chance.

6.3.1.1 Object Position. A mixed factorial ANOVA was conducted to examine the influence of the intention condition (passive, power and precision), the object's position (left, centre or right of table viewed from straight ahead) and the question type. No main effects of the intention condition ($F<1$), the question type, $F(3,58)=1.53$, $p=.226$, or the object's position were found ($F<1$). However, the interaction between the position and the question type was significant, $F(4,116)=3.03$, $p=.020$. Examining this interaction further showed a marginal effect of the object position in the responses to shape questions, $F(2,62)=3.13$, $p=.051$, with the means indicating that items positioned at the left (M=0.65) and right (M=0.67) were recalled better than those in the centre (M=0.58, ps<.05). However, these effects did not reach significance when examined with a post-hoc comparison. The responses were then examined for each of the intention conditions separately.

Passive. Participants in the passive intention condition showed a marginal effect of the object's position, $F(2,18)= 2.96$, $p=.077$, with a trend in the data that indicated objects on the right hand side of the table (M=0.67) tended to be recalled better than those at the centre (*M*=0.61) or the left (*M*=0.60, ps<.05). However, a post-hoc comparison did not show a significant difference in memory performance between the different positions on the tables. No other differences were found, with participants showing equal performance for all question types (F<1), and no interaction emerging between question type and position, F(4,26)=2.00, p=.115.

Examining the orientation question separately showed that the performance for objects at each location were significantly above chance (p<.05). However, no difference was found between orientation memory for objects at each of the three locations, F(2,19)=1.22, p=.32.
Figure 6.2 displays the proportion of correct responses for each question type at each position for the participants in the passive condition.

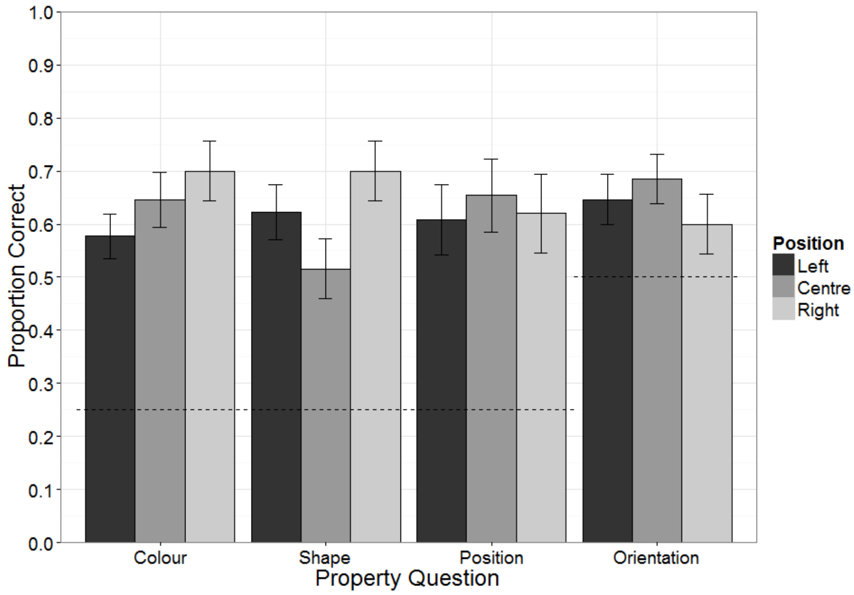


Figure 6.2. Memory scores for object properties at the three positions, encoded under passive intention conditions

Precision. For participants in the precision intention condition, no main effects or interactions were found. Participants scored equally highly on the three property questions, F(2,20)=1.83, p=.19, and recall was unaffected by the position the objects were placed in (F<1). There was also no significant interaction between the factors (F<1).

For the orientation questions, it was found that responses to objects at all positions were significantly above chance (p<.01). The object's position had no influence on the score for orientation questions, (F<1). Figure 6.3 displays the proportion of correct scores for each question type at each position for participants in the precision condition.

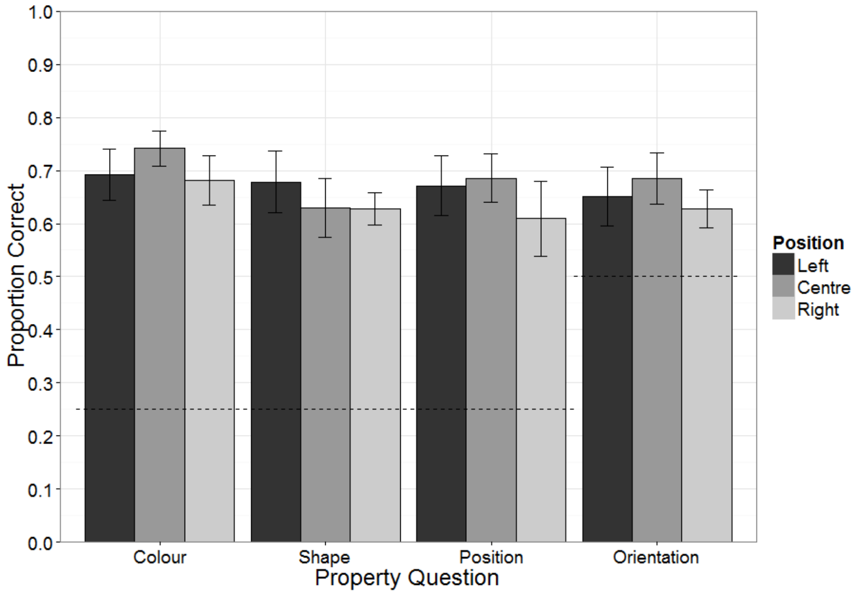


Figure 6.3. Memory scores for object properties at the three positions, encoded under precision intention conditions

Power. A similar pattern emerged for the participants in the power condition. Responses to the three property questions were equal, $F(3,30)=1.21$, $p=.325$, and unaffected by the object's position (F<1). There was also no interaction between the factors, $F(4,40)=1.14, p=.35$.

Responses to the orientation question showed that only responses to objects positioned at the left and centre of the table showed responses above chance ($p<.05$). Recall of object orientations for those at the right hand side were no different from chance ($p=.85$). However, a significant effect was found for these scores, $F(2,20)=8.24$, $p=.002$. Participants were significantly better at recalling the orientation of objects at the centre of the table ($M=0.69$) compared to those at the right, ($M=0.51$, $p<.01$). Figure 6.4 displays the proportion of correct scores for each question type at each position for participants in the power condition.

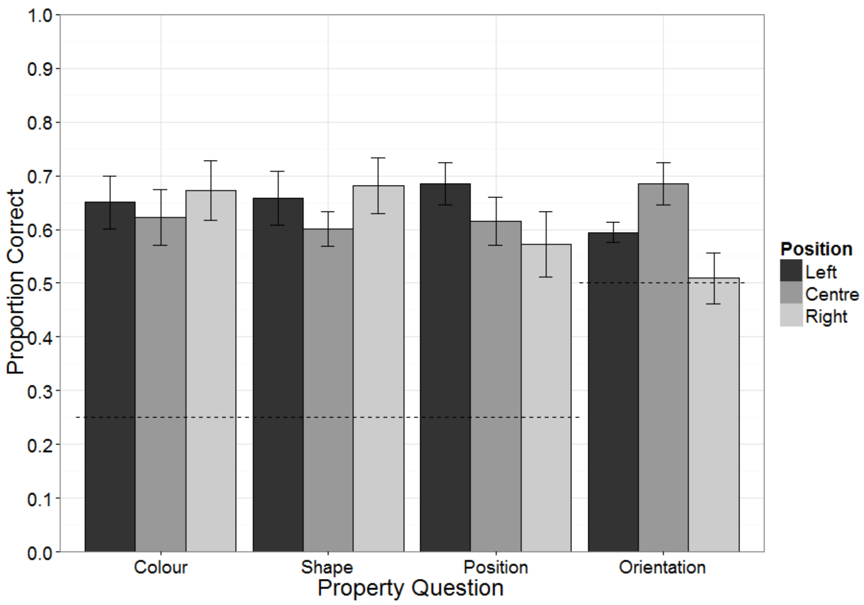


Figure 6.4. Memory scores for object properties at the three positions, encoded under power intention conditions

6.3.1.2 Object Grip. The influence of the object's grip type was investigated using a mixed factorial ANOVA: however, this did not show any strong results. The intention condition of the participants did not have a significant effect ($F<1$), and participants showed no advantage for recalling any particular property, $F(2,62)=1.47$, $p=.239$ or a particular grip category, $F(1,29)=1.28, p=.267$. No interactions were found to be significant (F's <1).

In order to determine if differences between power and precision items might be more easily detected when examining the intention conditions separately, analyses were conducted on each group in turn.

Passive. Participants in the passive intention condition recalled all object properties equally well, and both categories of object grip (Fs <1). There was also no significant interaction between grip type and question type ($F<1$).

Examining the orientation question score separately showed that participants were above chance when recalling the orientation of either category of object. However, no significant influence of the grip category was found on recalling this property ($F<1$). Figure 6.5 shows the proportion of correct responses to objects in both grip categories made by participants in the passive group.

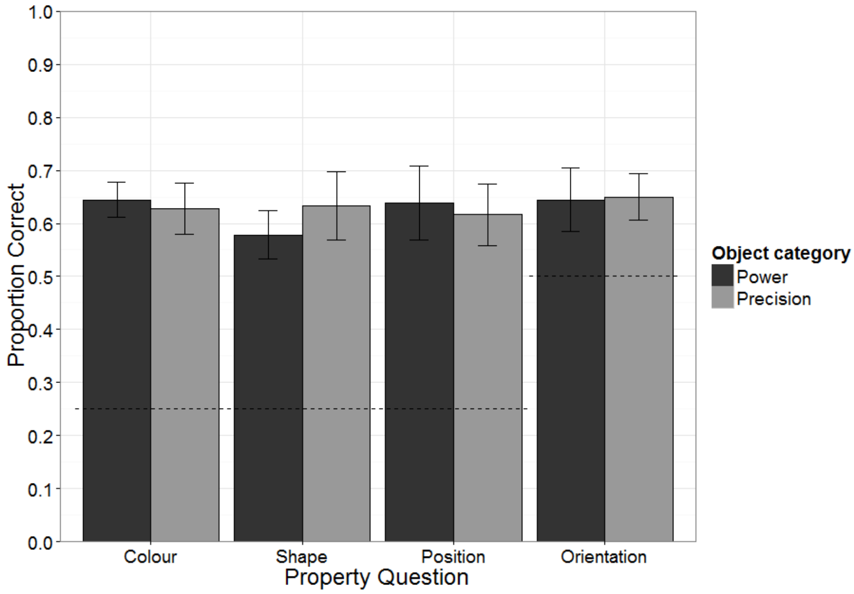


Figure 6.5. Object property memory scores for the two grip categories encoded under passive intention conditions

Precision. For participants in the precision intention condition, there was also no difference in memory performance for either the grip type of the object, $F(1, 10) = 2.73$, $p = .129$, or the type of question, $F(2, 20) = 1.87$, $p = .181$. Similarly, the interaction between grip category and property question was non-significant ($F<1$).

The scores for the orientation questions showed that participants scored above chance for both grip types ($ps<.01$). Again, there was no significant difference in the correct responses to the objects' orientations for the two grip conditions ($F<1$). Figure 6.6 shows the proportion of correct responses to objects in the two grip categories for participants in the precision group.

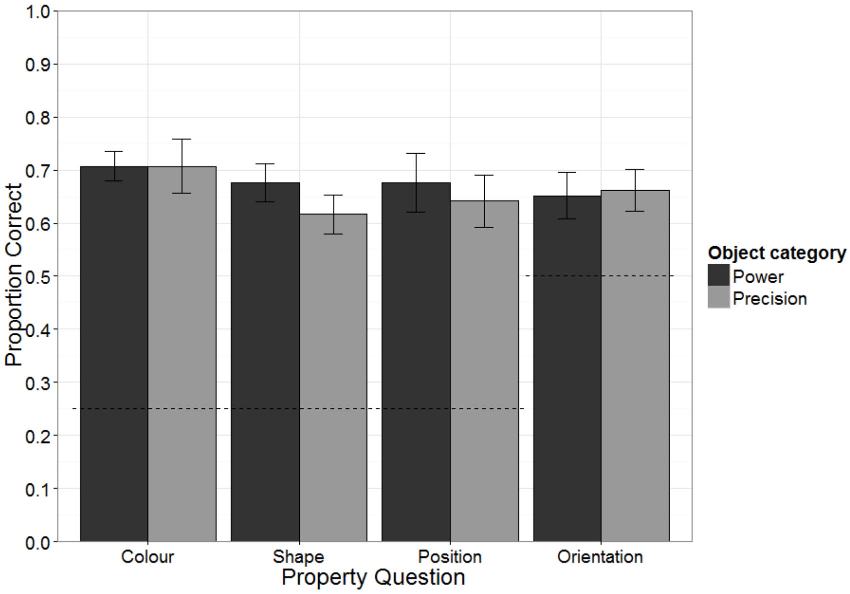


Figure 6.6. Object property memory scores for the two grip categories encoded under precision intention conditions

Power. As for the other two intention conditions, participants in the power intention condition showed no difference in their responses to the property questions, or the two grip types (Fs<1). The interaction between the factors was also non-significant, $F(2,20)=1.90$, $p=.175$.

The orientation responses were found to be significantly above chance for both object grip types (ps<.05), but there was no significant difference between the scores for each of the object types, $F(1,10)=2.15$, $p=.174$. Figure 6.7 shows the proportion of correct responses to objects in the two grip categories for participants in the power group.

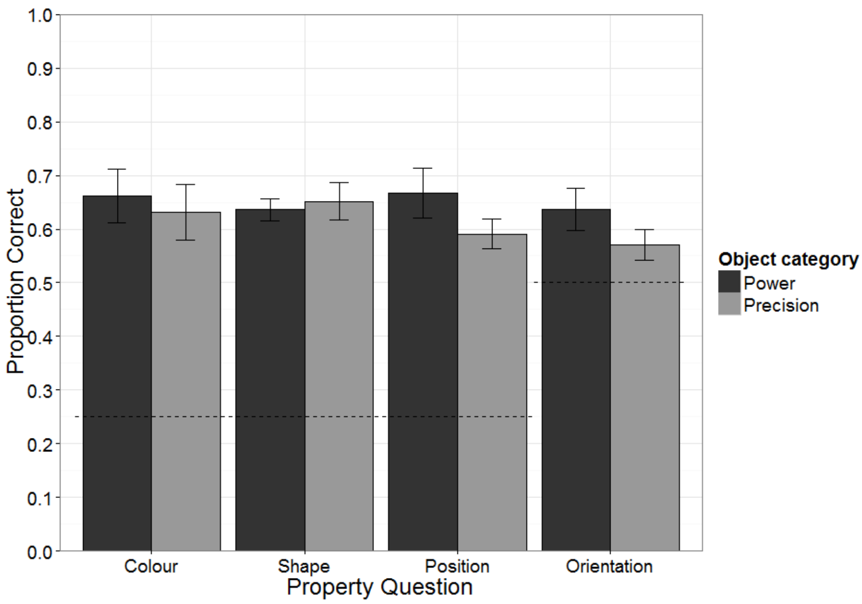


Figure 6.7. Object property memory scores for the two grip categories encoded under power intention conditions

All factors (question type, object position and object grip type) were combined, to determine if any further effects emerged as a result of the combination. A mixed factorial ANOVA was used to examine any possible interactions between the grip categories of the objects, the objects' positions, and the property question type, for each of the intention conditions.

Passive. Examining participants in the passive condition did not reveal any further effects: participants showed no difference in their responses to the question types or the grip category (F's<1), although a marginal effect of the position was found, F(2,18)=2.65, p=.098, whereby items at the right (*M*= 0.67) tended to be better recalled than those at the other positions, (left *M*= 0.60, centre *M*=.060, ps<.05) although when examined with a post-hoc test, the differences did not emerge as significant. For the interactions, most were also found to be non-significant (Fs <1), but the interaction between position and question type showed a marginal difference, F(4,36)=2.19,p=.090, as did the interaction between the grip type, position and question type, F(4,36)=2.59,p=.053.

Breaking down these interactions using 1-way ANOVAs for each property score, across the three position regions, showed that participants recalled the properties of colour and position equally well at each of the three regions (Fs<1). However, a significant difference was found between the three locations for the recall of shape properties, F(2,18)=6.39, p=.008, with participants marginally better at recalling object shapes at the right of the screen (*M*=0.70), compared to the centre (*M*= 0.51, p=.073), but not the left side (*M*=0.63).

Further investigation of the three-way interaction also suggested that the effects were localised to the central regions of the table tops. For these items, a significant interaction was found between the property type and the grip type, F(2,18)=4.21, p=.032, with participants recalling the shape of precision items (*M*=0.61) significantly better than they recall the shape of power items (*M*= 0.40, p<.05). Significant effects were not found at either the left or the right locations (Fs<1). For the passive intention condition, it seems that items at the centre show the greatest differences in terms of score.

Again, the orientation responses for this group were examined separately. These scores showed no main effects or interactions (Fs<1), indicating participants were recalling object orientations equally well for each of the positions and grip types.

Precision. For participants in the precision condition, a main effect did emerge when the three factors were analysed together. Participants showed a significant advantage for recalling the power compatible items (*M*=0.69) over precision compatible items (*M*= 0.64), F(1,10)=5.37, p=.043. No other effects showed an influence on memory score (Fs<1).
One interaction was also marginally significant, between the object's position, and the grip type, F(2,20)=3.48, p=.051. This was found to arise from the objects at the right of the table top, where participants in the precision condition showed an advantage for recalling the power items (*M*=0.70) over precision compatible items (*M*=0.55, p=.053).

For the orientation responses, while there were no significant effects of the grip condition, or the position, the two factors did show a marginally significant interaction on these scores, F(2,20)=3.14, p=.065. Further investigation showed that participants performed differently at each of the three table locations: while they were marginally better at recalling the orientation of precision items at the left hand side (precision *M*=0.69; power *M*= 0.61), F(1,10)=4.52, p=.060, performance was significantly better for the power items at the right hand side (power *M*= 0.70; precision *M*= 0.52), F(1,10)

= 6.42, p=.030. For items at the centre, there was no difference in the recall of object orientation for the two grip categories.

Power. For participants in the power condition, the main effects of the property question, the objects position and the grip type of the items remained non-significant. However, analysing the factors together in this manner revealed two interactions, a significant one between the grip type and the object's position, F(2,20)=6.66, p=.006, and one marginal interaction between the grip type and the property question type, F(2,20)=3.25,p=.060.

Breaking down these interactions showed that participants were better at recalling the details of objects that were compatible with a power grip. For the position interaction, F(1,10)=15.78, p=.003, power objects (*M*=0.70) were better recalled than precision objects (*M*=0.55) when they were positioned at the right of the table. The interaction with the question type showed that it was the position of power objects (*M*=0.67) that was marginally better recalled than the position of precision objects (*M*=0.59), F(1,10)=3.89, p=.077.

For the orientation questions, participants in the power condition showed no difference in their responses to power and precision compatible items, F(1,10)=2.82, p=.124, however, their recall of orientation was affected by the items position, F(2,20)=9.11, p=.002. Post-hoc comparisons showed an advantage for recalling items positioned at the centre of the table (*M*=0.69), than those at the right hand side, (*M*= 0.51; p<.01). The interaction between grip and position was not significant (F<1).

6.4 Discussion

The aim of Experiment 5 was to examine the influence of an action posture during encoding on the construction of the subsequent memory representation (as in Experiment 2.2). However, to address possible issues with the ecological validity of Experiment 2.2's setting, for Experiment 5, the stimuli used were real objects, physically present in the same environment as the participants. Thus a more realistic setting was created, to determine if the observer's presence in the environment would enhance any influences of the action posture that might have been lost due to the previous lab settings. The data were examined in terms of how being present in a real environment influenced recall performance alone, as eye movements were not recorded during this study.

6.4.1 Property questions

For Experiment 5, participants showed very little difference between their scores for the object properties. Only in a few analyses did a difference emerge: for participants in the passive intention condition, with regard to objects positioned at the centre; and for participants in the power intention condition, with regard to objects positioned at the right hand side. In both cases, participants showed an advantage for recalling the location of objects compared to recall of their shape.

These findings are in contrast to those from Experiment 2.2, where the advantage for recalling position information was consistently present across all conditions. Examining the means for Experiment 5 indicates the change was due not to participants performing worse on position questions, but simply that they scored higher for the other properties. Participants in Experiment 2.2 showed mean scores of 0.52, 0.50 and 0.58 for colour, shape and position, respectively, while participants in the current study had mean scores of 0.66, 0.63 and 0.64 for these three properties. This is unsurprising: the quality of the visual information received from the real world scene may well be greater than that from the photographs; for example, differences in the colour values may be more easily distinguished. The general finding that recall from a real world situation is better than that in lab based situations has been shown in previous studies, (see e.g., Tatler et al., 2005; Tatler et al., 2013).

It is interesting to note that, where differences between property responses did emerge, these were still in the direction consistent with experiment 2.2, with better performance on the position questions, and typically rather poor recall of the shape information. The findings of somewhat better performance for position information are in agreement with previous work showing that position information is extracted early in viewing (e.g., Tatler et al., 2003), and the proposal that this information acts almost as a marker for more detailed information to be built upon (e.g., Hollingworth and Rasmussen, 2010). Poor recall of shape information is consistent with the findings from studies which used a similar line drawing measurement to those employed in this thesis to test this property (e.g., Tatler et al., 2005). It appears that participants found it difficult to match an object representation to a simple outline. Thus, it seems that transferring the stimuli from a lab environment to an immersive one did not change how participants represent the information. While it may have been easier for participants to extract this information from the real-world environment, leading to better recall performance overall, they were still using the same processes, so the same patterns still emerged.

6.4.2 Object position

Examining the influence of the objects' positions on the table showed very little influence on memory performance. When position was analysed alone, participants in the power and precision conditions showed no difference in how they recalled the information. Only for the passive condition participants was an effect found, with a general advantage for items positioned on the right hand side, an effect which was fairly weak. The overall pattern was therefore rather similar to that of Experiment 2.2: memory performance was also largely unaffected by the position of the objects in the scenes, with the exception of one group. However, here the similarities end, as in Experiment 2.2, it was participants in the precision condition who showed a better performance for objects on the left hand side, the opposite of what was found in the present study.

When the influence of the object grip type was added into the analysis, then further effects did emerge. For the passive condition, while the weak general right hand side advantage was found, it appeared that central items were best recalled when tested on their position. Better recall of precision objects was also localised to the centre, with a particular advantage for recalling the shape of these items being shown. For participants in both the power and precision intention conditions, object recall was best for those at the right hand side, in an interaction with the grip type in which both intention conditions showed an advantage for the power compatible objects.

Experiment 2.2 showed little effect of the objects' position on memory, the only exception being the participants in the precision condition, where items on the left were recalled marginally better than the other conditions. As Experiment 2.2 also measured the eye movements of the participants, it was shown that participants in the precision group were also tending to spend more time fixating the left hand items. The current study shows a similar lack of position influence on the memory performance, except for the participants in the passive condition, where the memory advantage was now found for objects at the right hand side. However, without measurements of eye movements in this study, it is not clear if participants in the passive condition spent a similarly increased time fixating objects at this right hand location.

The previous studies in this thesis which included eye movement measures showed a clear left-to-right gaze progression, most likely due to the structure of the stimulus scene layout. Given that the displays for Experiment 5 were direct replications of this layout, then it is possible that participants were following this same viewing procedure. Items on the right would be the last to be examined, and so better performance on their recall might indicate a recency effect in memory. Of course, this is in contrast to Experiment 2.2's findings, where the left side advantage would suggest a primacy effect in memory. It is therefore unclear how plausible a recency effect explanation is.

Once the object grip type was introduced into the analysis, this right side recall advantage was also seen for both power and precision groups, suggesting this was a consistent effect for this study. One possibility is that this reflects an influence of the real world setting. Tatler et al. (2005) noted that memory scores in the real world version of their study showed stronger effect sizes, indicating that subtler effects might be more easily seen when testing in an immersive environment. Thus, the better performance on right side objects in the present study could be indicating a recency effect which was not strong enough to be picked up in a lab setting. Furthermore, it is interesting that this finding was strongest for the two grip conditions, with the passive participants showing a much weaker, but similar pattern. This is a similar pattern to what was seen in the eye movement measures for Experiment 2.2: these three groups showed the left-to-right progression, but in a much more pronounced fashion for the two grip conditions. Therefore, perhaps the presence of the grip posture at encoding was once again influencing the viewing patterns, while the real world environment aided encoding and recall in such a way that we finally saw some effect emerge in the memory measures. However, as pointed out, this is not supported by eye movement records, so is largely speculative.

Another factor to consider is that the participants in this study were able to move around the stimulus display. As participants now had the ability to view the scenes and objects from several different angles, the encoding of position information would become more complex as a result. Position in a static scene is a single piece of information, indexing the object to its location in the environment. In a dynamic scene, where the observer is moving, the position information must also incorporate these movements the observer makes, and other objects relative to the target (Tatler and Land, 2011). It has been suggested that in such dynamic scenes, encoding of information may proceed differently, with potentially multiple representations created in order to hold this more complex information. If so, the differences we found in the current study, compared to Experiment 2.2, might reflect the increased demands the situation places upon encoding position information.

The ability of the participants to move around the viewing table does not appear to have had a strong influence on other aspects of the memory performance. For example, performance on the orientation questions were not noticeably lower, which might have been expected, given the different viewpoints of objects that participants would have received, due to their movements.

Given that participants moved of their own choice, rather than having items moved around them, this finding is in line with previous studies (e.g., Simons and Wang, 1998). Furthermore, the amount by which the participants could move was somewhat restricted. As all the tables displaying the objects were placed against the walls, participants could not walk directly behind them, preventing them from seeing objects in a complete reversed position, which might have been the most disruptive to later recall.

6.4.3 Object grip

While no influence of the object's grip type emerged for any group when this factor was examined alone, when position and grip were combined in the same analysis, interactions showed some advantages for particular objects. For both the power and the precision intention conditions, participants are better at recalling power-grip compatible objects (but only when they are positioned at the right hand side).

Since both groups show an advantage for recalling power items, it is unlikely that this reflects an influence of the specific grip posture maintained during encoding. However, the two grip conditions do appear to differ from the passive condition, which does not show this advantage for power objects in any analysis. This might indicate a more general advantage of the action posture over an absence of any kind of action pose, which only emerges in a real world environment. Experiments 2.2-4 all show longer fixations on power items, which is most likely due to their larger size. Once again, this effect was not seen in the recall performance for these studies, but may be emerging here due to nature of the environment. Furthermore, the fact that this advantage was only found on the right hand side for the two grip conditions may indicate that this was also linked to the possible recency effect that may be present in the grip conditions, due to the viewing behaviour. Thus, while there may be some influence from the action maintained during encoding, there is no evidence to suggest that the representations constructed were biased in favour of only grip relevant items.

By transferring the stimulus objects into a real environment, we wished to determine if the results obtained in the earlier, laboratory based versions of the study would persist in the real world, or differ in the new environment. As participants were present in the same environment as the objects, interaction would have been possible, and the actions maintained might have been connected more closely with the objects in front of them. However, the results do not support this possibility, but instead continue to show no influence of the encoding action on the resulting memory, much like Experiment 2.2. Without eye movement measures, it is not possible to determine if there was any effect of the action on the viewing behaviour, but any such influence did not persist beyond the ending of the action. As suggested previously, this might indicate that, in a situation where the action is completed, the resulting representation is purpose-neutral (Wilson, 2002).

However, while the potential for action was present in this study, the participants received no instructions to do so: in fact, they were specifically told not to interact with the items. Thus, our studies so far have focused only on those situations in which the only action present was the preparation for action. These investigations were necessary in order to establish how the indication of action, via these action postures might affect both viewing and memory, and so far, our studies seem to indicate that the effect, while present under certain situations, is rather weak. The next step, therefore, is to increase the realism of the situation once again, by allowing participants to follow through on the preparation of action, and physically interact with the objects as part of an everyday task.

Chapter Seven- The independent contributions of task relevance and physical interaction to object memory

7.1 Introduction

In examining the interaction between action and perception, the previous studies in this thesis (with the exception of Experiment 5) have all been conducted in a lab environment. Even Experiment 5, where participants and objects were in the same space, was not entirely realistic, as participants were still prevented from interacting with the items. Perhaps most importantly, there was no specific instruction to use the objects, and no need for participants to use the objects to achieve a goal. All connections between the action and the objects was implied, and while this was found to have influences on both eye movements and recall, it is possible that, with a specific task setting these effects would be stronger, or indeed entirely different.

When an item is task-relevant to an observer, there is a change in the way this object is examined and represented. It is well established that the nature of the task has a strong influence on what is looked at and when: Land et al. (1999) and Hayhoe et al. (2003) both demonstrated clearly how the eye movements of the participants were constrained to the items currently necessary to achieve a goal. In terms of representation, Triesch et al. (2003) and more recently, Tatler et al. (2013) demonstrated a memory prioritisation for relevant object features. This was shown both throughout the task, in the case of Triesch et al.'s (2003) findings, and persisting in the representations tested after the task was completed, as in Tatler et al.'s (2013) results. These two studies also support the idea of independent properties, which has been important throughout this thesis. Each demonstrates the features of the objects that are most relevant to the situation (either by informing the on-going task, or facilitating possible later interactions) are more prominent within the representation.

Importantly, these changes in the way relevant items are represented cannot be explained simply by the increased time spent fixating these items (e.g., Hollingworth, 2012). Võ and Wolfe (2012) showed that advantages from previously fixating target objects only persisted if the items had been fixated in the course of an identical task earlier. That is, if an item was fixated in the course of a search task, subsequent search tasks would be facilitated. However, if previously fixated in the course of a memory task, then later searches did not benefit. Further support comes from Tatler and Tatler (2013), who showed that changes in memory for objects classed as task-relevant or irrelevant could only be partly accounted for by the differences in fixation. The fact that they were relevant to the specific task was another significant factor in the changes to memory: within a given number of fixations, different amounts of information were extracted and retained from the task-relevant and irrelevant items. The task setting is a clear contributing factor to the way in which information is extracted and retained.

While there is strong evidence that task relevance is an important factor, another aspect remains largely un-investigated: that of actual physical interaction with objects. Studies which do include object interaction have demonstrated that this process can lead to changes in the representation of the objects used. In Tatler et al.'s (2013) study, participants either participated directly in the task, using the relevant objects to make a cup of tea, or they observed videos of others performing the task. In subsequent memory tests, the active participants showed better recall of the task-relevant objects' position information, and some indication that the colour information for these objects was de-prioritised. In contrast, the participants who observed without interaction showed no such evidence of prioritisation. It seems that the interaction with the objects changed their importance, by marking them as items necessary for the achievement of the task, and ensuring this importance continued to be marked in memory. Properties which might be considered to be particularly useful were biased within the representation, making them easier to recall. While participants who watched videos of the task were aware of what items were relevant to the goal, this knowledge alone did not lead to the representation biases seen for those who actively used the objects, thus suggesting that interaction is an important factor in the construction of representations.

However, this study uses only two groups of objects: those that are task-relevant and therefore interacted with and those that are not relevant, and are not touched. As a result, there is a potential confound between the influence of task-driven interaction, and physical interaction with the objects which is not driven by the demands of the task. It is possible that the act of manipulation itself can also influence the way in which the representation is formed, and may do so separately from the influence of task-relevance. Thus, it is necessary to tease these two factors apart, in order to determine if they do have separate influences on the resulting object memory.

In order to differentiate between actions that are task-relevant, and those that are simply interactions, we draw a distinction which is similar to Bub and Masson's (2006) suggestion of action gestures for form, and action gestures for function. When we act with an object in order to use it for its designed purpose (e.g., picking up a kettle in order to pour hot water), this is a functional action: only a kettle could be used for that specific task. When simply interacting, i.e. by picking the object up to hold or move; then the identity of the object is not important in the same manner; rather, it is an action of form, or a volumetric action, dependent on aspects such as weight and shape, but not identity.

However, previous studies investigating action in the real world have not distinguished between these two aspects, despite their differences. The aim of this final study, therefore, is to tease apart the separate contributions from task relevant interaction and form based interaction, in order to determine if these two factors are indeed separate and contribute differently to the resulting extraction and maintenance of object information.

In order to examine this, real-world tasks will be used, placing the participants in a real environment where they are specifically instructed to work with the objects. Using mobile eye-tracking technology, the influence of the two types of action on inspection behaviour can be investigated, along with the influences of action on the participants' later memory for the objects used, after the task is completed. As in the previous studies in this thesis, memory will be tested by examining recall for individual object properties, in order to determine if separate properties are differently affected by the types of interaction used and their relevance to the task.

We aim to determine if the two action types have separate influences on the way in which participants inspect and represent the objects in a scene. Such a finding would indicate that the nature of the task (and the participants' understanding of the goal) contributes something different to these processes, which cannot be gained from simply picking up an object. It would suggest that the participant must have some sort of goal in order for information to be extracted and represented in a manner that is biased towards the nature of the task.

Alternatively, it may be that there is no difference between the two types of interaction, in which case, any way of interacting with an object will lead to similar effects on inspection and recall. This will also suggest that task relevance may not be such an important factor, if simply holding an item is enough to prioritise.

In order to separate the two action types, participants in Experiment 6 were required to either use an object in the course of completing a task, or simply move an obstructing object out of the way. While moving an object can be regarded as part of the task itself (particularly if the object must be moved in order to access a task-relevant item), we feel that there is enough of a distinction between the two actions for effects to be expected. The process of moving an object is strongly form-based: it is completely irrelevant what the identity of the obstructing object is, and its properties (with the possible exception of shape) are not important to the on-going task to be performed. This is in contrast to the task-relevant items, where identity is the main factor in determining if the object is the correct one to use in order to fulfil the set goal.

7.2 Method

7.2.1 Participants

Twenty participants (6 males) with a mean age of 21.8 (SD= 1.63) were recruited from the undergraduate population at the University of Dundee. A further nine participants (3 males) were recruited from the same population for the control memory group. This group had a mean age of 22.3 (SD = 1.66). None of the 29 participants had previously participated in Experiments 2.2-5.1.All 29 participants had normal or corrected-to-normal vision, and received course credits in return for their participation.

7.2.2 Stimuli and Apparatus

7.2.2.1 Eye movement recording. Participants in the active task condition wore the Positive Science LLC mobile eye tracker during the task. This tracker consists of two video cameras, mounted on the frame of a pair of glasses, both recording at 30 Hz. One camera (mounted above the eye) faces forwards to record the head-centred view of the scene, while a second camera (mounted below the eye) faces towards the participant, to record the movements of the right eye. The movies from each camera are recorded separately, and synchronised after the on-line recording into a single video, using the Yarbus software package (v 2.2.3). Gaze direction was estimated via pupil tracking, and a nine point calibration procedure at the start and end of the active task. The system is accurate enough to allow spatial estimates of gaze direction to within a degree of visual angle.

7.2.2.2 Task setting. Twenty one objects were obtained and placed in a kitchen environment (Figure 7.1 shows the layout of this environment). Within the object set, 7 were necessary for a tea-making task (kettle, teapot, mug, spoon, milk jug, tea-bag box, sweetener container), 7 for a task in which participants made a sandwich and a glass of juice (plate, bread-bin, peanut butter jar, jam jar, knife, juice bottle, glass), and the remaining seven were items compatible with a kitchen environment, but not themselves linked by a task set (toaster, cooking pot, salt cellar, bowl, fork, washing-up liquid, measuring jug). These objects acted as a control group, as they were items that were simply present in the scene, but not interacted with in any way.

Figure 7.1. Photograph of the kitchen area and objects for the tasks

In placing the items in the kitchen, the items were positioned in groups of three. These groups contained a tea-making object, a sandwich-making item, and a background item (e.g., kettle, plate and toaster). Depending on the task that would be carried out, the relevant item would be obstructed by the alternative task item. For example, in the tea-making task, the task-relevant kettle would be obstructed by the task-irrelevant plate, which was placed on the top of the kettle. In the sandwich-making task, the now relevant plate would be obstructed by placing the irrelevant kettle on top. Thus, in order to use the obstructed (task-relevant) object, participants would have to interact with the obstructing (task-irrelevant) object, by moving it out of the way. In both situations, the background item (in this example, the toaster) would be placed in the vicinity of the task pair, but would not hinder access to either of the items.

Figure 7.2. Examples of the object positions used in Experiment 6, left: tea-making task; right: sandwich-making task

7.2.2.3 Stimulus questionnaire. For each of the 21 objects, three questions were created to test participants' memories for the colour, shape and starting position of each of the objects. All question types were 4AFC questions. For colour questions, the options were presented as colour names, with each of the foil options plausible colours for the item. The shape options were presented as line drawings of possible examples of the object type. For the position questions, a line drawing of the environment was presented, with four locations marked with letter options. The foils in each case were all positions for another item in the kitchen. The order in which the objects were asked about was randomised, as was the order of the property questions for each item.

Stimulus presentation and response collection was controlled by scripts written in MatLab, using the PsychToolBox extensions (Brainard, 1997; Pelli, 1997). Both the stimulus photographs and the question screens were displayed to the participants on the display monitor of a Macintosh computer, at a resolution of 1024 x 768.

7.2.3 Procedure

7.2.3.1 Active task. Participants in the active task condition were informed that they would carry out either a tea-making or sandwich-making task. They were also informed that there would be irrelevant items obstructing the objects they required to successfully complete the task. In order to deal with these, they were told to move them to another table in the kitchen, located on the other side of the room. Participants were told they should move the obstructing objects as they came to them at the stages of the task, rather than moving all items at the beginning of the task. This was to prevent participants from moving all the obstructing objects at the beginning of the experiment, and so avoiding the possibility of primacy effects in memory for these objects. Participants were fitted with the mobile eye tracker and calibrated, then began the task. No time restriction was given but for both tea and sandwich-making the average time taken was three minutes. At end of the task, the tracker was removed, and participants were informed they would now perform a memory task for the items in the kitchen, which they were previously unaware of. The questions were presented on the lab computer, and participants responded using the keyboard, and the number keys 1-4, which had been relabelled A-D.

7.2.3.2 Memory control group. Participants in the control group were not fitted with the eye tracker. They were informed that there was a memory test, and their only instruction was to memorise the items that were present in the kitchen. They were instructed not to pick up or interact with the items. After viewing the environment for three minutes, the participants were taken to the lab computer where the memory test was presented as before.

7.2.4 Design and Analysis

Experiment 6 had one independent within-subjects variable, which was the relevance of the objects participants saw and interacted with in the kitchen setting (task-relevant, task-irrelevant and background). Dependent variables were participants' memory performance in recalling the features of colour, shape and position for the objects, and the participants' eye movement and fixations on objects. The measure of average fixation duration was used, indicating the time participants spent fixating each object during the task.

For the active condition, the videos from the scene and eye cameras were combined to produce a single video for each participant, showing the gaze estimation for each frame of the movie. To analyse the data, manual frame-by-frame coding of the videos was conducted, by counting the number of frames in which each of the 21 objects was fixated, and the number of frames in which the necessary objects were gripped. Grip times were estimated via the scene camera as the times when the hands were visibly in contact with the objects.

Analysis of the effect of the types of interaction was performed using linear mixed effects models, using the lme4 package in the R statistical programming environment (Bates, Maechler and Bolker, 2013; R Development Core Team, 2013).

Models were run to predict total fixation time (the summed duration of all fixations on the object), the total grip time (the summed duration of all grips on an object) and memory performance for each of the three property questions. Previous work has shown that memory accumulates across fixation time (e.g., Hollingworth and Henderson, 2002), and so by using this measure, we can determine not only if fixation time is predictive of memory performance in the different conditions, but if, when fixation time is controlled for, differences still emerge between the memory conditions which can be attributed to differences in the tasks themselves. The measure of time spent gripping the objects was included as it provided data on whether information received from the tactile contact with the objects could also inform the construction of memory representations. The distributions of both the total fixation time and total grip time were examined, and subsequently log-transformed, in order to meet the assumptions of LMMs.

For modelling the total time spent either fixating or gripping the objects, the object type (relevant, irrelevant or background) was used as a fixed factor, while subjects and objects were included as random factors. For modelling performance in the memory questions, logistic models were run using the object type (relevant, irrelevant, background) and fixation time as the fixed factors, and subjects and objects as random factors. In all models, we used the most complex random effects structure that resulted in models that converged: that is we used models with random slopes and intercepts where possible (as recommended in Barr, Levy, Scheepers and Tily, 2013). However, these maximal models often do not converge and in such cases we simplified stepwise by first removing the calculation of correlation parameters, followed by removing the random slope(s) for any interaction term(s), followed by removing random slopes for main effects. In all cases the results are reported from the model with the most complicated random effects structure that converged.

Both binomial and continuous models were run on the data, as appropriate. For the continuous models, the criterion for significance used was that the absolute t values must be greater than 2. This is in agreement with earlier studies using LMMs (see, e.g., Kliegl, Masson and Richter, 2010)

7.3 Results

7.3.1 Control participants

LMMs were run on the data from participants in the control group. This was to determine that the three object groups were equally memorable to participants under conditions where there was no interaction required. Object identity and subject were included as the random factors in the models. For each of the property questions (colour, shape and position), memory performance was predicted using the object type. For the control participants, this was the task the objects were associated with: tea-making; sandwich-making or background items.

7.3.1.1 Colour. For colour questions, memory performance was not influenced by the object type. Colour recall scores for objects in the tea-making group did not differ significantly from the recall of objects in the background condition, $\beta=0.445$, s.e. = 0.476, z= 0.934, p= 0.350, or sandwich making items, $\beta=-0.539$, s.e. = 0.471, z= -1.15, p= 0.252. Similarly, recall of sandwich-making items did not differ significantly from background objects, $\beta= -0.094$, s.e. = 0.434, z= -0.217, p=0.828.

7.3.1.2 Shape. For shape questions, memory was also unaffected by the object type. The shape of the tea-making objects was not recalled significantly differently from the shapes of items in the background condition, $\beta=0.990$, s.e. = 0.956, z= 1.036, p= 0.300, or in the sandwich making condition, $\beta=-0.366$, s.e. = 0.558, z= -0.656, p= 0.512. The shapes of sandwich making items were also recalled no differently compared to background items, $\beta=0.624$, s.e. = 1.01, z= 0.618, p= 0.537.

7.3.1.3 Position. As for colour and shape, position memory was not affected by the object type. Tea making objects did not differ significantly in position recall compared to background items, $\beta= 0.536$, s.e. = 0.647, z= 0.829, p= 0.407; or sandwich-making items, $\beta=-0.899$, s.e. = 0.676, z= -1.33, p= 0.183. Sandwich-making objects were also not recalled significantly differently from those present in the background, $\beta= -0.363$, s.e. = 0.605, z= -0.600, p= 0.549.

Figure 7.3 shows the memory scores for each of the three property questions, across the three object types.

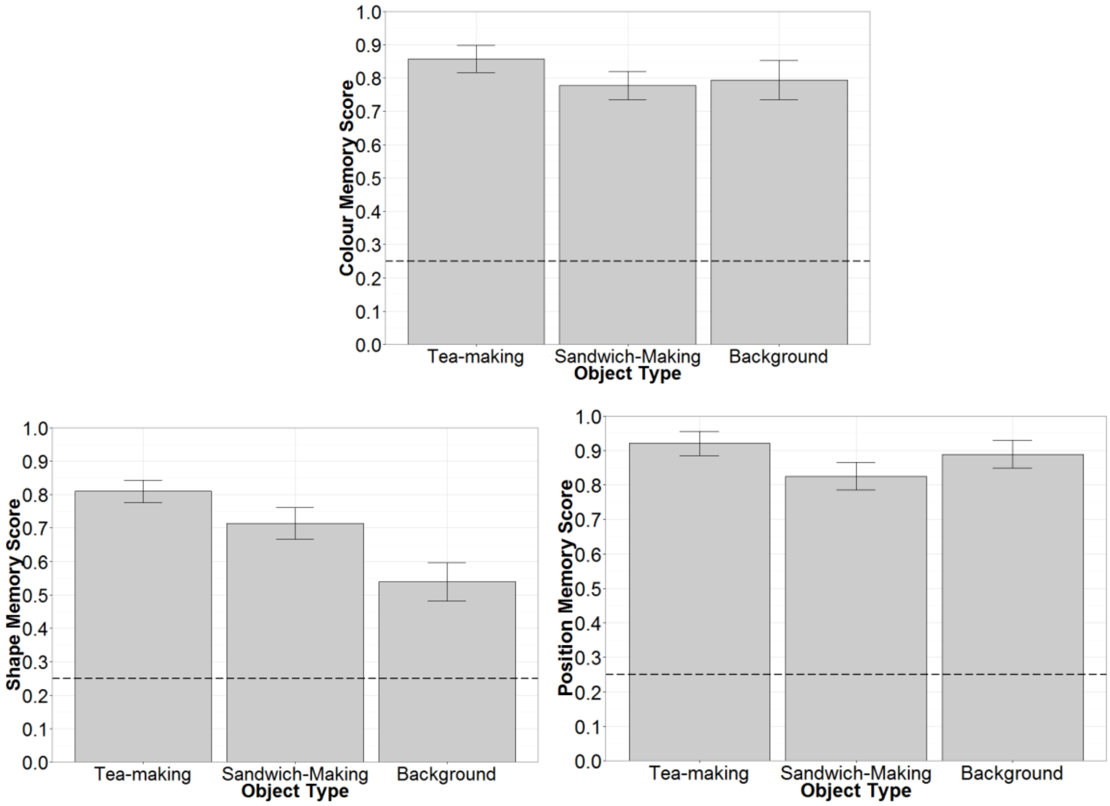


Figure 7.3. Proportion of correct scores for Colour, Shape and Position memory question for the three object groups

7.3.2 Active participants

For participants who had taken part in the active task, data from both eye movement and memory measures were available. Objects that received no fixations during the task were excluded from the analysis, as we were interested in how information was extracted from fixations made to the objects under the different action conditions.

Participants were placed in two groups, depending on whether they had performed the tea-making or the sandwich making task. To determine if participants in the two groups acted similarly with the objects, LMMs were run in which the group of the participant was used as the fixed factor to predict performance on the three property questions, and the fixation behaviour shown by participants in each group.

For each of the three property questions, memory recall was not significantly different between the two groups of participants. No difference was found between the groups for colour recall, $\beta= -0.391$, s.e. = 0.380, $z= -1.03$, $p= 0.303$; shape recall, $\beta=$ -

0.275, s.e. = 0.323, z= -0.851, p= 0.395, or position recall, β= -0.209, s.e. = 0.260, z= -0.803, p= 0.422.

Similarly, the participants' group did not predict a significant difference in the total fixation time spent on objects, β= 0.143, s.e. = 0.138, t= 1.04.

7.3.2.1 Selection: Fixation time. Investigating the effect of object type on total fixation time showed that the task relevant items were fixated for significantly longer than the background items, β= 1.23, s.e. = 0.088, t= 13.96, (background *M* =2.61 ; task-relevant *M* =3.84) as were items irrelevant to the task, but still interacted with, β= 0.574, s.e. = 0.087, t= 6.63 (task-irrelevant *M* =3.18). A significant difference between the time spent fixating relevant and irrelevant items was also found, β= -0.659, s.e. = 0.085, t=-7.72.

Figure 7.4 shows the log-transformed fixation times to the three object types.

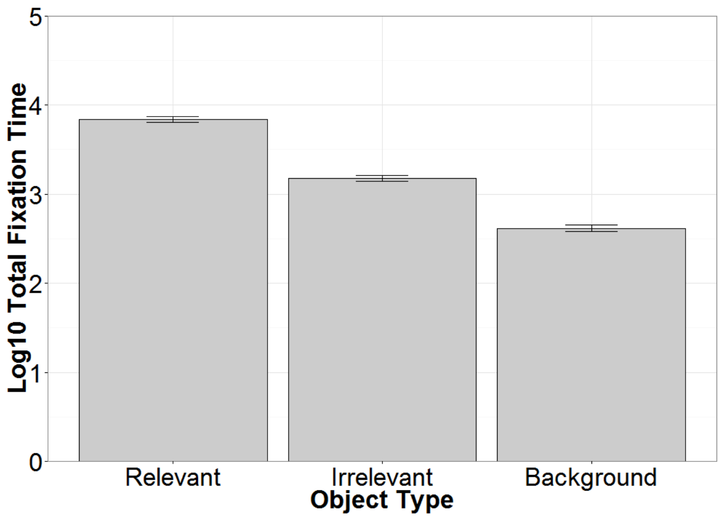


Figure 7.4. Log transformed total fixation times for task-relevant, task-irrelevant and background objects

7.3.2.2 Selection: Grip time. When using the total grip time as a fixed effect, items in the background condition were removed from the analysis, as participants never physically interacted with these objects. Analyses were conducted only on the relevant or irrelevant items.

It was found that the object type did influence the time spent holding the items, with participants spending significantly longer holding items that were relevant to the task than those that were irrelevant, but still needed to be moved out of the way, β= -0.598, s.e. = 0.036, t= -16.57 (relevant *M*= 4.05, irrelevant *M*=3.45). Figure 7.5 displays the log-transformed grip times for the two object groups.

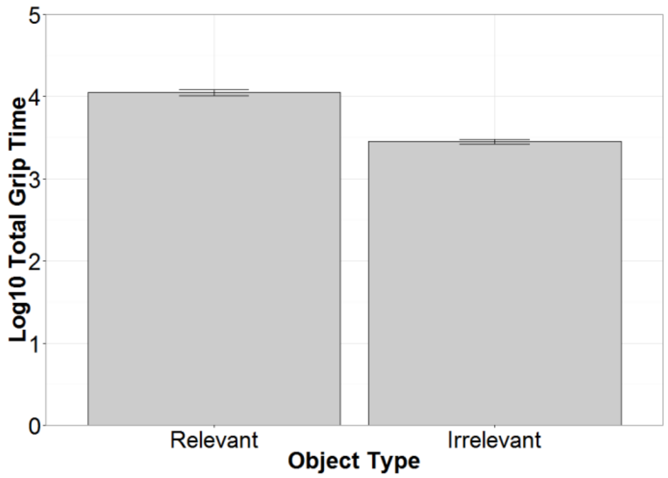


Figure 7.5. Log transformed total grip times for task-relevant and task-irrelevant objects

7.3.2.3 Memory: Influence of object type and fixation time. Performance on object memory was examined for each of the three property questions by running three models for each of the property questions. The first model included the object type as a fixed effect, to determine if there were overall differences in memory between the three conditions. The second model used only fixation time as a fixed effect, to determine if there were differences in memory due to differences in fixation times. The third model incorporated both object type and fixation time as fixed effects, allowing us to determine if any memory differences were solely due to differences in fixation time, or if further differences emerged which could be attributed to the task conditions.

Colour. Figure 7.6 shows the proportion of correct memory responses to the colour questions for the three types of object.

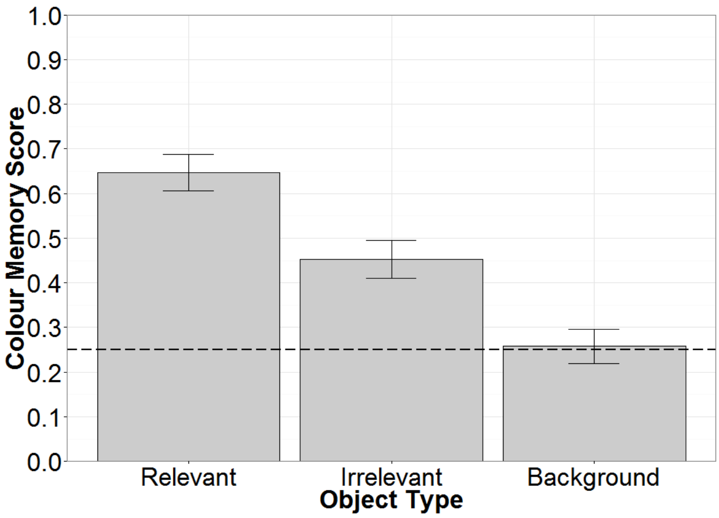


Figure 7.6. Proportion of correct responses to colour questions for relevant, irrelevant and background objects

In the first model (object type only), scores for colour memory were influenced by the object type, with relevant items, (*M*= 0.65) being significantly better recalled than background items, (*M*=0.26) β= 2.05, s.e. = 0.529, z= 3.88, p< 0.001; and irrelevant items being similarly significantly better recalled than background items, (*M*=0.45) β= 1.15, s.e. = 0.476, z= 2.42, p= 0.016. A significant difference was also found between colour recall for relevant and irrelevant items, β= -0.962, s.e. = 0.384, z= -2.51, p= 0.012.

The second model (fixation time only) showed fixation time was a significant predictor of performance on colour recall, β= 0.980, s.e. = 0.311, z= -3.15, p= 0.002, with greater fixation time on an item predicting better recall of that item's colour.

The third model, which included both fixation time and object type as fixed effects showed that the pattern of memory performance changed. Task-relevant objects were still recalled significantly better than background items, β= 1.55, s.e. = 0.658, z= -2.36, p= 0.018. However, recall for the irrelevant items did not significantly differ from recall for the background items, β= -0.801, s.e. = 0.498, z= 1.61, p= 0.108. Recall for irrelevant items also did not significantly differ from recall of relevant items, β= -0.750, s.e. = 0.472, z= -1.59, p= 0.112.

When fixation time was included in this model, it was shown to no longer have a significant effect on colour recall, β= 0.320, s.e. = 0.328, z= 0.974, p= 0.330.

Shape. Figure 7.7 shows the proportion of correct memory responses to the shape questions for the three types of object.

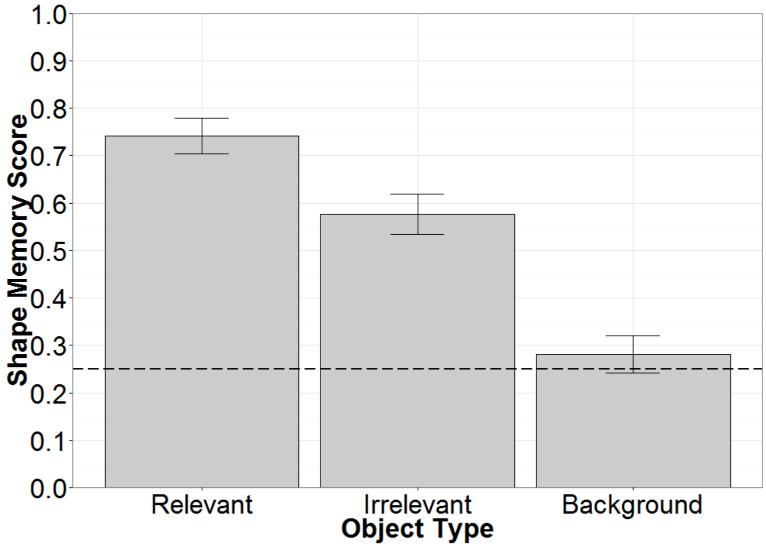


Figure 7.7. Proportion of correct responses to shape questions for relevant, irrelevant and background objects

The first model, using object type showed that this was a significant predictor of object shape recall. Participants showed significantly better recall for relevant items (M=0.74) compared to background items (M=0.28), β= 2.49, s.e. = 0.560, z= 4.44, p<.001, and irrelevant items (M=0.58), β= -1.02, s.e. = 0.369, z= -2.77, p=.006. The shape of irrelevant items was also recalled significantly better than background objects, β= 1.35, s.e. = 0.423, z= 3.19, p= 0.001.

The model for fixation time showed this measure to be a significant predictor of shape recall, with longer fixation time on an object predicting better recall of the object's shape, β= 0.834, s.e. = 0.365, z= 2.28, p=0.022.

The final model, which included both object type and fixation time continued to show similar patterns in the recall performance for shape information. Participants still showed significantly better recall for the shape of relevant items compared to both irrelevant, β= -1.30, s.e. = 0.558, z=-2.33, p=.020, and background objects, β= 2.82, s.e. = 0.802, z= 3.51, p<.001. The significant difference between shape recall for irrelevant and background was also maintained, β= 1.53, s.e. = 0.479, z= 3.20, p=0.001.
As for colour, shape recall was also no longer influenced by the fixation time when the

model included both object type and fixation time, β= -0.184, s.e. = 0.463, z= -0.397, p= 0.691.

Position. Figure 7.8 shows the proportion of correct memory responses to the position questions for the three types of object.

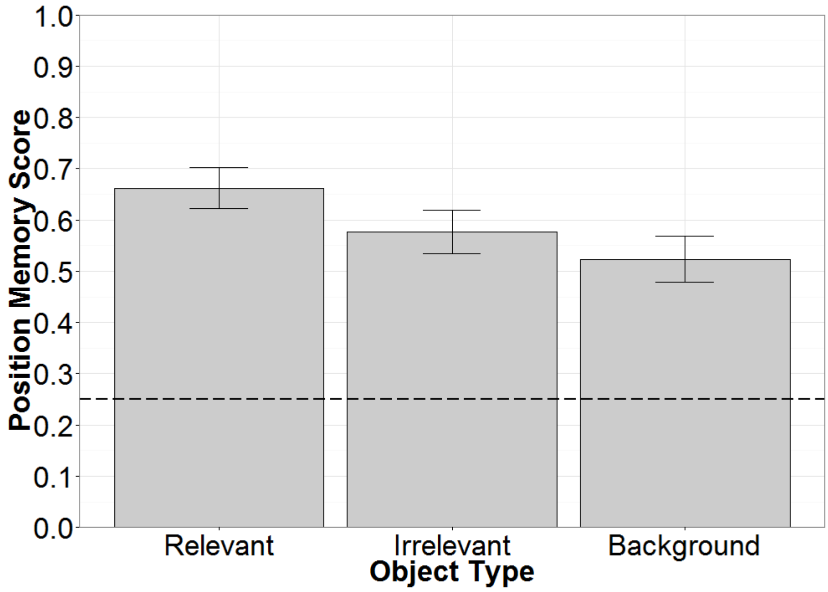


Figure 7.8. Proportion of correct responses to position questions for relevant, irrelevant and background objects

When object type was included as a single fixed effect, it was not found to be a significant predictor of performance on the recall of position information. The positions of task-relevant items (*M*=0.66), were recalled no better than the position of irrelevant items (*M*=0.58), β= -0.397, s.e. = 0.259, z= -1.53, p=0.126, and background items (*M*=0.52), β= 0.626, s.e. = 0.474, z= 1.32, p=0.187. No significant difference was found between the irrelevant and background objects recall for position, β= 0.236, s.e. = 0.480, z= 0.492, p=0.623.

The model using fixation time as a fixed effect showed that fixation time was a significant predictor of position recall performance, β= 0,503, s.e. = 0.217, z= 2.32, p=.020. Participants showed better recall for the position of items that they had fixated for longer periods.

When a model was run including object type and fixation time as fixed effects, the pattern of performance was unchanged. Participants still showed no significant difference between their recall of task relevant items and irrelevant items, β=-0.129, s.e.

= 0.441, z=-0.292, p=0.770, or background items, β= 0.173, s.e. = 0.706, z= 0.245, p=0.806; or between irrelevant items and background items, β= 0.076, s.e. = 0.571, z= 0.133, p=0.894. Furthermore, the influence of fixation time was no longer significant when included with the object type analysis, β= 0.484, s.e. = 0.350, z= 1.38, p=0.166.

7.3.2.4 Memory: Influence of grip time. As well as using fixation time as a predictor for performance on the three property questions, the time participants spent gripping the items was used in order to determine if tactile information about the objects received via interaction could influence the way in which object representations were formed and thus underpin any of the effects found in the above analyses. As for the previous grip analyses, the background objects (which were never interacted with) were removed from this part of the analysis.

Colour. Memory for colour was affected by the time spent gripping the objects, β= 0.987, s.e. = 0.482, z= 2.05, p=0.041. The colours of items that were gripped for longer were recalled significantly better than items held for a shorter period of time.

The analysis was then run including both grip time and object type as fixed factors. When object type was included, the influence of grip time on colour memory was no longer to significant β= 0.021, s.e. = 0.363, t = 0.234. The difference between the recall of relevant and irrelevant items remained non-significant as well, β= 0.181, s.e. = 0.093, z= -1.96.

Shape. Shape recall was not affected by the time spent gripping the item. Participants did not show better recall for the shape of items that were held for longer periods, β= 0.459, s.e. = 0.340, z= 1.350, p=0.177.

Position. As for shape, the recall for position information was not affected by the length of time objects were held for, β= 0.099, s.e. = 0.292, z= 0.340, p=0.734.

7.4 Discussion

In Experiment 6, the influences of task driven and simple physical interaction on inspection and memory were examined. Items that were task-relevant were fixated for longer, and recalled better than those objects that were simply in the background. However, differences were also found for the items that were not task-relevant, and yet still interacted with, in order to be moved out of the way. While participants did not fixate or recall these items as successfully as those objects that were task-relevant, there was still a clear difference between these objects, and those in the background that were not interacted with. The finding that there was a difference between task relevant and task irrelevant objects suggests that the process of interacting with an object to achieve a goal has an influence that is separate to that of simply interacting, and that these two processes have separate effects on the memory formed.

7.4.1 Fixation time and inspection behaviour

The findings for fixation time in Experiment 6 were much as would be expected based on previous studies. Participants spent longer looking at items that are relevant to their task, replicating a well-established finding from both lab based (e.g., Yarbus, 1967) and real-world situations (e.g., Land et al., 1999). Increased fixation time on such items is clearly necessary, allowing participants to gain the information they need to successfully work with the items, and complete the task.

Experiment 6 also showed a difference in fixation time between the irrelevant items: those that were moved out of the way by the participants, but otherwise played no part in the task - and the relevant and background items. These irrelevant items were not fixated for as long as the task-relevant objects, but were still attended to for longer than the background objects. Clearly, the irrelevant items were not required for as long within the task setting; participants were simply required to locate and then move them, rather than having to obtain visual feedback during more complex manipulations. However, they did still require some interaction, and so the time spent fixating them was increased. This is in line with previous work demonstrating the close link between task and fixation: participants follow a ‘do it where I’m looking’ strategy, attending to those objects that are required for the current stage of a task (e.g., Ballard et al., 1992). Thus, these differences in fixation time across the object groups are in line with what would be expected.

However, when considering the influence of the factor of fixation time on recall performance, it appears that this does not have a strong influence on the memory. Instead, it is the object type, in particular, how relevant the object is to the task, which has the greatest effect on performance.

7.4.2 The influence of object type

The results of Experiment 6 show that the object properties were remembered differently for the different types of object. There is previous work which suggests that differences in memory for objects can be accounted for simply by the differences in fixation time (e.g., Hollingworth, 2006; 2012). The current findings do not show this: instead, the results are much more in agreement with studies by Võ and Wolfe (2012), Tatler and Tatler (2013) and Tatler et al. (2013). The task relevance of an object contributes to memory performance beyond that accounted for by fixation time, indicating that, for these items, there is a difference in the way in which information is extracted from these fixations. Task-relevance therefore appears to lead to strategic prioritisation in the encoding and retention of information from such objects. However, the act of physically manipulating the objects in order to move them out of the way also seems to lead to changes in the prioritisation of object properties in memory. In order to consider these effects more closely, we examine the differences that emerge in property recall between task-relevant and background objects, task-irrelevant and background objects, and task-relevant and task-irrelevant objects.

7.4.2.1 Task relevant and background objects. By comparing memory performance between the task-relevant and background items, we gain insights into how important the task instructions are to the extraction and retention of information. Such a comparison is similar to those made in previous studies, which used these two object groups, interacted and not interacted with (e.g., Tatler et al., 2013), and so allows us to make a comparison with earlier works.

For colour information, the task relevance was a significant predictor of performance, with participants significantly better at recalling the colours of task relevant items than the colours of background objects. This is perhaps a surprising result: most previous studies consider colour to be a strongly visual property (e.g., Jeannerod, 1994; Tipper et al., 2006), and, as such, not of much relevance to the actions conducted with objects. This is the not the case in the current study. One possibility is that the prioritisation of colour is linked to the need to identify the objects necessary for the task. Unlike the background items, where the identity is not important, the task-relevant item is relevant precisely because of what it is, and the role it plays in helping to achieve the end goal. As a result, colour information may be extracted and maintained as a way of helping to identify the relevant objects. Alternatively, colour may be automatically included in the representation as a result of participants examining the objects with the aim of identifying them. Bub and Masson (2006) suggested something similar when they found that participants were unable to ignore the colour of an object if they were required to name it as well.

Similarly, participants were significantly better at recalling the shapes of task-relevant items compared to background items. This is more in accordance with the nature of the property. Shape is considered to be a strong active property (although Jeannerod (1994) would suggest that it has visual aspects as well). However, it is clearly an important factor when interacting with objects, as the shape of the item informs the grip that must be formed in order to do this successfully (Tipper et al., 2006). The task relevant items must be interacted with, and so prioritisation of this information is important.

In contrast to shape and colour, position information was unaffected by the task demands, and only influenced by the time spent fixating the objects. This finding is in contrast to that of Tatler et al., (2013), where it was specifically the position information that was prioritised for the task relevant items, suggesting that position is a more action-relevant property than a visual one. It is unclear why this difference between Experiment 6 and previous work by Tatler et al. (2013) exists. One possibility is simply the difference of the tasks: although both use similar real-world settings, the current study did put more of an emphasis on moving the irrelevant objects, which might have made position more important for these items, and so increased the prioritisation of this property. However, this explanation does not easily account for why participants were also very good at recalling the position of the background items; it is noticeable that while shape and colour recall for the background were at chance level, position was much higher. Furthermore, the question used to test position recall asked participant to recall the starting position, which is perhaps of less use to maintain, as it reflects a situation which doesn’t exist any longer for moved objects: thus, there is no particular reason why this property should be prioritised in memory.

An alternative explanation fits with the idea of position as a property which acts as a binding site for all the other properties when an object representation is constructed (see e.g., Hollingworth and Rasmussen, 2010). In this way, the position information is automatically extracted from the scene, for all objects that are fixated, in order to allow the rest of the representation to be formed. This would account for the higher performance on even the background items. It is also in agreement with other studies. For example, Tatler et al. (2003) found that the absolute position of objects in a scene is extracted quickly, with high performances achieved by 2 seconds of viewing, suggesting that this property is accumulated early on. Similarly, the study by Kondo and Saiki (2012) showed that position information was incorporated into an object representation, regardless of whether it was task relevant or not. These studies, in conjunction with the findings of Experiment 6, do suggest that position information may be accumulated differently, independent of the task requirements. Further investigation would be necessary to clarify why this role for position information is not evident for Tatler et al. (2013).

7.4.2.2 Task-irrelevant and background objects. Using the data from the task-irrelevant items, we can go further in teasing apart the contributions of task relevance and physical manipulation. Comparing the irrelevant and background items gives an idea of how important manipulation alone is to the construction of memory representations.

For colour information, we found no significant difference between the recall of irrelevant and background information. While the colour seemed to be important to task-relevant items, this is not the case for irrelevant and background items. This is perhaps because neither of these object sets needed to be identified with great specificity: background objects were not interacted with at all, and irrelevant objects needed only to be moved out of the way; thus, what they are was not important. If, as we suggest for the facilitated colour memory for task-relevant items, colour information is useful mainly for object identification, it may be that there was no need to prioritise colour information for the irrelevant and background items as well.

Significant differences did arise between the recall of shape information for irrelevant and background items, with better performance on the task-irrelevant items. This difference most likely arose from the fact that the irrelevant items still had to be interacted with, in order to reach other objects. Shape is the property which informs the grip required to interact with the object, and so was of the most importance to the task-irrelevant object set. As a result, unlike colour information, this information was prioritised in memory for the objects in the irrelevant group. The process of simply manipulating an object does therefore seem to influence the way in which shape information is extracted and maintained.

As for the task-relevant items, there was no difference in position memory between the task-irrelevant objects and background objects. The recall of position information was high for both object types. Similar explanations can be suggested here: that position information was automatically extracted from the scene to act as a binding site for all other featural information.

While no studies have previously differentiated between task-driven and form-driven interaction, an earlier study by Thomas et al. (2013) is in agreement with the current findings that physical interaction alone can lead to changes in the representation. In this earlier study, participants were tested on their object memory following a learning period in which they were allowed to either hold the objects in the test display, or only inspect them visually. When participants touched the items, their recall was changed, with participants recalling the objects as being presented in a smaller space, with reduced inter-object distances. There are clear differences between Thomas et al.'s (2013) findings, and those of Experiment 6: most notably that the current study shows an improvement in memory accuracy for properties, rather than a distortion in recall. However, both studies indicate that simply acting upon an object is enough to change the memory formed. Thomas et al. (2013) suggest an action-specific account for the changes in memory: by representing an environment of manipulable objects as closer together, the memory encourages later interaction with items, by presenting them in a more manageable display. It is less clear how such an account could apply to the findings of the current study: while the task relevant objects might be re-used, this seems to be less necessary for the irrelevant items, once they are moved out of the way. Another possibility is simply that any interaction will lead to automatic changes in the weighting of the representation, and the enduring memory trace. This can be seen as similar to many of the earlier studies showing an effect of action preparation (e.g., Bekkering and Neggers, 2002), or hand proximity (e.g., Davoli et al., 2012) on inspection behaviour. These manipulations cause subtler differences, while here the interaction leads to stronger effects on memory: but the representation is still constructed with the influence of action.

7.4.2.3 Task-relevant and task-irrelevant objects. By comparing the memory performance for task-relevant and task-irrelevant objects, we can determine whether there are influences on memory that come from the nature of the task instructions, beyond any contributions of simply interacting with the objects.

For both colour and position information, there were no such differences. For position information, it therefore seems that this information is not affected by the task used in the current study, as we consistently found that position information for all of the object types was well recalled, and unaffected by the group the object was in.

The lack of a difference between the groups for colour is more confusing. As we have already suggested, the benefit shown for colour information when comparing task-relevant and background objects suggests that the use of colour for identifying objects may have increased the importance of this property for the task-relevant items. This would not be expected to be the case for task-irrelevant items, and so a difference would be predicted here, but did not emerge.
In contrast, for shape information, there was a significant difference between the two object types. The shape of task-relevant items was recalled better than the shape of the irrelevant objects, although, as shown by the comparison between irrelevant and background items, manipulation alone did lead to prioritisation of this information. This difference can be seen to further illustrate the necessity of actually identifying objects in the task-relevant condition. Not only does the shape inform the grip necessary, it is tightly linked to the identity of the object. An item's shape is a very clear indication of how it should be used for a task, and so whether it is suitable to be used for a particular stage in achieving and end goal. This necessity for identification is not present for task-irrelevant objects: shape only informs the actions required to move the object, whatever it happens to be.

Thus, while shape information is important for both object types, it is a different quality of importance, and so it seems that the prioritisation of this information in memory differs for task-irrelevant and task-relevant items in this experiment. Using an object as part of a task, to achieve a goal therefore seems to influence the construction of a representation beyond changes resulting from the simple manipulation of the objects.

We have found further evidence to show that the nature of a task influences not only where participants look during the task, but also what information they best recall from the objects used. The current study can go further by suggesting that simple physical interaction with the objects will lead to similar changes in fixation time and memory. However, physical interaction and actions driven by task do not lead to identical effects in memory: the use of an object as part of task instructions leads to further biasing of some object information, beyond the changes due to a task-irrelevant interaction.

7.4.3 Influence of grip

As well as the time spent fixating the objects, the time spent holding them was considered as a potential predictor. Participants could have been gathering information about the items not only through visual feedback, but haptic feedback as well. Shape is the property most likely to benefit from any information received due to the item being held: however, grip has no influence on performance at all, suggesting that all information is being extracted from the visual fixations to the objects, which are driven by the nature of the task. This is perhaps not so surprising if the objects' sizes are considered: most of the items were larger than the hands, so participants could not experience the whole object by touch. Indeed, in order to use the object successfully (and safely) they may have needed to only hold certain parts (e.g., the handle of the kettle). Vision was therefore a more helpful source of information regarding aspects such as shape and position.

There was an influence of grip on the recall of colour, with better colour memory for items that were held longer. However, as for the measure of fixation time, this result did not remain when the object type was included in the model as a factor. This finding is therefore most likely an artefact of the fact that the relevant items were the ones which were used and looked at more, due to the nature of the task. When the object type was not included in the model, some of the variance could be accounted for by factors such as grip or fixation time, when in fact these differences were themselves driven by the importance of the object to achieving the task goal.

In conclusion, Experiment 6 demonstrates that, in real world settings, the task is a significant factor in both directing our fixations, and prioritising information. However, it also goes further in demonstrating that any physical interaction can lead to changes in viewing and memory strategies. While these effects are not as strong as the influence of a task-set, they still lead to a strategic prioritisation of the information that is most necessary for the action to be completed successfully. Our representation system appears to be sensitive to the different requirements of different actions, and constructs the resulting representation accordingly.

Chapter Eight- General Discussion and Conclusion

8.1 Background and Aims

The main aim of this thesis was to further investigate the involvement of memory representations within the context of grounded cognition, particularly theories of situated action such as the Theory of Event Coding (TEC, Hommel et al., 2001). Based on the proposal that action and perception are able to influence one another in a bi-directional manner, we investigated both directions of this relationship under memory conditions. Participants were required to draw on memory representations of objects formed under different situations in order either to perform actions, or recall object details. This allowed us to determine if, as when performing on-line tasks, there was any weighting of the representation due to the situation of the task, indicating that memory representations can be tailored to the demands of the task, in order to better serve an action to be performed.

Grounded theories of cognition, in particular accounts of situated action like the TEC, suggest that perception and action are more than just low-level input and output devices. Rather, they are the central driving force in the system, with the aim of most processes being to aid the production of action in the context of a task. The TEC in particular takes the view that perception and action are functionally equivalent processes, with the codes for both held in the same representational domain. Within this domain, event codes, consisting of the necessary action and feature codes, are constructed, and weighted by the situation of the task, so that the relevant features are more strongly represented within the code. This allows them a greater influence on the subsequent performance of a task. Weighting can be either via perceptual means (attention to an object) or action based (the intention of making or preparation of an action).

Previous studies have shown evidence for both types of situational weighting. Affordance tasks show a situation where perception of an object leads to priming of relevant actions, preparing for the response to be executed, while variations of visual search tasks have been used to show how the intention of performing an action can lead to a biasing of attention to action relevant properties and their associated objects. However, the majority of these earlier studies have been conducted in on-line settings, where the objects remain visible throughout the task. Very few studies have considered whether and how a memory representation might be affected by similar situational weighting. Indeed, theories concerned with memory representations alone (e.g., Hollingworth and Henderson, 2002; Melcher, 2001) have tended to examine memory in a more task-neutral setting, without including action. While Glenberg (1999) proposes that memory, like perception, is to serve action, this has been judged to be too broad an account to hold for all memory processes. More recently, however, memory studies have shown a role for task relevance in influencing the resulting memory performance, (e.g., Tatler and Tatler, 2013; Võ and Wolfe, 2012; Tatler et al., 2013) While there is still some debate over whether such effects are due to the increased fixations on such items, or if it is more strongly linked to the nature of the task itself, these recent memory studies all show support for the latter account. Such consistent findings do suggest that the nature of the task may be an important factor in shaping our memories of events and the objects involved, although more work is still needed to bring further understanding to this area.

Investigating the nature of the action-perception link, and situational weighting in memory representations is important for providing more information about how the systems of perception and action work together. Our studies concentrated on expanding from the experiments already conducted on both sides of the link. While previous work on the influence of perception on action had shown that certain aspects of a task (such as how participants attended an object e.g., Tipper et al., 2006; or responded to it e.g., Bub and Masson, 2010) could influence how perception primed action, no such work had been conducted to determine if the same was true for studies using off-line affordances. The finding that off-line affordances do occur (e.g., Derbyshire et al., 2006) indicates that the object representation constructed in these tasks does indeed contain both featural and action information. By determining if other task factors could also influence the effect, we are able to consider whether this stored information can be weighted by the nature of the task.

For the influence of action on perception, there are studies such as those by Võ and Wolfe (2012) and Tatler et al. (2013) which have shown that the performance of a task can affect the formation of the memory. In contrast, there are no studies investigating how simple action preparation might affect memory, although there is a large body of evidence to suggest that it influences perception. We therefore examined this aspect of action preparation across four studies, to determine if the representation might be similarly biased, perhaps in anticipation of the future action. The last study for this thesis was conducted in a real world environment, based on the findings from the earlier, lab-based studies we carried out, as well as the evidence from previous work which suggested the importance of real-world locations in this area (in particular Tatler and Tatler, 2013, and Tatler et al., 2013). The final study examined how flexible the weighting of representations might be when different types of actions were performed within the same task setting, and in particular to tease apart the contribution of action and task goals in weighting memory representations. The findings from these experiments are summarised below.

8.2 Overview of Empirical Findings

The first study conducted for this thesis examined the influence of boundary conditions in affordance effects that were carried out from memory. Two such boundary conditions were used: the property cue (shape or colour, a strongly active or strongly visual property), and the type of response (a simple button press, or a more object-specific pantomime gesture). In visually based affordance studies, both such conditions have been found to have an influence on the emergence of the effects, suggesting that they contribute to the situational weighting of the event code. It was found that, in Experiment 1.1, the property cue had the expected influence (shape cues facilitated responses, while colour cues did not). The gesture response also had the expected effect: gestures compatible with the object were initiated more quickly than those that were incompatible, and - perhaps due to the construction of the study - the gesture did not override the influence of the property cue. The effects due to the boundary conditions also persisted in memory, indicating that the mental representations could be weighted by the situation. However, such influences on action production only occurred when the display used four objects. When this was reduced to two, either the affordance effect was entirely absent, or the use of a boundary condition had no effect, in either visual or memory conditions (Experiment 1.2). Such findings seemed to suggest that the complexity of the scene might be another factor in the emergence of the effect.

Following this indication of the influence of complexity, the next experiments used a larger set of objects as stimuli, and placed them in everyday environments. These experiments also concentrated on the other side of the action-perception link, focusing on the influence that preparing and maintaining an action can have on perception and inspection, and subsequent memory. Experiment 2.2 required participants to maintain this action posture during the encoding phase of a memory test, while participants viewed the scenes, to examine how it might affect inspection (measured via eye movements) and memory. While this first study showed an influence of action postures on perception, with certain gestures affecting fixation time and patterns of eye movements, there was no influence on the memory results, in contrast to what was expected.

A second version of the study (Experiment 3) required participants to maintain the action posture at the retrieval stage of the study rather than during scene inspection. In this way, rather than providing conditions that might lead to the construction of the representation being weighting, the conditions provided instead had the potential to weight the retrieval of the stored memory. Retrieval is equally important to memory as encoding, and different factors can contribute to success or failure at this stage, independent of encoding (see e.g., Hollingworth et al., 2001). Thus, investigating this stage allowed us to determine if retrieval was susceptible to the action manipulation. The findings from Experiment 3 showed that there was an effect of the action posture at retrieval, suggesting that maintaining action postures when retrieving memories influences the nature of the retrieved memory. Taken together the results of Experiments 2.2 and 3 suggest that maintaining an action posture influenced only concurrent processes and these effects did not persist beyond the completion of the gesture.

The third version of the study (Experiment 4) therefore placed the action manipulation at both the encoding and retrieval stages of the task. For this study, the effect was entirely absent, with no influence on either stage. This result was somewhat unexpected. However, it is speculated that the manipulation of an action posture was not strong enough to persist over a long period, possibly suggesting that the effect decays over time if the gesture is not ended and reformed to indicate a new task beginning. Another possibility is that there was no way for participants to interact with the objects, and the overall setting of the experimental paradigm was still too unrealistic. Previous work which has shown evidence for the weighting of memory representations was conducted in real environments (e.g., Tatler et al., 2013), and thus this particular condition was introduced into our own experiments.

Two ways in which realism could be an issue were considered in the final two experiments. Experiment 5 replicated Experiment 2.2, but with the stimulus objects in the same physical environment as the participants during encoding. In this environmental context, it might be easier for participants to imagine interacting with the objects in the future, and so construct their representations accordingly. The findings of Experiment 5, however, did not show this, but replicated those of Experiment 2.2, with no influence found on the memory for the objects, suggesting that it was not environment alone that had resulted in a lack of influence of action postures during encoding on the formation of object memories. However, it remained a possibility that actually being able to interact with objects would lead to different memory encoding. Thus, the final study, Experiment 6, used a real world task in which participants did interact with the objects in order to complete the task. This task examined the contributions of different types of actions to the construction of object representations, by comparing the memories for objects that were used as part of achieving the task goal, and those that were simply moved out of the way. The findings from this experiment showed that simply interacting with an object will change the way in which the item is examined and represented, but that this effect can be dissociated from the effect of using the object as part of the task instructions. This final study suggested that, under the right conditions, the context of a task and physical interaction can have quite specific and separable influences on the construction of memory representations.

8.3 Theoretical Implications

8.3.1 Implications for the TEC. A central part of the TEC (Hommel et al., 2001) is that it is a cognitive model, rather than an ecological one; and so the capacity for forming internal representations is an important aspect. Indeed, as mentioned in Chapter 1, the authors acknowledge the necessity for off-line representation in forming the weighted representations. Part of the weighting is suggested to come from prior experience of objects, gained across the previous interactions with the items, so that the features that have been found to be most relevant for the task ahead are known, and can be prioritised via the preparation of action or the direction of attention. As the earlier review of the literature demonstrates, there is some scattered evidence for memory representations being similarly affected, and so the studies conducted in this thesis were attempts to close the gaps in our knowledge, and demonstrate that memory representations could show evidence of weighting in favour of an upcoming task.

Taking this view, it seems that our results do not entirely fit the expected pattern. If weighting occurs to allow for preparation for the upcoming action (by cueing the correct response, or directing attention to the correct location), then we would perhaps expect to find evidence for memory weighting when action postures were maintained during the encoding of photographic scenes (Experiments 2.2 and 4), or while viewing a real set of objects (Experiment 5). All these present a situation where the action posture is present during the viewing stage, and was expected to lead to influences on memory in favour of the task-relevant objects. However, the actual outcome is different: memory weighting does not occur in a situation with implied action. Instead, the evidence is only seen when there is direct interaction with objects, following the completion of the task (Experiment 6). This is the reversal of what we might expect: nothing seems to be stored to facilitate the performance of any potential future task, but weighting persists in a real task, although the goal has been achieved when the memories are tested. However, the finding of an influence of real world activity on memory representations is consistent with previous investigations of how natural tasks shape memories (e.g., Tatler et al., 2013).

In contrast to our findings for Experiments 2.2-5, the results for Experiment 1.1 are much more in line with the finding of Experiment 6, and the idea of memory holding weighted representations to aid action. The differences in attention affect whether the actions are facilitated, and this can be equally well drawn from a mental image of the object as a visual one. Experiment 1.2, however, does suggest that there is also another boundary condition: the complexity of the setting. The idea of boundary conditions is only really considered in the affordance literature, but examining the results from studies in the present thesis, we can suggest that one of the emerging findings is that the process of action weighting memory might be subject to these conditions too.

Boundary conditions have been proposed as a way of preventing the automatic conversion from vision into action (for affordances). Tipper (2010) pointed out that not every fixation made to an object is intended to result in an action. This can equally well be applied to the other side of the action-perception link: not every idea or plan is necessarily going to lead to a performed outcome. Alternatively, (but not necessarily exclusively) there may not be enough information available to the observer for accurate weighting to occur, for example, if it is perhaps not clear which objects are task-relevant in a situation. Thus, there may very well be situations in which an intention to act or a prepared action will not influence the weighting of memory representations.

The condition that we have considered throughout this thesis (and which has driven each new paradigm) is realism. However, realism is a fairly broad term: there are several ways that a study can be made more realistic. Within affordance studies, where realism has already been considered as a boundary condition, there are several ways in which earlier studies have explored this idea. For example, previous experiments have considered the influence of the realism of the action response, as well as the action states of the objects (e.g., Tipper et al., 2006), and the perceived ability of the participants to act with the objects (e.g., Yang and Beilock, 2011). Within the studies presented in the current thesis, Experiments 1.1 and 1.2, indicate that it was the complexity of the setting (i.e. the number of objects) which seemed to have an influence. Other possible factors that may influence the realism of an experimental paradigm are the specificity of the task instructions, the means by which the action manipulation is formed, and finally whether there is interaction with the objects; the last of these was explored in more detail in Experiment 6.

Experiments 1.1 and 1.2 are the least realistic of the studies within this thesis, and it could be argued that complexity is only a small part of realism. It is certainly possible to have very sparse real scenes, and completely chaotic fake environments. However, for the requirements of the task, participants needed to locate or recall one object amongst a group of distractors. Priming the responses, based on information received from the property cue may allow for responses to be made faster when the object is located or recalled, even if the initial search or retrieval process will take longer. In the easier condition, there is no need for this kind of preparation (although learning the repeated cues and their associations may also be a factor here, as noted in the discussion of Chapter 2).

The specificity of the instructions is most relevant for the studies in Chapters 3-6. Within these studies, the task given to participants was to memorise all of the objects displayed. This is in contrast to the earlier studies examining action preparation on perception, where typically there was one single object which was the target (e.g., Bekkering and Neggers, 2002; Fagioli et al., 2007). In the studies for the current thesis, the instructions mean that all objects are essentially targets. Although the action posture or response was not specifically linked to the objects presented in all the earlier studies, as well as our own, it seems that when instructions do not specify particular objects in a display, no memory weighting will occur. It is interesting that perceptual influences still take place, with longer inspection of objects relevant to the grip being formed (shown in Experiment 2.2), but this does not carry through to the representation. One possible explanation for this is that in a situation such as the one presented in Experiment 2.2, the action posture influences fixations on objects, perhaps because it is not particularly costly to spend more time on certain items while the entire scene is still being displayed. However, as there is no clear target, there is much less point in forming a representation biased towards any particular item if it is not certain that these will be required later. Indeed, as we considered in the discussion of Experiment 2.2, the nature of the memory task is such that all objects should be prioritised, as all of them will be tested at the recall stage. Thus, the lack of memory weighting for a specific type of object may indicate that the task goals for memory override any action effects that might otherwise have been found. Instead, it is much more efficient to prioritise none of the objects, on the grounds that any of them could be required in the future. Essentially, without enough information, it is more risky to bias memory in a way that might be incorrect. Alternatively, in line with the ideas of the ideo-motor principle within the TEC (Hommel, 2009), it may be that the production and maintenance of the action posture causes a weak association between action and objects, but because the gesture and what it relates to (that is, one specific object in the set) are not specified any further, the binding is not strong enough to influence the formation of the representation, only the initial examination.

A further aspect to consider is the stage of the gesture used for the action manipulation. In all our studies using the paradigm introduced in Experiment 2.2, the gesture was technically complete; as it was formed by the fact the participants' hand was holding something. This is a factor which is more difficult to compare across earlier studies, as they have varied in what stage the gesture is held during the experiment. Some have required participants to prepare the gesture, but only perform it after the task is completed (e.g., Symes et al., 2008). Others have used completed gestures as we do (e.g., Witt et al., 2005). It is possible that if the action is completed, then, again, there is nothing to prepare for, as the hands are already occupied. Indeed, Witt, Kemmerer, Linkenauger and Culham (2010) found that if participants were asked to name objects while holding a rubber ball, they were slower and less accurate at naming tools if the handle was towards the occupied hand. It was suggested that, when the hand was occupied, this interfered with the simulation of motor actions that occurred during fixation. This then impaired object identification, by preventing the use of such simulation. However, as noted in the discussion for Experiment 2.2, this may be less likely, based on the finding that the influence of proximal hands and the influence of the power grip gesture have very similar effects, at least on the eye movement data. This is important, as some studies have suggested that the open-hand posture used when placing the hands close to displays is an early stage of the postures the hands goes through when being closed into a power grip (Thomas, 2013). Furthermore, unlike Witt et al.'s (2010) study, where the gesture was not specific to the tools, the postures participants adopted in Experiment 2.2 were compatible with a subset of the stimulus objects. It is possible that the more specific gestures took the role of simulation. Given our findings, in particular the similarities between hand and power conditions, this does suggest that the stage of the gesture is not as important in determining whether a memory should be weighted or not in our experiments, although this is rather speculative.

We suggest that these factors (scene complexity, instruction specificity and the stage of formed gestures, under scene realism as a whole) may be considered (perhaps to different degrees) as boundary conditions for the influence of action on the formation of memory. Based on the results of Experiment 2.2, the action posture seems sufficient to influence inspection behaviour. It is simply that this is not enough for a representation to be formed which is biased towards one particular action. Our thoughts on this are rather similar to Wilson's (2002) idea of purpose-neutral representations, which allow the observer to maintain more information than would be needed for one task, in order that there would be enough stored information for whatever the future task might require (in our studies, the need to recall all the objects).

In Experiment 6, participants conducted a real world task that involved interaction with the objects. It could be debated as to whether object interaction is simply another aspect of task relevance, as it is the task instructions which determine what objects are interacted with. Indeed, there are studies which have not allowed participants to interact with objects, and yet still show a strong influence of the task instructions on the memory (e.g., Võ and Wolfe, 2012; Tatler and Tatler, 2013), which could suggest that it may be task relevance that is the most important aspect. However, Experiment 6 demonstrates that interaction in its own right may have some influence on the memory weighting as well, demonstrated by the findings for the task-irrelevant items.

With these conditions, of more specific task instructions and physical interaction, it was found that the resulting memory was influenced. We suggest that this is a reflection of the learning process by which the weighting is initially required. The fact that the bias remains after the end of the task is likely to reflect the information gained during the task (for example, that shape is an important property), and this allows for the acquisition of new weightings, or the strengthening of old ones, by confirming that these properties are important. This is similar to the ideas of the action-specific theory (e.g., Witt, 2011). According to this view, both action preparation and the completion of actions results in biased perceptions which aim to encourage the actor to either attempt the task, or avoid it, if it might be too much for them. Thomas et al. (2013), who conducted one of the few memory based versions of the studies, suggested that their finding (interaction with objects leads to recall of smaller inter-object distances) indicates encouragement for future action, as a smaller environment means a future task would be easier to perform. It should be noted that our own results show an improvement in memory, rather than a skewing of the information, which is a rather different way for the system to encourage future actions. However, both such aspects might be useful in storing information that might be necessary for later actions. Thus, following the successful completion of a task, the memories for the items continue to maintain their situational weightings while the information is stored for more long-term use, when the same task arises again.

In summary, the findings of the current thesis provide further support for the TEC. We demonstrate that both perception and action can influence each other, in accordance with the demands of the task situation. Furthermore, we show that this weighting can occur for memory representations as well, and, perhaps most importantly, we demonstrate that there are certain boundary conditions that need to be met in order for the weighting of a representation to be seen. By determining what conditions are necessary in order for weighting to occur, we can better understand the circumstances under which action and perception can influence each other. These situational restrictions suggest that our cognitive systems are indeed geared for action, but are also more flexible and efficient than simply preparing for action at any hint of a possible task. In many ways, this is in keeping with the idea of the TEC as a theory which allows the intentions and goals of the actor to be taken into account. It is simply that, in many of the studies presented in the current thesis, the intentions and goals are not so clearly drawn, which requires a different strategy. When there is not enough information, or not a strong indication that action may be required, then our representations remain un-weighted, in order to provide us with whatever information may prove to be useful in the upcoming task. Finally, by using paradigms that followed a path of increasing realism, we have demonstrated how ideas seen in previous studies that were rather more lab-based (the visual search tasks of Fagioli et al., 2007, and others) can extend to real-world situations.

8.3.2 Implications for theories of representation. The findings of this thesis have implications for the more general theories of representation. While these theories did not initially have a specific role for action, accounts of visual memory have suggested a strong link between factors such as task relevance, fixation patterns and the resulting memory for the objects (e.g., Hollingworth, 2009; Tatler et al., 2003), although the relative contributions of the different factors is debated. One suggestion is that it is the fixation pattern that is key in the acquisition of memory, with object prioritisation in memory the result of increased fixations on these items, rather than a more specific influence of the task instructions themselves leading to changes in acquisition of information (within fixations): that is task relevant objects are remembered better because they receive more and longer fixations, rather than because information extraction within fixations differs. However, many of our studies show results which are more in line with the alternative view, that it is the task setting which has the greatest influence, directing not only where participants fixate, but what information is extracted from such fixations (e.g., Tatler et al., 2013; Võ and Wolfe, 2012). Experiment 2.2, for example, shows changes to attention and fixation, and yet this did not result in similar changes to the memory performance. Similarly, Experiment 6 shows that while there are changes in fixation pattern according to the task demands, it is actually the task itself which has the greatest influence on the changes to memory. These findings, along with the earlier research, suggest that task settings act as a boundary condition to the formation of more task directed memory representations, rather than memory acquisition being due to information extracted from the scene based on where the participant fixates.

Given that the influence of task is now a well recorded factor in influencing memory performance, it seems necessary for action to be a more integral part of these accounts of visual representation. Inevitably, task goals specify actions to be performed on the environment and as such it seems likely that the relationship between our actions and memories should be accounted for in theories of representation. Glenberg's (1999) theory of memory for action was seen as too extreme, with the suggestion that all memory is for action. However, the alternative proposal, that our representations are largely purpose-neutral (Wilson, 2002), seems too rigid as well, given the findings in the current thesis, and shown in earlier studies.

Glenberg's account is, in many ways, a situationally weighted representation, with memories constructed so that only what can be used for action is included. Yet, based on the studies presented here, there are certainly situations in which the memory representation is unaffected by the task setting. Indeed, in Experiment's 2.2, 4 and 5 the representations act more like Wilson's purpose-neutral representations, containing information beyond that which would be necessary for the future task, so that whatever the future task does turn out to be, the information required will still be there. Indeed, as we have noted, in memory tasks such as were used in these studies, the purpose-neutral representation fits with the task goals of recalling all the objects: neutrality is the best strategy, and the action postures used did not interfere with these goals. Experiment 6, on the other hand, presented a situation in which such neutrality was not present, with clear task goals, and objects relevant to that task. This is in agreement with earlier studies demonstrating how differences in the task setting can change how objects are prioritised and encoded. In Tatler and Tatler's (2013) study, recall in the directed memory task (memorise only objects related to tea-making) was best for those items specified as task-relevant by the instructions. Performance when memory was undirected (memorise all objects in the room) showed no such differentiation. When the task setting specifies a subset of objects within the environment, our memories show a bias in the encoding and subsequent recall of these objects and their properties, which may also have a role in aiding the performance of similar tasks in the future.

It is also worth noting that even in a situation such as Experiment 6, where there is a clear task, the resulting memory is not so restricted as to only maintain the useful information and support a strong action bias as Glenberg might suggest. This is in line with studies of incidental object memory, which have shown that participants will extract information from a scene without any task instructions to guide this process (see e.g., Castelhano and Henderson, 2005). In Experiment 6, this incidental recall is demonstrated by participants' ability to recall details of the irrelevant items. However, it seems that incidental memory can be improved when items are manipulated: participants in Experiment 6 are better at recalling details of the irrelevant (but manipulated) items than the background (non-manipulated) items. Acting with objects therefore seems to affect not just the intentional extraction of useful information, but enhances the incidental acquisition of object details.

The findings of Experiment 6 also extend our current understanding of memory representations in one important manner: the influence of plain object manipulation, without a strong task instruction behind it. The manipulation of objects leads to changes in the formation and recall of representations, separate from the changes due to the task instructions. This is a new finding, and demonstrates that our representational system is sensitive to such manipulations, and also flexible in the weighting applied to features in construction: manipulation may cause changes to the maintenance of object information, but these biases are not as strong as that associated with the interactions in the course of task completion.

The fact that manipulation alone contributes to the construction of memory representations may indicate that the predominantly visual representations are also incorporating information from other modalities: in this case, from touch. Earlier studies have shown that other senses can modulate the performance of certain tasks: for example, a light can be perceived as brighter if it is accompanied by an auditory stimulus (Stein, London, Wilkinson and Price, 1997). Within studies of memory representations, there is evidence that information gained from touching an object can be used to help later visual recognition. This indicates that representations formed in one modality can be used to help performance reliant on another separate sense (Bushnell and Baxt, 1999), although there is still debate about how exactly the crossmodal information is maintained (i.e. within one multisensory representation, or separate representations for each sense: see Lacey, Campbell and Sathian, 2007, for a review). Such crossmodal representations are in agreement with the ideas of embodied cognition: specifically those that suggest that representations are formed by capturing states from across the modalities at the time of an experience, and reactivating these different modalities at a later time when required (e.g., Decety and Grèzes, 2006). However, it should be noted that in Experiment 6 that our measure of haptic experience (using the time participants spent holding the objects) did not significantly influence the memories once the influence of task instructions had been accounted for. Thus, there may be other factors involved beyond simply the extraction of information from touch, and thus the exact means by which manipulation influences representation remain to be investigated.

Our findings would seem to suggest neither Glenberg's nor Wilson's account is entirely accurate when describing how action influences the memory representation, but that the best description of the involvement of action in memory is one that lies somewhere in between the two extremes. The present thesis demonstrates not only that we can form memories biased by a task, but that simple manipulation can also influence the memory formation: although this too is flexible, as memory for manipulated objects is not as accurate as memory for the truly task-relevant items. However, despite these biases, we will acquire and maintain information incidentally, despite the fact it is not directly relevant to the situation. This gives our cognitive system a large amount of flexibility when we need to successfully interact with the external environment.

8.3.3 Implications for our understanding of properties contained in object representations. Object properties were used in this thesis as both cues to act and measures of memory, due to the previous work demonstrating that they are held relatively independently in memory, and may be classed as particularly action or visually relevant. These factors allowed us to use them as indicators of weighting in memory.

For the first of these two factors (the independence of properties), the studies presented here were not designed to specifically test this claim. However, the results obtained from the experiments do provide further support for this idea. Experiments 1.1 and 1.2 demonstrated how attention to a particular property could lead to different effects on the resulting responses, while in Experiments 2-6, different patterns of memory were found across the individual properties. These findings therefore agree with earlier studies which demonstrate the separate nature of properties (e.g., Tatler et al., 2003), and accounts of memory which suggest that the separateness of properties is a key aspect (e.g., Brady et al., 2011).

For the second factor, regarding how to group object properties, our findings suggest that the view of properties as belonging strongly to one group or another may not be so accurate. Experiment 2.1 considered whether certain properties were regarded as more or less action/visually relevant by asking participants to class them accordingly, and fairly consistent results emerged in this study. However, this is a very qualitative measure, and when considering the results obtained in the later experimental studies, it seems that the task setting may be a stronger influence on whether an object property is considered particularly action-relevant.

While accounts such as Glover's (2004) suggested a more rigid classification of properties (spatial or non-spatial in this case), Jeannerod (1994; 1997) proposed that properties could better be considered as falling on a continuum between visual and active. Certain properties are always strongly on one side of the line (colour is always visual, weight always active), but other properties such as shape are positioned somewhere in the middle, possessing both action and visual aspects. This is a more flexible way of classifying properties, and the findings of the present studies show evidence which agrees with this account. For example, in the only lab-based study to show effects of memory (Experiment 3), the only influence of the manipulation was facilitated recall of position information. In this situation, position is particularly useful: if interaction with the objects may be required in the future (as might have been implied by the requirement for participants to form postures at recall), then recalling where the relevant ones (i.e., those that matched the retrieval grip posture) are located is important in facilitating the potential future action. In contrast, shape was not particularly well recalled in this study, suggesting that, in this situation, it is not particularly action-relevant, perhaps because this is information which could be gained by simply fixating the objects if there is a future interaction or perhaps simply because the photographic stimuli suggests there will be no later interaction, and so shape is simply considered less necessary. These findings are in contrast to those of Experiment 6, in which position memory remains unaffected by the nature of the task, but shape is quite clearly influenced. Here, where there is interaction taking place, shape becomes more important, informing that interaction and the use of the objects. The link between shape and actions has been demonstrated previously, not only in affordance studies suggesting that the perception of the property can speed responses (Tipper et al., 2006), but in investigations that have focused on the specific aspects of preparing to act with an object, such as the preparation of the correct grip aperture. As participants reach to grasp target objects, the influence of the target's shape is seen around halfway through the process, influencing the hand configuration that is adopted for the upcoming interaction (Santello and Soechting, 1998). Without this shape information, the time taken to reach the object is increased and the aperture formed less precise to the object (Churchill, Hopkins, Ronnqvuist and Vogt, 2000). The property of shape seems therefore to be closely linked to interactions, and can not only influence (as in studies examining grip aperture) but also be influenced, as demonstrated in our own Experiment 6, where shape memory benefits from interaction.

Position, or at least the starting position of the objects, is much less relevant in this situation. The items have been found and usually moved to another place by the end of the task and so their position is no longer a concern. Indeed, even if there were to be future interaction, the starting position is, for most items, no longer current or useful information. However, for this point we must also consider the finding from Tatler et al. (2013), where the task-relevance of the objects was associated with increased recall of their position. Given that the memory test followed the completion of the task, as it did in Experiment 6, the maintenance of this property information is unexpected. Such a difference may be attributable to differences in the two studies used, as considered in the discussion of Experiment 6, but this is an area to be further explored, in order to clarify if there are conditions which will change the way this particular property is maintained.

The finding that manipulation and task-relevance contribute separately to the construction of memory representations also provides us with further insight into the weighting of properties within these representations. This is particularly so for the property of shape: recall is improved both by manipulation and task-relevance, but, importantly, not to the same extent. Property weighting, it seems, is not an 'all-or-nothing' occurrence, but one which allows the context of the task to have some influence. The present thesis therefore extends our understanding of object properties, and their role in memory representations. Properties are a key part of memory formation, maintained in such a way that task influences will bias their presence, allowing for weighting to occur. While object properties may be more commonly associated with visual or active roles, we suggest that such classification and biasing may be as flexible as the construction of the representation. By teasing apart the contributions of task-relevance and manipulation, we demonstrate that this weighting is sensitive. Properties are not simply ‘weighted’ or ‘not weighted’: rather, there is a continuous degree of bias, indicating sensitivity to the demands of the task and the importance of the object within it.

8.3.4 The influence of realism. Throughout the studies presented in this thesis, there has been a gradual increase in the realism of the settings. While the means by which this was achieved have differed, the results of the studies suggest that realism is an important factor for all the experiments. For Experiment 1.1, it is the more complex layout that shows the affordance effects being influenced by the boundary conditions, whereas such effects disappear when the number of items is reduced. Similarly, there are changes even between the results from Experiments 2.2-4, which use images of real world scenes, and 5, which uses a very similar paradigm, but in a real environment. Participants in the real environment (Experiment 5) were better at recalling all properties than those who viewed images (Experiment 2.2), rather than showing any kind of bias, in line with the earlier findings of Tatler et al. (2005) which similarly showed improved memory for object properties when they were viewed in a real world setting. The differences, particularly in the emergence of weighting are at their most notable between the lab based studies of Chapters 3-4, and the real world, real task version of Chapter 7.

The realism of a situation is important to consider across many types of investigation, but it seems to be particularly important when addressing action. Following the ideas of grounded cognition, expressed by Bridgeman and Tseng (2011), our cognitive and perceptual systems are there to help us act in the real world, in which tasks and interaction are key parts of our daily routine. Not only have these processes been developed for action, they have developed for action performed within these types of environment, where there is a clear task set and an end goal, and memory is a more incidental influence that we are not otherwise consciously aware of, rather than the final goal itself.

Lab based studies are still necessary, allowing us to reduce down to smaller and easily controlled chunks the aspects we wish to investigate. The results obtained from such studies are also necessary to drive the design of later studies, and provide useful evidence in their own right. However, it is clear from the findings presented here that quite different responses can be obtained from studies conducted in different environments, and so it is necessary to have both accounts. In the current studies, memory seems to be formed differently across the experimental tasks, and it is only in the real world (Experiment 6) that we see the weighting procedures we might expect. It seems that the lab-based studies allow us to see how our cognitive system might operate in a more restricted environment, but studies set in the real world are necessary to determine how we operate every day. The current thesis illustrates this clearly with the changes that occur as complexity and realism increase. While, once again, it seems that our cognitive systems are flexible enough to cope with the situation in these lab studies, increasing realism allows the cognitive and perceptual processes to work as they should, and present a more accurate account of how we act.

8.4 Future Investigations

The findings from this thesis suggest several areas which would benefit from further investigation. These future research ideas are all related to the notion of examining the concept of boundary conditions more closely, for both the influence of perception on action, and the influence of action on perception. Through better understanding of the conditions in which effects emerge, we will be able to better understand how action and perception influence each other and under what conditions these influences can be studied.

Studies of affordance effects have already established a large number of boundary conditions, some of which we used in our own studies. However, the main new finding from Experiment 1, (as well as the possibility of weighting for off line affordances) is that complexity is an important issue. Given that realism seems to be important for the action influencing perception side of the loop, it is possible that this may also be an issue for affordance effects. Alternatively, it may simply be the number of objects in a scene, whether more or less realistic, which influence the way in which the conditions affect the emergence of affordances. Future research is necessary to tease this apart, determining whether increasing the complexity (via the number of items) or the realism (perhaps by transferring the task into a real world setting) will affect the responses in the same way, or separately.

Following our suggestion that there are situational factors which may act as boundary conditions for action influencing perception, there are several areas that require further examination to determine this. The aim of all such studies would be to determine at what point the simple preparation of action used in our own studies would be enough to influence not only the initial perception and viewing of a scene, but would also affect the memory of the items.

One issue considered is the necessity of including a task which would more specifically make certain objects relevant for future action. Such a change would make the study more in line with the search tasks of Fagioli et al. (2007) and others. Having only one target might be problematic for memory, so one option would be to have similar stimulus sets as in Experiments 2-5, with a task to find all the items which would be necessary for a particular task/ be found in a particular environment. Within this group would be items that were both power and precision compatible, while participants viewed the scenes while making one of the two grip postures. A subsequent memory task could then determine whether the set of task-relevant items that were also compatible with the grip would still be recalled more accurately than task-irrelevant items, or those that were incompatible with the grip.

Given the influence of realism demonstrated by Experiments 5 and 6, an important aspect to consider in future work is directly replicating the experiment in the real world (as in Experiment 5). However, with this version of the study, participants would be informed that there would be interaction with the objects in the future, after they had examined them with the task to locate items that would fit a particular category. Engelkamp (1997) used the performance of action phrases rather than object memory, but nevertheless demonstrated that if participants were intending to enact the phrase at test, then their recall was better than if they only intended to verbally recall the phrases. A conscious intention to act might also lead to improvements when recalling objects and their properties. In such a study, the memory test would be inserted between examination and interaction, allowing us to determine if there were influences that came from the knowledge that there would be a future requirement to act, a situation in which it is most likely that memory weighting would be a necessary process. This is in many ways similar to the studies of Droll and Hayhoe (2007) and Triesch et al. (2003) which demonstrated that participants maintain the information that are likely prove to be necessary for performing a later part of a task. Participants in this proposed study might show a similar strategy, by prioritising potentially important information gained prior to the investigation.

There are areas worth investigating following the findings of Experiment 6. This study reveals that not only is memory weighting apparent in the object representations after interaction, but that there is also flexibility in the system: even within the same task, different object types (e.g., task-relevant; task-irrelevant, but requiring interaction, and background) can be classified and their representations weighted for what is appropriate. What is of most interest is whether the biases formed in memory as a result of the interactions will continue to have an influence on how these objects are used and recalled.

A previous study (Tatler, 2001) examined memory by placing participants in an environment in which the lights would be switched off at intervals, and the participants were required to determine what they last remembered seeing. A future study for this area would be to borrow this particular paradigm, and have participants interrupted in their task at various stages. They would then be asked to recall the details of the objects in their environment, which would include some they had worked with, some they had planned to work with, and some which they might not yet have even fixated. A comparison of memory performance across the object types would allow us to see how the weighting worked during the actual execution of the task.

A second follow up study would examine how the weighted representations fared after the task was completed. It is important to determine how long the effect might last, and also what influence the weighted representation has on subsequent performances and memory. This is more difficult to test: for example, it would be possible to have participants re-perform a task after having been tested for the memory of the first go, but it is likely that the subsequent re-fixation on the objects would lead to a re-setting of the memory for the new trial, as the new information would be there in front of the participants (and they would very likely be alert to the possibility of a new memory test).

These ideas regarding the influence of memory weighting on later tasks could be further investigated to determine how well the weighted memory serves the participant, using, for example, techniques from false memory and misinformation studies. By introducing false memories, it would be possible to determine if the weighting protected memories, and for how long after the task was completed this might continue to work. Such a study would have links to ideas proposed by Maxcey-Richard and Hollingsworth (2013), which suggests that we can protect relevant information within visual working memory, allowing this prioritised information to be maintained. Unprotected information, that has been classed as irrelevant, is lost from memory. Using actions to bias particular objects and their features might lead to similar strategic prioritisation of this information, protecting it not only from decay, but from replacement by subsequent incorrect information.

Such studies would allow for the questions raised by the findings of this thesis to be further investigated, and perhaps provide further understanding of the processes involved in weighting memory for action.

8.5 Conclusions

The present thesis explored the contexts in which perception and action might interact to influence participants' memories of objects and their features. Both sides of the perception-action link were considered, first the influence of perception on the production of action, followed by investigations into the influence of action (both prepared and enacted) on the perception and recall of objects. The findings of these studies support the ideas of grounded cognition: that perception and action are more than just peripheral input/output devices to an internal processor, but that they are both central to our everyday interactions with the world. In particular, it was found that memory plays a part in this. Depending on the situation, relevant information can be stored and retrieved for later use. This may allow for actions to continue in a situation where the view is briefly occluded, but a response is still required; or be part of an on-going acquisition of information about objects and their properties, for use in upcoming tasks.

Furthermore, our findings demonstrate the efficiency of our cognitive processes. Across the tasks used in these studies, as the demands and instructions change, so does the way in which information is acquired and stored. In some cases, this is as might be expected, with the situational weighting of particular features and actions, in order to best aid the task. However, in other settings, it is the absence of weighting which is the adaptive response, allowing a wide range of information to be stored for whatever the next, currently unknown stage of a task may be. Our memory systems, like other cognitive and perceptual processes, have developed in order to best serve our need to act within an environment, and to deal with the changing demands of those environments.

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Appendices

Appendices 1A

Experiment 2.1: Example question sections for forced choice and free response questionnaires.

Questionnaire: Forced choice response

1. In what room would you most expect to find a HAMMER? Choose ONE of the four options.
   Garage Kitchen
   Bathroom Office
2. What do you think are the main uses of a HAMMER?
3. What properties (e.g., shape, colour) do you think are most appropriate to how a HAMMER looks? Choose as many options as you think are appropriate.
   Colour Shape
   Size Weight
   Handle orientation Object orientation
   Decorative patterns Texture
4. What properties (e.g., shape, colour) do you think are most appropriate to how a HAMMER is used? Choose as many options as you think are appropriate.
   Colour Shape
   Size Weight
   Handle orientation Object orientation
   Decorative patterns Texture
5. When we use objects, we can hold them in one of two different grips. In one, we hold the object with a PRECISION grip- holding the object between the thumb and fingertips. The other grip is a POWER grip- where the object is held using all the fingers against the palm of the hand.
   When using a HAMMER, which ONE of these two grip types do you think is appropriate?
   Power Precision

Questionnaire: Free response

1. In what room would you most expect to find a HAMMER?
2. What do you think are the main uses of a HAMMER?

3. What properties (e.g., shape, colour) do you think are most appropriate to how a HAMMER looks?
4. What properties (e.g., shape, colour) do you think are most appropriate to how a HAMMER is used?
5. When we use objects, we can hold them in one of two different grips. In one, we hold the object with a PRECISION grip- holding the object between the thumb and fingertips. The other grip is a POWER grip- where the object is held using all the fingers against the palm of the hand.

   When using a HAMMER, which ONE of these two grip types do you think is appropriate?

   Power   Precision

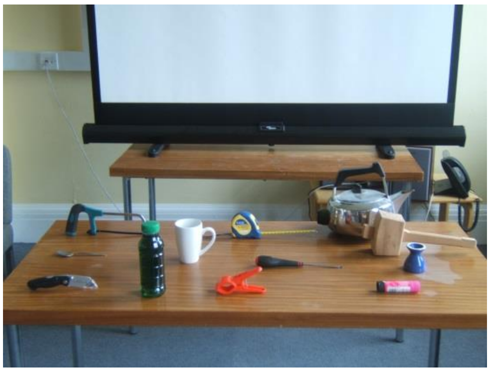
Appendices 1B

Experiment 2.2: Nine stimulus photos showing the three object groups positioned within each of the three background environments (garage, kitchen and neutral).

Object Set 1



Object Set 2

Object Set 3