QUANTIFYING THE EFFECTS OF CONTENT, COMPLEXITY AND DELAY ON MEMORY FOR REAL-WORLD IMAGES

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Quantifying the effects of content, complexity and delay on memory for real-world images

Abstract

"A picture speaks a thousand words", yet retrieval of a specific, previously viewed image from a large image collection may result in a substantial number of unwanted returns. This thesis offers an investigation into the feasibility of a novel solution to the retrieval of pictures. Rather than offering an alternative to current image retrieval strategies, research presented examines whether a novel approach, grounded in human cognition, can have specific benefits within specific contexts.

The HELM analytical model (Lansdale, 1998) was adapted to 8 experiments observing location memory for everyday pictures. Experiments 1 and 2 replicated some of the earlier work conducted by Lansdale, Oliff & Baguley (2005), and examined memory for location in a novel set of real-world images. Experiment 3 looked at the impact of image content on the distribution of errors in recall. Experiment 4 examined the effect of threat-victim relationships between objects on memory for location. Experiments 5 and 6 were concerned with the effects of object density within a scene. And Experiments 7 and 8 examined the effects of forgetting of spatial memories over periods of recall delay.

Data from these experiments demonstrated that memory for location in complex real-world images is prone to two types of error, near-miss errors which fall at locations neighbouring the target location, and far-miss errors which fall at locations distant to the correct location value. The presence of threat within an image resulted in participants foreshortening the estimation of space between two objects. Recall was shown to be more accurate for single-object over multiple-object images. And forgetting can be characterised as both a loss of the availability of location information in memory, and a spread of the distribution of error in recall. Findings are discussed in terms of the applied consequences for the design of query languages for image retrieval.

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Abbreviations

CBIR	Content based image retrieval
PI	Proactive interference
RI	Retroactive interference
AFC	Alternative forced choice
CA	Category adjustment (Huttenlocher, Hedges & Duncan, 1991)
HELM	Hybrid Encoding of Location Memory (Lansdale, 1998)
HELM2	Hybrid Encoding of Location Memory (modified)
SD	Standard deviation
RMS	Root-mean-square
RMS_c	Root-mean-square (corrected)

Chapter one: introduction

Abstract

Images are fundamental sources of primary data. In the present digital era, effective indexing and retrieval of images is of primary concern. A key consideration for database design is how comprehensively to capture and represent images in a manner which facilitates the effective retrieval of a desired image whilst at the same time minimises unwanted returns (Salton & McGill, 1983). Historically, image search and retrieval strategies have been dominated by keyword search and, more recently, content based image retrieval (CBIR). Yet each of these approaches are subject to their own unique limitations, including, but not limited to, the inability for users to easily retrieve a specific, previously viewed image from a large collection of pictures which are highly similar in content.

Based upon the understanding that user interactions with pictures form a richer descriptive language than current indexing and retrieval approaches, the information science community has drawn upon research within the field of cognitive psychology to inform image search strategies (O'Connor & O'Connor, 1999). Hybrid Encoding of Location Memory (HELM) is an analytical tool which offers a means of quantifying the accuracy of user's memories for the location of objects in previously viewed real-world images (Lansdale, 1998). The specific aim of research presented within this thesis is to investigate whether a psychologically motivated approach to image retrieval can have specific benefits within specific recall contexts. Through an examination of the accuracy of spatial information held in memory, subsequent experimental chapters address some of the theoretical and applied questions surrounding the feasibility of this approach.

1.1 The applied problem

An old saying holds that "*a picture speaks a thousand words*". This sentiment is supported by the highly consistent empirical finding that memory for pictures is superior to memory for words (Madigan, 1974; Pavio & Csapo, 1973; Shepard, 1967). Yet, despite the known capacity for images as fundamental sources of primary data, a rapid increase in digital image collections in recent years as a result of technological advances (Jörgensen, Jaimes, Benitez, & Chang, 2001; Seloff, 1990) have not been matched by corresponding advances in image retrieval strategies (Lansdale, Oliff, & Baguley, 2005; Smeulders, Worring, Santini, Gupta, & Jain, 2000). As a result, research interest into the problems associated with retrieval strategy design is on the increase (Enser, 2008). Kristen Grauman (2010) illustrates succinctly the level of importance given to adequate image cataloguing strategies when she writes,

> "If a tree falls in the forest and no one is there to hear it, does it make a sound? [For]…image retrieval, the question is: if an image is captured and recorded but no one is there to annotate it, does it ever again make an appearance?" (Grauman, 2010, p.84)

Approaches to image retrieval

Historically there are two main approaches which have attempted to address the issues of how adequately to capture and represent images in a way which effectively and efficiently aids image retrieval. The first is concentrated on the use of keywords and textual descriptors for database interrogation. There was a concern that keyword search would be highly ineffective and that inconsistencies in the use of keywords between users (Seloff, 1990) would result in failure to retrieve desired documents (Furnas, Landauer, Gomez, & Dumais, 1983). However, internet-based search engines such as Google Image provide evidence to show that keyword search is a user-friendly, cost-effective and widely adopted image search strategy. Nevertheless, the process of cataloguing large collections of images using a keyword index is labour intensive activity. A key unresolved issue with keyword search, however, is the semantic disconnect between words and visual content. Images can convey many concepts, any of which may be more or less significant to different viewers depending upon the context in which it appears, whereas words are, “human construct with precise intent” (Grauman, 2010, p.84). As such, keywords may provide an impoverished account of the rich and detailed visual information they intend to capture.

The computer science community offered an alternative retrieval approach based upon the composite features of an image. Content-based image retrieval (CBIR) systems formulate machine-interpretable descriptions of an image’s low level features such as colour and texture (see Jörgensen, 2003 for a review). These composite or *extracted features* are then used by CBIR systems as a query image for similarity comparison. The query image is compared with all images contained within the image database, and results are listed in order of decreasing similarity to the query image (Smith & Chang, 1997; Swain & Ballard, 1991). CBIR avoids issues of user inconsistency as the approach is based solely upon the image features. Nevertheless, where CBIR does falter is where a content-based description of an image can differ significantly from that of a human viewer's description. This is commonly referred to as the *semantic gap*,

> "…the lack of coincidence between the information that one can extract from the visual data and the interpretation that the same data have for a user in a given situation" (Smeulders, et al., 2000, p.1353).

Despite CBIR having been first explored in the 1980's (Chang & Fu, 1980), there has been no general breakthrough for large varied databases with images of varying sorts and characteristics to date (Müller & Gehrke, 2004). In a review of CBIR systems, Jörgensen argues,

> "the emphasis in the computer science literature has been largely on what is computationally possible, and not on discovering whether essential generic visual primitives can in fact facilitate image retrieval in 'realworld' applications" (Jörgensen, 2003, p.197)

Consider a real-world issue faced by one wishing to recall one particular image from a database of multiple images of the same content matter. The three images below all depict scenes within WWI trenches (Figure 1.1).

Figure 1.1: Three images depicting WWI trenches[1].

Each image is black and white, contains similar definable objects (soldiers, weapons, military clothing and ground) and depicts a similar non-confrontational trench activity. For these reasons, the three images are likely to be defined using similar keywords or extracted features. The retrieval of a specific WWI trench scene from a large database of similar images would require the manual processing of all returned images depicting similar scenarios. Yet visually, the properties of each image are distinct, with each picture varying in terms of its object density, composition and the spatial layout of the objects within the scene. Should it be possible to utilise the individual composite properties of an image within a search strategy, the number of retrievals may be substantially reduced, and this would in turn offer a more cost-effective search. As such, the research presented within this thesis does not aim to provide a method of image retrieval which supersedes current retrieval strategies. Instead, it is concerned with the investigation of whether a novel,

[1] Pictures shown are non-copyrighted images freely available via Google Image (www.google.com).

psychologically motivated approach to the retrieval of images can be of particular use in particular contexts.

The need for adequate technology to successfully handle large quantities of visual data is a current problem for a range of areas including, but not limited to, medical, architectural, and engineering domains (Enser, 2008). Lansdale, Scrivener & Woodcock, (1996) highlight an example of the applied need for the referral to images from previous patient record for medical prognosis requirements, for example, ophthalmologists who are required to examine a patient's retinal condition to form a diagnosis. In the majority of cases the examination will result in either a normal retina or a recognisable pathology. However, during some examinations the ophthalmologist will see a retina which is unusually abnormal and this may remind them of previous cases they have experienced. If the records of the patients who had shown these previous abnormalities could be accessed, they may prove useful in formulating a diagnosis in the present patient, yet the ophthalmologists' visual memory of the abnormality is unlikely to be accompanied by the names of those previous patients. Current systems have no way of using visual information regarding a previous image as a basis for a retrieval query. If a database were able to exploit ophthalmologists' memory for the visual details of a previously encountered pathology image, then the likelihood of accessing that particular record would be substantially increased.

1.2 Viewing and remembering images

When considering strategies to improve the retrieval of real-world images from collections, the relative information a given user has available regarding a to-be-retrieved image is fundamental to the relative success of the retrieval strategy. There have been two dominant theories within the literature regarding the nature of our stored visual representations. One holds that the visual system constructs a highly detailed visual representation of our surroundings (e.g. Marr, 1982). Another states that the representation of visual information in memory may be more sparse, or even abstract in nature (Dennett, 1991). Some even argue that internal representation are completely unwarranted as the visual world acts as a continuous external source of ‘outside memory’ (O'Regan, 1992; O'Regan & Noë, 2001). The most prominent view within the modern cognitive literature is that the visual system *does* hold visual detail in memory (Brady, Konkle, Alvarez, & Oliva, 2008; Castelhano & Henderson, 2005; Henderson, 2003; Hollingworth, 2005; Melcher, 2006; Tatler & Melcher, 2007), although exactly how detailed this information is, is still open to debate.

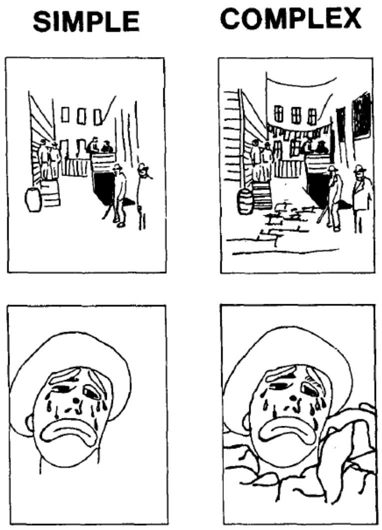
What do we remember about real-world images?

In the field of modern cognitive psychology, research into the nature of memory for images is still in its relative infancy. Following the technological revolution of WWII, previously dominant behaviourist approaches were suppressed and research into mental processes were once again at the forefront of psychologists agendas. Yet, during the 1950's and early 1960's, research concerned with the remembering and forgetting of information was dominated by highly artificial and carefully constructed stimuli, such as paired-associate learning of nonsense syllables or trigrams (Brown, 1958; Peterson & Peterson, 1959; B. J. Underwood, 1949, 1957). At this time, images were deemed too complex a stimulus to warrant rigorous exploration, they simply presented too many variables for which to control for.

Some of the earliest studies into memory for images during the 1960's and early 1970's involved picture recognition experiments. These experiments served to demonstrate an individual's immense capacity for long-term recognition of previously viewed scenes, often with very brief presentation times, (Nickerson, 1965; Shepard, 1967; Sperling, 1960; Standing, 1973; Standing, Conezio, & Haber, 1970). For example, Standing et al. (1970) presented participants with 2560 photographic images for a duration of 10 seconds each over the course of several days. When probed with a forced-choice recognition test, memory for all images was found to be over 90 percent correct. Yet by providing participants with a simple binary forced-choice (old or new) decision at recall, exactly what information participants have available to them in memory, and hence what information they use to assist with this binary judgement, is not clear.

Investigations into memory for pictures have been conducted using highly artificial stimuli, carefully constructed to support experimental design. For example, a study by Pezdek and colleagues examined picture memory for the recognition of added or deleted detail in simple and complex line drawings (Figure 1.2) [2].

Figure 1.2: Simple and complex line drawings used by Pezdek et al. (1988, p.469).



Findings suggested that memory for both types of image were comparable, although the authors concluded that added or deleted details were better detected in simple images, as these did not include, “elaborative details less essential for communicating the central schema of the picture”, which are, “represented in memory in a manner which makes them difficult to retrieve.” (Pedzek, Whetstone, Reynolds, Askari, & Dougherty, 1989, p.475).

[2] Image reproduced with the permission of K. Pezdek.

Due to the highly artificial nature of the images used within this study, it is not possible to relate these findings to memory for real-world pictures, especially considering that it had been discovered over a century prior that memory for photographs is superior to memory for line drawings (Loftus & Bell, 1975b; also, Tatler & Melcher, 2007).

Limits to human visual memory

Despite the rich and detailed nature of everyday visual experience, research has demonstrated that visual memory may not be as detailed as we would expect. Studies looking at the concept of change blindness (Henderson & Hollingworth, 1999, 2003; Hollingworth & Henderson, 2002b; Rensink, 2000c; Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1998), and inattentional blindness in real-world images (Mack & Rock, 1998; Rock, Linnett, Grant, & Mack, 1992; Simons & Chabris, 1999) suggest that people are insensitive to large changes applied during an eye movement (saccade) or visual disruption. For example, Simons and Levin (1998) demonstrated that 50 percent of people failed to notice that the person they were talking to was substituted by another individual during a brief visual disruption.

In contrast to the inability to detect change, the *boundary extension* effect offers an example of instances in which people remember seeing more than was available at scene viewing. Participants reproducing an image of partially displayed garbage cans often drew complete garbage cans at recall (Intraub & Richardson, 1989). Furthermore, people falsely report having seen books in an office where no books were present (Brewer & Treyens, 1981). These findings suggest that memory for visual details are not as complete as our perceptual system would suggest.

Looking at real-world scenes

Where we look when we view a visual scene will have substantial influence over what information we perceive, understand and subsequently remember (Findlay & Gilchrist, 2003). In recent years, a number of eye movement studies have been used to explore the nature of gaze control for viewing real-world scenes, typically in relation to visual search. Saccadic eye movements represent the visual system's overt attempts to focus the fovea on important parts of the visual world in a serial manner (Henderson, 1992). Historically, research in this area can be divided into two main schools of thought. First there are those who believe that deployment of gaze is directed by the low-level visual properties of an image or scene, generally referred to as the visual saliency hypothesis (Itti & Koch, 2000; Koch & Ullman, 1985; Parkhurst, Law, & Niebur, 2002). Second are those who suggest that higher-level cognitive factors (Henderson, Malcolm, & Schandl, 2009; Torralba, Oliva, Castelhano, & Henderson, 2006b) and task demands (Hayhoe & Ballard, 2005; Land & Hayhoe, 2001; Yarbus, 1967) are more influential in the deployment of attention.

The visual saliency hypothesis states that we look at images based upon image properties such as colour, intensity, and contour. For this reason, where we look is a direct reaction to the visual properties of the image or scene we are viewing (Itti & Koch, 2000). This hypothesis has been widely adopted by researchers, perhaps largely due to its integration into a saliency-based computational model (Itti & Koch, 2000; Koch & Ullman, 1985) which predicts that regions of high contrast are more likely to be fixated upon. Several studies have shown that individuals scan patterns for a given image are often very similar during the first few seconds of viewing (Buswell, 1935; Mackworth & Morandi, 1967; Noton & Stark, 1971; Tatler, Baddeley, & Gilchrist, 2005), suggesting that particular features within an image are likely to attract fixations.

It has been recently argued however, that for visual search of real-world scenes, saliency-based computational models are no better than random models at predicting eye movements (Henderson, Brockmole, Castelhano, & Mack, 2007). And studies have long suggested that bottom-up feature-based models of eye-guidance are inadequate for modelling eye movements where top-down task requirements are concerned (Hayhoe & Ballard, 2005; Yarbus, 1967). Early research conducted by Buswell (1935) demonstrated that uninformative areas of a scene rarely get fixated. Buswell showed his subjects a range of artworks, some depicting naturalistic scenes including complex buildings. Data revealed that rather than being random, fixation locations were relatively consistent among subjects and were concentrated on areas of detail such as objects rather than on the scene background. Work by Antes (1974) and Mackworth &

Morandi, (1967) also offered early evidence to suggest that a viewers' gaze will be quickly drawn to important aspects of visual scenes.

Previous research by Einhauser, Spain and Perona (2008) argue that 'interesting' objects (i.e. those frequently recalled) rather than low-level visual features such as saliency serve to guide human attention. Participants inspected photographs of common natural scenes whilst performing different tasks (artistic evaluation, analysis of content and visual search). Objects were shown to be better predictors of fixations than early saliency irrelevant of task. It should be noted however, that Einhauser, et al., (2008), and similar work by Elazary & Itti (2008) demonstrate a bias for objects chosen by participants as 'interesting' within a scene as being visually salient. Nevertheless, Elazary and Itti (2008) noted a number of responses in an object labelling task in which participants had labelled items which were 'out of place' within the image, such as a dog in an indoor party scene, suggesting that context may also play a critical role.

In 2006, Antonio Torralba and colleagues proposed a model of attentional guidance in real-world scenes based upon global scene context. The model combines bottom-up salience, scene context, and top-down mechanisms (specific task constraints) to predict which areas are likely to be fixated by people performing search tasks in real-world scenes. The model was shown to be able to predict human eye movements with high levels of agreement, suggesting that the component of 'scene context' provides the most explanatory power (Ehinger, Hidalgo-Sotelo, Torralba, & Oliva, 2009). Although the computational model was shown to substantially outperform models of pure saliency within this research, it was still unable to perform as well as the participants themselves (Torralba et al. 2006; Ehinger et al. 2009), suggesting that other factors may be involved in the deployment of attention across real-world scenes.

In a similar vein, the recently proposed cognitive relevance hypothesis (Henderson, et al., 2009) places primary emphasis on knowledge-based structures for the deployment of attention over images. Henderson and colleagues argue that objects within images are prioritised for attention and fixation based on cognitive knowledge structures interacting with task goals. In this model, potential fixation targets are ranked based upon their relevance to the task and the current scene understanding. In the model, the visual scene is parsed to generate a visuo-spatial landscape of potential object locations and their spatial layout. Saccade target rankings are then generated based upon cognitive relevance dependent upon the task. For example, if the viewer's task is to find a misplaced cell phone, potential objects in regions of space that are likely to contain the phone are ranked more highly than others (Henderson, et al., 2009).

What is encoded?

Ultimately, what we remember regarding a real-world image is inherently linked to where we look when we encounter that image. As such, it would be reasonable to assume that individual image properties will have effects on ensuing memories. It is therefore surprising that very few investigations into quantifying the accuracy of memory across real-world images exist within the vast literature to date. Although the majority of memory experiments concentrate on which items are remembered from scenes, little work has focused on which elements of those images are encoded. Rensink, O'Regan and Clark's (1997) study of change blindness demonstrated that participants failed to detect large changes in natural scenes which were made during grey screen masks. Yet, changes were more likely to be noticed when they included objects of "central interest". These "central interest" objects were defined as such in a norming study whereby participants wrote a sentence to describe the scene. These findings therefore suggest that some aspects of real-world scenes may be more likely to be encoded, and subsequently recalled, from memory.

Nevertheless, exactly what information is extracted from fixated regions or objects is still subject to some debate. Jones (1976) used stimulus delivered as discrete location elements (9 locations arranged on the basis of a 3 x 3 divide) to explore the nature of recall for colour photographs. Images consisted of everyday objects (e.g. a cup, a ball, a pair of scissors) presented in a simulated shop window, with left, right, and centre locations on three ascending steps. Each object had four components, the object identity, colour, spatial location and serial position in the presentation series. Memory for objects was then cued using one, two or three of these components. The fragmentation hypothesis which ensued from this work postulates that a memory trace corresponds to a fragment of a perceived situation, and that this fragment can be elicited by any one single cue. Providing multiple cues therefore adds no benefit to recall (Jones, 1976).

More recently, research by Tatler, Gilchrist and Rusted (2003) had subjects view natural scenes, which were then tested immediately in a 4AFC paradigm on either the presence of the items within the scene, their location, colour or shape. Data revealed better memory for all features as viewing times increased, yet the rate of improvement varied across individual features. Whereas memory for colour did not improve significantly after 5s viewing, memory for shape was still improving at a significant level after 10s viewing time. A finding which was replicated by Robinson & Triesch (2008) using novel real-world stimuli. As such, even when objects elicit attention, these findings suggests that different features of objects in natural scenes are encoded at varying degrees.

1.3 Memory for location

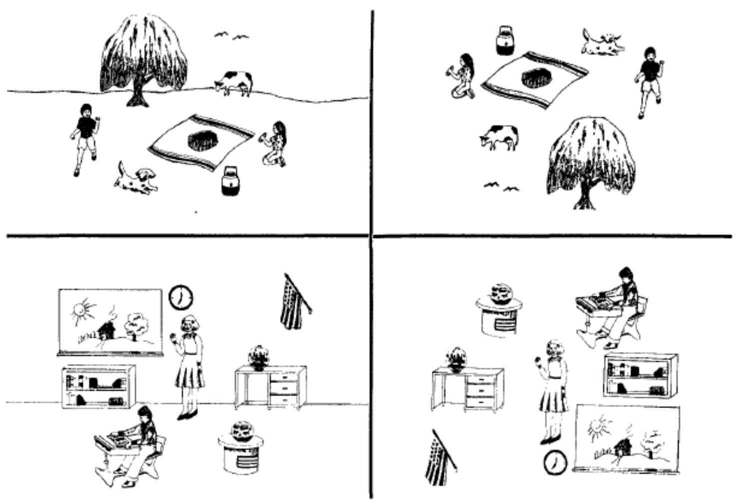
The study of spatial memory is broad and heterogeneous, ranging from object reconstruction experiments to spatial navigation processing. The research presented within this thesis will concentrate on a particular aspect of spatial memory, memory for cued target location of objects in previously viewed photographic real-world images. Previous research into quantifying object location has focused on two main issues, firstly how participants extract object location information from an image, and secondly, quantifying exactly what it is that they remember (Lansdale, 1998).

Memory for location in scenes

Experiments concerning estimates of object locations within scenes often categorise representations of space as either egocentric, where the position of objects are judged relative to the viewer, or allocentric frames of reference, where location judgements are relative to the locations of other items in the scene (e.g. Pani & Dupree, 1994). *Landmarks* or *anchor points* represent salient objects or features which can facilitate the allocentric encoding of location by serving as reference points from which spatial knowledge can be organised (Sadalla, Burroughs, & Staplin, 1980). It would therefore be expected that numerous landmarks or anchor points would strengthen the relative estimate of cued target object locations. Indeed there is a large body of evidence to support individuals' abilities to maintain multiple allocentric and egocentric reference frames (Burgess, Jefferey, & O'Keefe, 1999; Halligan, Fink, Marshall, & Vallar, 2003; McNamara, 2003; Wang, Johnson, & Zhang, 2001). Yet, when Thom Baguley and colleagues tested the dynamics of attempting to access two spatial memories simultaneously within images, findings demonstrated that two anchor points provided little or no benefit to recall. This suggests therefore these two allocentric representations of object location are exclusive at both encoding and retrieval (Baguley, Lansdale, Lines, & Parkin, 2006). Nevertheless, unlike the techniques used to elicit memory for images; stimuli used to test memory for location within images tend to be highly simplistic in nature. The stimuli used by Baguley, et al., (2006) described above for example used photographs of model military buildings, which were highly constructed to facilitate the experimental method. It is difficult therefore to extrapolate the findings of this study to natural images.

Research by Jean Mandler and Richard Parker (1976) used line drawings representing organised and unorganised indoor and outdoor scenes to investigate the types of information participants held in memory for pictures (Figure 1.3)[3]. After viewing, participants were asked to reconstruct the scene by placing objects on a blank page as they remembered them being arranged.

Figure 1.3: Examples of organised and unorganised versions of an indoor and an outdoor scene used by Mandler & Parker (1976, p.40).



[3] Image reproduced with the permission of J. Mandler.

Despite the simplistic nature of the stimuli used within this experiment, findings suggested superior object location recall for organised over disorganised scenes. Furthermore, following a period of delay, participants reconstructing disorganised scenes had a tendency to place the objects relative to typical scene organisational properties. This suggests that they may have been adopting schematic information regarding the nature of typical scenes over and above stored representations of the specific pictures viewed. Memory for object identities did not differ across scene type, but was greater for immediate over delayed recall (forgetting was occurring over time). Each of the three dimensions of appearance, size and orientation information declined in equal amounts over the one week delay period. The study also revealed that decline in levels of identity information for participants who were tested twice (both immediately and following a one week delay) was reduced, which may indicate that “recall of recall” was taking place at the second recall phase (J. M Mandler & Parker, 1976, p.46).

In a more recent exploration of memory for location, Irwin & Zelinsky presented subjects with an array of seven objects superimposed onto a baby’s cot (Figure 1.4). When cued with a location probe immediately after stimuli offset, participants were able to identify which object had appeared at the probe location with relatively high accuracy (78%) despite short viewing times (either 1-5 or 3-15 fixations).

Figure 1.4: Greyscale reproduction of one of the scenes used by Irwin & Zelinsky (2002, p.884) [4].

It should be noted however that each of the participants completed 147 trials immediately after stimulus offset, with the same objects consistently bound to the same 7 target locations (Irwin & Zelinsky, 2002). This implies that the highly accurate finding may be confounded by practice effects, and should therefore be interpreted with some caution.

Bias in memory for location

The category adjustment (CA) model (Huttenlocher, Hedges, & Duncan, 1991) proposes that individuals judge the location of a dot within a circle relative to fine-grain item information, and category-level imagined boundaries. Greater weight is given to the category-level information which results in biased responses. Data revealed that subjects

[4] Image reproduced with the permission of D. Irwin.

spontaneously impose horizontal and vertical divides to the circle into quadrants, and misplace the dot towards central locations in each quadrant. Further research applying the CA model to real-world scenes suggests that category-level information is also utilised in complex images, although upside-down images and images which had no colour cues (negative versions) provided alternative patterns of location recall error. The authors conclude that semantic information is also involved in the segmentation process for visually complex scenes (Holden, Curby, Newcombe, & Shipley, 2010). In addition, a central bias has been noted in a number of studies which cue recall for properties presented on a continuum (Jones, 1976; Lansdale, 1998; Tversky & Schiano, 1989). For the case of visual memory, this may be inherently linked to a central fixation bias, which has been noted for scenes viewed on computer monitors (see Tatler, 2007 for a review).

Despite a relatively large body of literature surrounding memory for location, the fact remains that the majority of research in this area has been conducted with simple stimuli (Lansdale, et al., 2005). The inherent problem with using highly constructed stimuli is that memory for location may become confounded by categorical factors inherent within these highly symmetrical, regimented images (Huttenlocher, et al., 1991; B. Tversky & Schiano, 1989). Although simple experimental approaches are necessary in to isolate component cognitive processes involved in visual memory, Hollingworth (2009) argues that the nature of simplistic experiments tell us very little about how cognitive processes are combined to accommodate the complexity of real-world perception, encoding and memory.

The neuropsychological basis of location memory

Object location memory is an important form of spatial memory, comprising of different subcomponents which each deal with different types of stored representation. First there is the memory trace associated with the object itself, second is the object position, and third the binding of these features within memory.

The neural basis of object location memory encoding (trace formation), storage, and retrieval is complex and involves multiple brain regions. Two brain areas in particular have been implicated as particularly important for object location binding. These are the medial temporal lobes (in particular the hippocampus) and the posterior parietal cortex. The hippocampus plays an essential role in binding different features within memory, such as object and location information (Crane & Milner, 2005; Piekema, Kessels, Mars, Petersson, & Fernández, 2006), whereas the parietal cortex plays an important role in remembering the relation between objects and their locations, (Kessels, Kappelle, De Haan, & Postma, 2002; Sommer, Rose, Weiller, & Büchel, 2005). In addition, the parahippocampal gyrus has also been shown to contribute to the processing of spatial information (Epstein, Graham, & Downing, 2003) and in the coding of object-location associations (Duzel et al., 2003). Successful learning of object-location associations have been shown to be related to the effective connectivity between these two areas (Buchel, Coull, & Friston, 1999). However, Cansino and colleagues also showed that successful retrieval of the locations of objects correlated with activation of areas which are also involved in object recognition (fusiform gyrus and the lateral occipital complex) suggesting that these systems may in fact work together to formulate object-location associations (Cansino, Maquet, Dolan, & Rugg, 2002).

Both physiological (O'Keefe & Dostrovsky, 1971) and behavioural (Morris, Garrud, Rawlins, & O'Keefe, 1982) studies in rats established a prevalent role for the hippocampus in spatial cognition, primarily the formation of a ‘cognitive map’ for spatial navigation purposes (O'Keefe & Nadel, 1978). Studies of epileptic patients who have undergone brain surgery suggest that lesions of the right temporal-lobe which encroach substantially upon the hippocampal and parahippocampal gyrus impair delayed, but not immediate, recall of object locations from within a random array (Zelinsky & Loschky, 2005). This has been shown with a variety of simple and complex tasks such as recalling the position of a point on a line (Corsi, 1972; Rains & Milner, 1994) to visual (Zelinsky & Loschky, 2005) and tactual (Corkin, 1965) maze learning. Furthermore, Milner, Johnsrude & Crane, (1997) used positron emission tomography (PET) and magnetic resonance imaging (MRI) to study blood-flow activation to pinpoint the specific brain regions concerned with object-place associations in human subjects. Findings highlighted a contribution from the anterior part of the right parahippocampal gyrus (entorhinal cortex). Data suggested a strong hemispheric asymmetry in the storage processes underpinning memory for object locations, where legions of the right, but not the left medial temporal lobe impaired delayed recall for the location of real objects in an array.

The availability of attentional resources (Baddeley, Lewis, Eldridge, & Thomson, 1984) and the level of processing of information (Craik & Lockheart, 1972) have both been identified as factors which influence the amount of associated contextual information (including spatial information) encoded with an item (Java, Gregg, & Gardiner, 1997; Kensinger, Clarke, & Corkin, 2003; Yonelinas, 2001). In 2005, Sommer and colleagues demonstrated that the degree of neural activity within the superior parietal lobe and parahippocampus during encoding reflect the level of processing of the spatial information of items in memory, which in turn lead to varying degrees of recognition performance (Sommer, et al., 2005). Thus, the literature suggests that it is the interplay between object and object location memory trace formation, together with the degree of neural activity during encoding all combine to impact upon memory for objects and their locations at recall.

1.4 Location memory as the applied solution?

The last fifteen years has seen a substantial growth in research for memory for visual information. Using the search term ‘visual memory’, 15,917 of a total 22,409 articles returned from a search of the Pubmed database were published since 1995 (almost 67%). Furthermore, a recent publication entitled *The Visual World in Memory*, (Brockmole, (Ed), 2009), serves to highlight a huge diversity of research within the field. Topics covered range from visual memory in motor planning and action, to spatial navigation, to memory for faces. Although each of these research topics can be broadly categorised under the umbrella term of 'The Visual World in Memory', each of the specific areas of investigation are unique in approach and research focus. To make an analogy, this is like saying than both biscuits and lobster can be grouped together as 'things which can be eaten', which although true, tells us little about the individual properties of each.

In striking contrast to the substantial body of research into visual memory, surprisingly, some of the fundamental questions regarding how people encode and recall real-world images still remain untested. For example, just how accurate is location memory for objects within real-world images? Does the relative complexity of a real-world image have an effect on recall for location? What effects (if any) do inter-object relationships and semantic inferences have on the accuracy of recall? And how is memory for real-world images forgotten? Research looking at techniques to quantify the accuracy of recall for real-world images simply hasn't been undertaken. Undoubtedly this poses a substantial void in our understanding of human memory for images, which if investigated in detail, may prove useful insights into the use of memory processes for practical applications. By looking at a particular aspect of memory for real-world scenes, such as location, is it possible to address some of these key voids in the literature to inform applied issues in image database design? Concerns highlighted by Ulrich Neisser (1978) resulted in his proposal of the following rule,

> "If *X* is an interesting or socially significant aspect of memory, then psychologists have hardly ever studied *X*" (Neisser, 1978, p.4).

In recent years, a substantial amount of research in the subject area of information technology has gone into the development of image database retrieval strategies (Enser, 2008). One particular line of enquiry has been to assess the applicability of human cognitive factors as a means of eliciting richer description of images to facilitate indexing and retrieval (O'Connor & O'Connor, 1999). Such research has explored participants' functional descriptions of pictures and found that descriptions could be categorised into three broad categories, 1. Narrative & Emotive Descriptors (reminds me of...; looks like), 2. Antonyms (one person may describe an image as lovely, whereas another would call it depressing) and 3. Geography (many people felt compelled to try and locate where the image was taken). The levels of detail offered by viewers' responses to the images serve to highlight the many different ways in which people can interact with visual images. Yet by adding this layer of interaction and meaning, the richness of the data was shadowed by large amounts of variation between individuals responses, "users make wildly differing assessments of particular (image) documents” (O'Connor & O'Connor, 1999, p.19).

When considering strategies to assist with image database retrieval, the only factor which can be assured to remain entirely stable across users is the image itself. It naturally follows that the cognitive processes research should be focusing on are those which draw upon the intrinsic visual properties of a picture. One way in which to approach this line of enquiry is to exploit viewers’ stored representations of the visual properties of an image. The use of memory for locations as a retrieval strategy is an appealing opportunity when taking into account the fact that many retrieval attempts are likely to be for images which the user has previously encountered (Lansdale, et al., 2005). It is therefore likely the user will have some form of memory for that image. Previous research suggests that memory for location captures information regarding the distinctiveness and meaning of an image (Baguley & Lansdale, 2000; M. W. Lansdale, et al., 1996). Furthermore, it has been demonstrated that the cognitive cost of encoding location information is low (Hasher & Zacks, 1979), and early attempts to utilise spatial memory as a strategy for retrieval have offered significantly higher levels of user satisfaction than a textual search strategy, “My query was an accurate representation of the type of image(s) I had in mind” (Jose, Furner, & Harper, 1998, p.5).

There are however a number of known difficulties in applying knowledge of location memory to database retrieval. Firstly, memory for object location is often imprecise. This means that a priori knowledge of the parameters of uncertainty must be established before location memory can be exploited for use in picture database retrieval strategies. It has long been recognised that the errors made by participants in their (immediate or delayed) recall of a stimulus presented on a continuous dimension are often near miss errors, clustered around the target value (Detterman, 1977; Jones, 1976; Lansdale, 1998; Lee & Estes, 1977b; Nairne, 1991; Toglia & Kimble, 1976). These near miss errors can be assumed to reflect imprecise information about location in memory (Lansdale, 1998), although many attempts to model human memory have repeatedly failed to consider the importance of such information (Jones, 1976; Raaijmakers & Shiffrin, 1981; Ross & Bower, 1981). It is therefore important to consider the nature of the spatial representations a user may have for a given real-world image. For example, representations may be exact, 'the tree was in the middle of the picture', yet it is more likely that memories for the locations of objects are inexact, for example approximations, 'the tree was to the right of the picture' or relative to other objects in the scene, 'the tree was to the left of the house'.

The second important consideration is that memory for location can be affected by image-specific features (Goldstein & Chance, 1970; Mandler & Johnson, 1976), which may in turn lead to issues in the generalisability of this approach. It is not well understood how individual picture composition or complexity may affect memory for object location for real-world pictures (Lansdale, et al., 2005), and further investigation is required to specifically address this issue.

A third consideration is that all the research to date concerned with quantifying location memory in real-world images has been confined to immediate recall. There have been no investigations of what happens to the availability of location memories following periods of delay. This is a critical issue when considering the applicability of location memory as a query language for image databases as a successful query language would need to be robust and remain accessible over time to render it useful.

Hybrid Encoding of Location Memory (HELM; Lansdale, 1998)

Experiments presented within this thesis seek to examine the accuracy of recall for a range previously viewed real-world images using a psychologically motivated analysis technique. Unlike previous attempts measuring recall for location, the present research is less concerned with location judgements being right or wrong, but instead is focused on *how* right or wrong memory for location in real-world pictures is.

HELM, standing for Hybrid Encoding of Location Memory (Lansdale, 1998) is a novel analytical tool designed to combine key psychological processes to model memory for location. Previous tests of the model for data elicited from cued recall of location in real-world image has resulted in consistently significant model fits (Lansdale, et al., 2005). The key benefit of this model is that it considers that memory for location (as with many stimulus dimensions presented on a continuum) is often imprecise, and therefore it accounts for the distribution of errors which may fall onto several response locations both on and around the correct location value. HELM accounts for such inexact recalls using two separate parameters, first is the probability that encoding has occurred and that there is an available memory regarding location (Availability, termed *A*), and a second parameter quantifies how tightly inexact recalls are clustered around the correct location value (Precision, termed λ). The purpose of the HELM model is to extract the most parsimonious account of the behavioural location memory data in order to quantify the state of memory which produced it. The way in which analysis is approached within this thesis allows me to see how few free parameters are required to provide a non-significant account of the data observed. Full details of the HELM analytical approach are presented within Chapter 2 (philosophy of approach and general methods).

1.5 Thesis overview

Within this thesis, I cast a wide net with regards to areas for investigation. This might be expected when considering the lack of research concerned with the accuracy of recall for natural stimuli. Through the use of discrete stimuli distinction of location, the present research aims to address some of the substantial voids in the literature with regards to how people remember real-world pictures. The experiments presented are empirical in nature, devoid of presupposed theoretical constraints. Instead, the data serve to inform us about the nature of location memory for real-world images across a range of real-world stimuli and conditions.

The structure of this thesis is as follows. First, I offer an overview of the methods and analytical techniques pertaining to the majority of experiments to be presented in subsequent chapters. This provides a detailed overview of the philosophy of approach adopted, and provides some key information regarding the methods employed for clarity later in the thesis. Second, I present two experiments which replicate previous work into the application of HELM to location memory for real-world images (Lansdale, et al., 2005), this is a cursory step to make direct links with the previous research and to investigate the applicability of the HELM approach to a novel set of complex stimuli. Next, although it is well documented that memory for location can be affected by image-specific features (Goldstein & Chance, 1970; Lansdale, et al., 2005; J. M Mandler & Johnson, 1976), little work has been done to explore the effects of image content and image complexity on the accuracy of visual recall. For this reason, subsequent experimental chapters seek to investigate memory for location relative to factors of individual image properties pertinent to the design of large scale images databases. Finally I explore the applied issue of forgetting in location memory in terms of quantifying what information is retained in memory over time. The findings are discussed relative to the feasibility of exploiting memory for location to inform storage and retrieval of real-world pictures.

Chapter two: philosophy of approach and general methods

Abstract

Experiments presented within this thesis share analogous methodologies and analysis techniques. The present chapter provides a detailed overview of the philosophy of approach and general methods adopted within this thesis for purposes of brevity and clarity in subsequent chapters.

The experiments to follow are designed to enable the quantification of error in the recall of cued object locations in real-worlds images over a range of manipulations relevant to the design of picture databases. Stimulus selection was based upon the methods of Lansdale et al. (2005) consisting of pictures from newspapers and image search engines on the world wide web. Images vary in levels of complexity (image density) and semantic content. Memory for location was tested for each image using cued recall for objects which appear in one of nine equally spaced locations along the horizontal axis. The use of stimuli dimensions defined as discrete elements such as location naturally lead to analyses techniques based upon a traditional psychological method of the confusion matrix (e.g. Jones, 1976).

Accuracy of recall is indicated using the route-mean-square distance of responses relative to the correct location value. HELM (Lansdale, 1998) is used to model the confusion matrix and estimate the most likely state of memory that produced the data. Through a cyclical process of model constraint, conclusions can be drawn as to how many free parameters are necessary to provide non-significantly different model predictions of the observed data. An overview of the stimuli and materials, as well as a glossary of the terms to be used in subsequent chapters is presented.

2.1 Introduction

The experiments presented within this thesis test cued-recall for the location of objects in real-world images. The nature of the present research predisposes experiments to analogous designs, methodologies and methods of data analysis and interpretation. For this reason, the purpose of the present chapter is to provide an overview of the stimuli, methods and analyses which form the basis of the experiments presented in subsequent chapters.

The present chapter is divided into four subsequent sections. Section 2.2 outlines the process of stimulus selection and development, as well as outlining the core experimental design. Section 2.3 then offers an overview of the analytical methodologies adopted for the data generated in subsequent experiments. The next section (2.4) outlines the general methods and procedure to be adopted in subsequent experimental chapters. Finally, section 2.5 provides a glossary of terms pertinent to the analyses adopted within this thesis.

2.2 Stimuli selection and experimental design

For the purposes of the present research, three different sets of stimuli were developed:

Set A: 27 *complex* real-world scenes (containing multiple definable objects in foreground and background)

Set B: 27 *simple* real-world scenes (containing one definable object and a minimal background).

Set C: 18 real-world scenes depicting *neutral* (9) and *threat* (9) relationships between two objects.

Images for stimuli set A were sourced from national newspapers and scanned to form electronic images (Appendix 1). Images for set B (Appendix 2) and C (Appendix 3) were all non-copy written images freely available via the internet (sourced from either www.google.com or www.bing.com). Example images from each stimulus set are presented in Figures 2.1 - 2.4.

Image selection

In order to ensure that recall for *real-world* images was taking place; searches were conducted for photographs of semantically coherent real-world environments. For stimuli set A, images contained multiple discrete objects arranged in a spatially coherent manner. For stimuli set B, images were photographs of single objects residing in a natural, yet relatively simplistic, background. For stimuli set C, images consisted of pairs of photographs, each containing two objects which portrayed either a neutral (e.g. surfer-surfer) or threat (e.g. surfer-shark) relationship. Images for stimuli set C were particularly difficult to locate, and as such, a number of images were manipulated using Adobe Photoshop CS2 to ensure spatially matched (threat and neutral inter-object relationship) counterpart images.

Figure 2.1: Exemplar image from stimuli set A: Complex real-world image entitled *Training.*

Image removed due to copyright restrictions

Figure 2.2: Exemplar image from stimuli set B: Simple real-world image entitled *Dog on Beach.*

Image removed due to copyright restrictions

Figure 2.3. Exemplar image pair from stimuli set C entitled *Matador*[5].

Neutral condition

Image removed due to copyright restrictions

Threat condition

Image removed due to copyright restrictions

[5]Objects within these image pairs appear at the same discrete locations along the horizontal axis. Images portray either neutral (top) or threat (bottom) relationships between the two objects

Aspect ratio

The first stage in the development of the stimuli was to ensure that each image assumed the same aspect ratio (1152 x 768 pixels). Images which were identified as potentially suitable, but did not conform exactly to the required size, were either cropped or transformed using Adobe Photoshop CS2 software. Images which deviated substantially from the required picture size were disregarded to ensure that there were no distortions of image clarity or image integrity introduced as a result of size transformations.

Discriminable real-world scenes

Images within stimuli sets A & B were given a unique title which directly related to the content subject matter. Each image was clearly discriminable from the others as to allow memory of a previously viewed image to be elicited by title alone.

Definable objects

For the purposes of examining location memory, the horizontal axis of each stimulus was divided into 9 equally spaced columns. If the selected target object within a given image did not fall within a target location, the images were cropped or resized to ensure an accurate fit (whilst still conforming to the aspect ratio of 1152 x 768 pixels). Care was taken to ensure that each of the nine locations was occupied by target items three times over the total 27 images (see example in Figure 2.4 below).

Figure 2.4: Exemplar image from stimuli set A entitled *Army Cadets* displaying the 9 categorical location distinctions (L1-L9) on the horizontal array and the target object location (washing up liquid at location L4)[6].

Inter-object relationships

For stimuli set C, 9 pairs of images were sourced. One of the images from each set depicted a neutral relationship between two items within the image (neutral stimuli) whereas the spatially matched counterpart image (threat stimuli) depicted a threat relationship (see Figure 2.5). Care was taken to ensure that the distances between objects were varied, and objects always demonstrated a minimum of 1 location space between the locations they occupied (maximum 5). Objects were avoided at the periphery locations (L1 and L9) due to a tendency for participants not to respond at these locations (see discussion within Chapter 3).

[6] Target object for this image is the washing up liquid bottle. Location **L4** denotes target object location. The location distinction grid was used for analysis purposes only and was not made available to participants.

Threat stimuli

Nine images were selected from non copyright images available in the public domain (a web search of Google image) on the basis of containing two separate identifiable objects occupying varying distances between each other on the horizontal axis. One of these objects represented a 'threat' object (for example, a shark) and the 'victim' object (a surfer). These images were then re-sized using Adobe Photoshop CS2 to gain a common size for all stimuli (1152 x 768 pixels) and to ensure that each of the objects occupied one of the target locations (between L1-L9 on the horizontal axis) with a distance between the two objects of at least one location (e.g. 'threat' at L3, 'victim' at L5).

Neutral stimuli

Nine neutral counterpart images were sourced, again using a search of non-copyright images available in the public domain (Google image search). These images were closely matched for content to the threat stimuli, but demonstrated a neutral relationship between the two objects within the scene (for example, the neutral counterpart image for the shark-surfer image contained two surfers). Each of the neutral counterpart images were then re-sized using Adobe Photoshop CS2 to ensure they matched the 1152 x 768 pixel size of the threat images, and care was taken to edit the images so that the objects occupied the same target locations (between L1-L9 on the horizontal axis) as the objects within the counterpart image[7].

[7] It is important to note that due to the experimental design, not all locations were represented by target objects in Experiments 4a and 4b. More importantly for the purposes of the present research, care was taken to ensure

Figure 2.5: Exemplar image pair from stimuli set C entitled *Surfing*[8].

Neutral condition

Threat condition

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a range of location distances between the two objects in an image were represented (location distances between objects in images ranged from 2 to 6 location segments).

[8] Images highlight the concordance in discrete object locations for both neutral (top) and threat (bottom) conditions.

Verbal commentaries

Verbal descriptions were created for each of the images in Stimuli set A (complex real-world images), which offered the image title, followed by a short story regarding the scene or event depicted. Each verbal commentary was presented at image onset, and ended either prior to, or at image offset (≤ 20 seconds), minimum commentary duration = 15 seconds, maximum = 20 seconds, with a mean duration of 17.48 seconds. Each of the commentaries served to draw the viewer's attention to the target object to be tested at recall for each of the stimuli. An example image and accompanying verbal commentary are presented in Figure 2.6. Verbal commentaries were constructed as to be comparable in nature to those used within previous research (Lansdale, et al., 2005), and described the content of the scene in each case. Commentaries were spoken in a clear male voice, and were recorded using a microphone connected to an iMac OS X, adjusted for equal volume using Audacity 1.2 (http://audacity.sourceforge.net/download/) audio editing software. Commentaries for all of the images in stimuli set A are presented within Appendix 6.

Verbal commentaries were presented to participants within Experiments 2 and 8 together with the images from stimuli set A using E-prime. Images resided on screen for 20s, and the verbal commentaries beginning immediately at image onset, and lasting ≤ 20s, minimum commentary duration = 15 seconds, maximum = 20 seconds, with a mean duration of 17.5 seconds.

Figure 2.6: Exemplar image from stimuli set A entitled ‘Camel Train’ together with accompanying verbal commentary. Target object for recall is the man on horseback at location L9.

Image removed due to copyright restrictions

Camel Train. For several months every year, traders from the Ethiopian Highlands make the arduous journey north in search of salt. The men load goods onto the camels, with the head camel carrying tents, grain and water. In this picture, ***one man*** *leads the camel train on horseback*.[9]

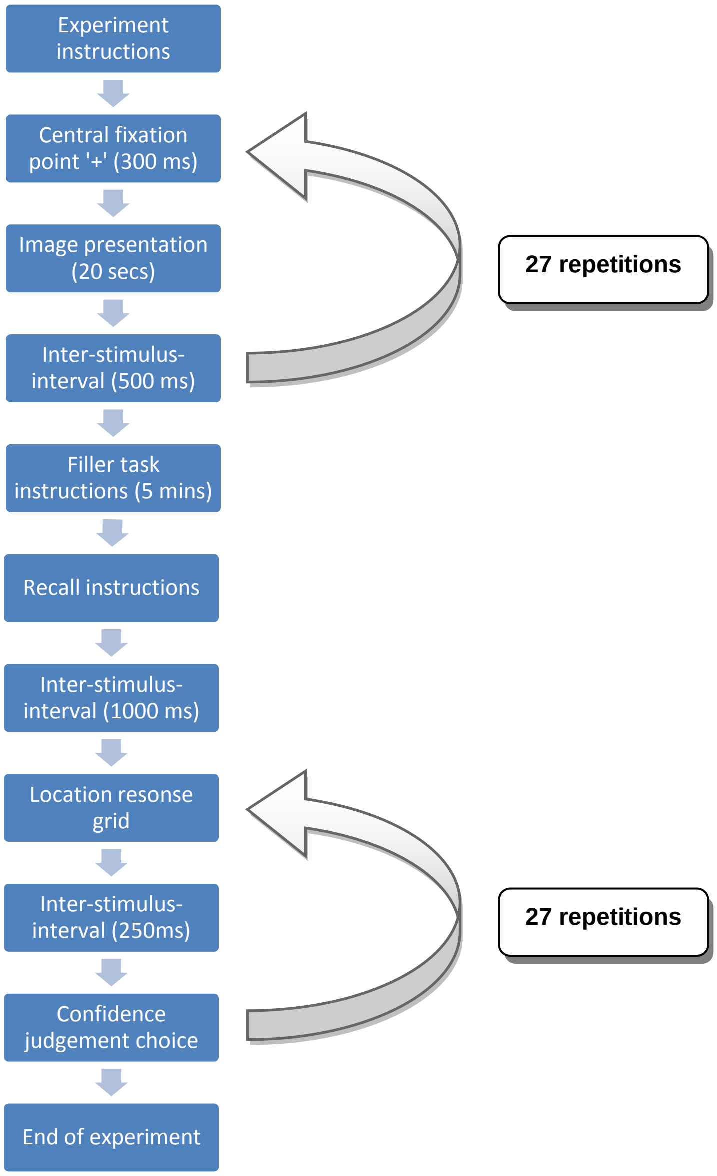
Experimental design

Stimuli were presented to participants using E-Prime v.1[10] (Psychology Software Tools Inc.). The software enabled stimuli to be presented to participants for stipulated time durations, and with fixed inter-stimulus-

[9] Target object is denoted by **bold** text. Verbal commentary = 19s (title duration = 2s, description duration = 17s)
[10] Although the release of E-Prime 2.0 took place during this research, it was decided not to transfer experiments over to this version as this offered no additional benefit for the experimental designs.

intervals, thus ensuring consistent presentation. A schematic example of the core experimental designs is shown in figure 2.7. Any variations from this core design are described in full within the methods sections of subsequent chapters.

Figure 2.7: Flow diagram outlining the core experimental procedure for experiments presented within subsequent chapters of the thesis[11].



[11] Where a process duration is not explicitly stated this was dependent upon participant input (mouse click), which was requested from participants within the instructions. Any deviation from the core experimental design will be outlined in detail within the following experimental chapters.

2.3 Analytical approaches

Confusion matrices

By subdividing the stimuli into discrete elements such as location, the ensuing recall data naturally lends itself to analyses in the form of confusion matrices (e.g. Jones, 1976). A confusion matrix conveys relationships between class prediction responses (rows) and observed responses (columns). Entries on the diagonal of the matrix count the correct responses, whereas entries off the diagonal count the misclassifications. Totals for each class are presented on the far right. For the purposes of the present research, confusion matrices serve to present cued recall data in terms of correct target location versus observed location response (Figure 2.8).

Table 2.1: Exemplar confusion matrix showing correct locations versus observed location responses for cued recall of target object locations in real-world images. Matrix shown is matrix A (Experiment 1) from research conducted by Lansdale, Oliff & Baguley, (2005)[12].

Response location

Correct location	L1	L2	L3	L4	L5	L6	L7	L8	L9	
L1	**16**	4	2	1	2	2	6	2	1	36
L2	0	**10**	14	9	1	0	0	2	0	36
L3	0	6	**14**	9	1	1	3	2	0	36
L4	0	0	17	**16**	2	1	0	0	0	36
L5	0	4	1	2	**22**	4	2	1	0	36
L6	0	0	0	0	0	**20**	16	0	0	36
L7	1	2	5	2	1	8	**14**	3	0	36
L8	0	1	0	0	5	11	13	**5**	1	36
L9	0	8	3	2	4	6	5	3	**5**	36
	17	35	56	41	38	53	59	18	7	

Presentation of location recall data in this format allows some basic conclusions to be drawn from the raw data prior to any theoretical input;

1. The largest frequencies of responses tend to fall on the correct location value (on the diagonal, as highlighted in bold) and indicate substantial levels of correct recall.

2. The second largest frequencies fall at locations around the correct value. An example can be seen for target location L3 (figure 2.8), where the matrix tells us that 14 responses fall on the correct

[12] Numbers in **bold** indicate correct location responses. Each column represents responses from thirty-six individual participants.

location value, and that the second and third most frequent responses fall at L2 (6) and L4 (9). Clusters of responses around the correct location value represent near-miss errors in recall. This is a phenomenon which has been frequently noted in the recall of a stimulus presented on a continuous dimension (Detterman, 1977; Jones, 1976; Lansdale, 1998; Lee & Estes, 1977a; Nairne, 1991; Toglia & Kimble, 1976), and can be assumed to reflect imprecise information regarding the correct continuum value in memory (Lansdale, 1998). This is a consistent trend across all location values (all rows).

3. There is bias against responding at the periphery of the array. Column totals, which represent the frequency to which locations are given as responses across all stimuli for all participants, are unequal. This demonstrates a bias against responding with location values at the periphery (Locations L1 and L9).

RMS_c as a measure of overall recall performance

An indication of overall performance for each target location can be highlighted from the confusion matrices by calculating the magnitude of variation in recall responses from the correct location value using the root-mean-square (RMS), which is the square root of the mean of the squares of the values. However, the range of possible responses is not consistent across all target locations. For example, target location L5 would accept deviations as large as four locations either side (to L1 or L9) whereas target location L8 would only allow for deviation to the left of one location (to L9). This leads to an unequal chance response level for each location, whereby random responses for cued target locations L1 and L9 would result in a mean RMS score of 4, whereas for L5 this chance value would be 2.22. For this reason, as with previous analyses of such data (Lansdale, 1998; Lansdale, et al., 2005), RMS values were rescaled as a proportion of the appropriate chance RMS value. The rescaled RMS value is reported as RMS_c (root-mean-square [corrected]). RMS_c scores of 0 indicate all correct responses, and chance performance values are normally distributed around a mean of 1.

RMS_c as an indication of overall performance is merely an abstraction of the raw data, and imposes no theoretical claims, apart from that it suggests the distance between locations L2 and L3 is equal to the distance between locations L7 and L8. Although this is physically true, we cannot assume that this is psychologically true with regards to memory for location (see Lansdale, 1998 for an overview). However, RMS_c provides us with no indication about the underlying properties of overall levels of performance, or the state of memory which is likely to have produced the data. In fact, the same RMS_c values can be calculated from two matrices with varying degrees of correct location recalls (Figure 2.9).

Table 2.2: Two confusion matrices (A and B) presenting the same RMS_c values despite varying levels of correct location recall.

Matrix A

Response location

Correct location	L1	L2	L3	L4	L5	L6	L7	L8	L9		RMS_c
L1	**12**	9	5	5	4	3	0	1	6	45	2.50
L2	5	**18**	5	3	2	6	3	1	2	45	1.40
L3	3	1	**21**	3	2	2	4	3	6	45	1.55
L4	5	3	2	**17**	2	1	4	5	6	45	2.24
L5	6	5	2	2	**22**	1	1	0	6	45	1.47
L6	6	3	2	1	1	**23**	2	2	5	45	1.34
L7	2	2	2	2	3	4	**24**	5	1	45	0.83
L8	4	5	2	4	3	1	2	**19**	5	45	1.67
L9	3	4	7	2	4	1	6	4	**14**	45	2.48
	46	50	48	39	43	42	46	40	51		

Matrix B

Response location

Correct location	L1	L2	L3	L4	L5	L6	L7	L8	L9		RMS_c
L1	**20**	0	0	0	0	0	0	0	25	45	2.50
L2	0	**26**	0	0	1	4	0	0	14	45	1.40
L3	0	0	**25**	1	0	0	1	9	9	45	1.56
L4	0	0	0	**22**	0	0	0	0	23	45	2.24
L5	0	0	0	0	**11**	33	0	1	0	45	1.47
L6	0	0	0	15	0	**15**	13	2	0	45	1.34
L7	8	0	0	4	3	0	**30**	0	0	45	0.83
L8	0	0	0	0	0	6	31	**8**	0	45	1.67
L9	23	2	0	0	0	0	0	0	**20**	45	2.48
	51	28	25	42	15	58	75	20	91		

Matrix A demonstrates largest frequency of recalls at the correct location value, and a pattern of errors (inexact recall) which are distributed relatively consistently across the remaining locations. In matrix B, although high frequencies of responses fall at the correct location, errors of equal or greater frequencies fall at other discrete locations. When compared, the matrices display different levels of correct recall, yet the RMS_c values produced are equivocal, suggesting identical levels of performance in each case. Similarly, this can be the case with equal levels of exact recall but substantially different distributions of inexact recalls, as displayed in Figure 2.10.

Table 2.3: Confusion matrix (matrix C) presenting the same RMS_c values as figure 2.9 (matrix A), despite a substantially different distribution of inexact recall responses.

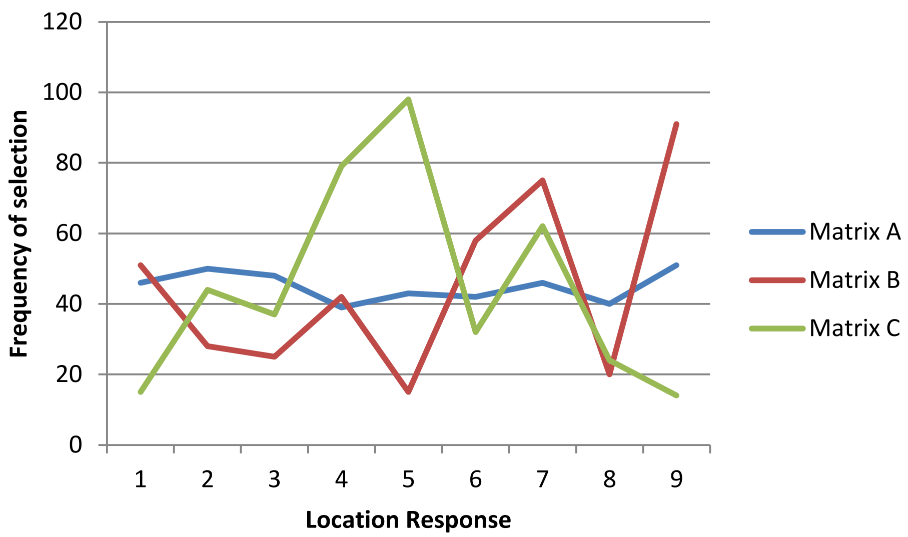
Matrix C
Response location

Correct location		L1	L2	L3	L4	L5	L6	L7	L8	L9		RMS_c
	L1	**12**	0	0	12	21	0	0	0	0	45	2.50
	L2	0	**18**	0	0	27	0	0	0	0	45	1.40
	L3	0	0	**21**	0	0	9	15	0	0	45	1.55
	L4	0	0	0	**17**	0	0	23	5	0	45	2.24
	L5	3	20	0	0	**22**	0	0	0	0	45	1.47
	L6	0	6	16	0	0	**23**	0	0	0	45	1.34
	L7	0	0	0	11	10	0	**24**	0	0	45	0.83
	L8	0	0	0	24	2	0	0	**19**	0	45	1.67
	L9	0	0	0	15	16	0	0	0	**14**	45	2.48
		15	44	37	79	98	32	62	24	14		

By looking at column totals, matrix A represents a fairly flat distribution of recalls across all locations, suggesting that responses are equally likely at all location values. Matrix C on the other hand indicates a central response bias, with reduced recalls at periphery locations (this is similar to the behavioural data witnessed in previous experiments concerned with memory for location for real-world images by Lansdale, et al., 2005). Despite equal levels of exact recall, matrices A and C demonstrate very different patterns of inexact recall, yet once again, levels of performance as indicated by the RMS_c values are equivocal.

Although RMS_c offers an estimate of overall performance based upon the average deviation of responses from the correct location value, it cannot tell us any more than this. Figure 2.8 highlights the substantial variation in recall distributions across all three matrices.

Figure 2.8: Line graph indicating the frequency distribution of location recall responses for matrices A, B and C.



In order to quantify the state of memory which may have produced these data an additional level of analysis is therefore required.

HELM (Hybrid Encoding of Location Memory; Lansdale, 1998)

When a participant views a real-world image, HELM supposes a set of psychological processes are involved whereby information regarding object location is extracted:

1. *Exact recall* refers to a participants ability to describe the location of an object with a categorical response, for example “the cat was in the centre of the picture” (location L5), or ‘the cat was on the far left of the picture’ (location L1). This kind of encoding represents an all-or-none recall response.

2. *Inexact recall* on the other hand suggests that a participant gradually gains information about the location of an object, but does not achieve sufficient levels of information to be sure (the exact nature of this information gain is not clear, yet it is possible to model this as a Poisson distribution of information gain over viewing time). In this case, the participant is selecting from a population of representations. The upshot of this gradual gain is that information of an incomplete nature is likely to result in a degree of near-miss error.

3. In the absence of any other information, participants do not respond at random, instead responses are subject to *bias*. Memory for spatial location has long been known to demonstrate various sources of error and bias (Huttenlocher, et al., 1991; Tversky, 1993;

B. Tversky & Schiano, 1989). The most common two types witnessed in memory for location being a central bias (bias against responding at the periphery of the array) and a reluctance to respond at previously selected locations (Lansdale, 1998).

HELM represents an analytical approach capable of modelling stimuli with discrete properties presented in continuum form (such as serial position or location). The model is used to estimate a set of parameter values of exact recall, inexact recall and response bias, generating a best model fit for an observed confusion matrix of responses. Although HELM can be applied to either the horizontal or the vertical dimension, for the purposes of examining memory for location, the horizontal axis is favoured. This is due to the fact that schematically, objects tend to reside in specific areas on the vertical axis (birds fly in the air, cars are found on the ground), whereas the horizontal axis is subject to less schematic bias (see Mandler & Parker, 1976).

The first use of HELM was to model a confusion matrix derived from responses for the location of an object that had appeared in one of nine equally spaced locations along the left-right axis of a picture (Lansdale, 1998). Over multiple tests of a specific object location, and with 9 specific locations across the duration of an experiment, a distribution of the frequency of which each location was chosen was generated to form a confusion matrix of 81 cells (9 correct locations x 9 possible response locations). HELM demonstrates that memory for object location within such cued-recall paradigms produce recalls which fall on and around a correct location. For each correct location tested, HELM produces an estimate of the proportion of exact recall (*E*), the availability of inexact recall (*A*), an estimation of the precision (λ) of this inexact information, and an estimate of bias[13]. From these parameter estimates, further analysis by way of implementing a cyclical process of model constraint allows the exploration of the complexity of the model required to provide a model which is a good prediction of (i.e. not significantly different to) the observed data. Neither exact nor inexact recall are essential to the workings of the model, therefore the process of parameter deletion enables a generation of the most parsimonious parameter account of the state of memory likely to have produced the observed behavioural data. When comparing HELM with RMS_c as a measure of accuracy in location recall, we can see that RMS_c has a lack of sensitivity to the direction of bias, or to the balance of exact (correct) and inexact (errors) recall in location memory performance.

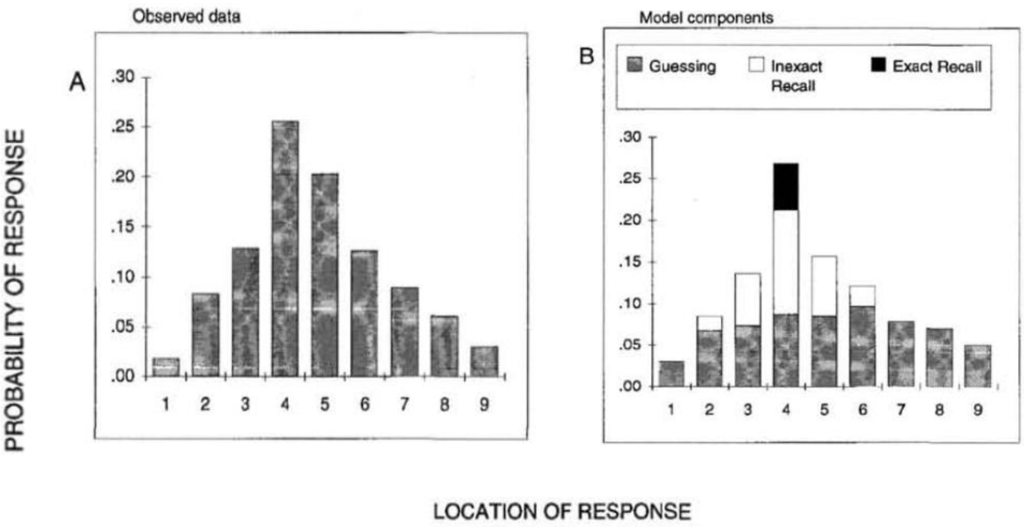
Components of the HELM model

HELM derives an estimation of the observed responses using the most parsimonious combination of it's constituent parameters in order to model the most likely state of memory to have produced the observed recall distribution. Figure 2.9 illustrates the recall distribution response for an image with a target at location 4 (A), together with the resulting HELM

[13] Definitions of these parameters can be found within section 2.5 (glossary of terms) at the end of this chapter. For full details of the development of the HELM model, refer to Lansdale (1998).

model predictions (B) displayed as the contribution of the components of guessing (bias), inexact recall, and exact recall.

Figure 2.9: Componenets of the Hybrid Encoding of Location Memory (HELM) model. (A) the distribution of location recall for a target at location 4 (Lansdale, 1998), and (B) a demonstration of how the processes of guessing, inexact and exact recall contribute to the overall model predictions[14].



Within this thesis, HELM is used alongside RMS_c estimates of recall accuracy in an attempt to quantify the state of memory most likely to have produced the distribution of recall responses on a continuous dimension of location (nine discrete columns) along the horizontal axis of a given real-world image. By using this psychologically motivated approach to the quantification of memory for location, analyses will form a large-scale investigation into the nature of memory for location in a variety of naturalistic images. The aim of this research is to establish the applicability

[14] Figure reproduced with the permission of M. W. Lansdale.

of knowledge for location as a means by which image storage and retrieval strategies may be improved. Little effort has previously been put into looking at the nature of accuracy of recall for location in real-world images. HELM is a novel analytical tool which may provide important insights into the factors which affect the accuracy location memory recalls. This has important implications when considering the feasibility of using location memory for specific image retrieval from picture databases.

2.4 General methods

Stimuli and materials

Stimuli consist of either 27 complex newspaper images (stimuli set A), 27 simple real-world images (stimuli set B) or 9 spatially matched pairs of real-world images (18 images) depicting threatening and neutral object relationships. All stimuli were presented in full colour (all stimuli sets are presented within the appendices). For stimuli sets A and B, target items were selected evenly across locations L1 to L9, so that a target item appeared at each location 3 times over the course of the full 27-image stimuli set. For stimuli set C, the location distance between objects was evenly varied between 2 to 6 absolute locations on the horizontal axis across the 9 stimuli pairs. Neither the indication of which of the items within the image was to become the target item, nor were the discrete location columns available to participants whilst viewing the stimuli.

As an amendment to previous research examining memory for location in real-world images (Lansdale, et al., 2005), stimuli were shown to participants for 20s rather than 30s, as only very small decreases in the amount of information available at recall have been identified between these two stimuli durations (Lansdale, et al., 2005; Mandler & Johnson, 1976). Images were presented to participants using E-Prime v.1 experimental software with a total inter-stimulus interval (ISI) of 800ms, comprising of 300ms fixation point '+' and 500ms blank screen. Participants view the stimuli from a distance of between 50cm to 60cm, with a viewing angle of no greater than 10^{o} from the perpendicular. Experiments are run on Pentium 4 desktop PCs running Microsoft Windows XP Professional. The PCs had a screen resolution of 1024 x 768 pixels delivered through a 17" monitor with a refresh rate of 60 Hz.

Procedure

Each experiment begins with the presentation of the specific experimental instructions (experimental instructions for both the viewing and cued location recall for images vary relative to each experiment and are presented in full within the relevant experimental chapters). Intentional learning paradigms were adopted (unless explicitly stated otherwise) as these have been shown to increase both the likelihood of a target location being available and the representation of the location more precise (Lansdale et al, 2005). Stimuli order is randomised for each participant, and each image was given a unique title from which recall of individual images were elicited. Following stimulus presentation, participants were asked to complete a 5 minute Sudoku puzzle distracter task (Appendix 8).

For experiments 1, 2, 6, 7 & 8, responses were elicited through the presentation of a black and white response grid following the methods of Lansdale, et al., (2005). The response grid covered the same area as the viewed images (1152 x 768 pixels). Above each test grid was the title of a previously viewed image, together with the name of the target item for recall.

For Experiments 4a and 4b (neutral vs. threat relationship images) recall was elicited through the presentation of the originally viewed images, with only the target item removed (edited out using Adobe Photoshop CS2). This was to ensure that no confusion could be made as to which was the target object when two objects in an image were the same object (for example the surfer-surfer image in the neutral stimuli condition). Target object location responses are recorded using the same Experimental software, by way of 9 equally spaced column divisions (L1-L9, which were unavailable to participants). The response images covered the same area as the experimental images (1152 x 768 pixels). Each test screen named the target item directly above the test image, for example “Target = Missing Surfer”. The order of images tested was randomised within E-prime for each participant. Participants are instructed to mark the exact location the target item appeared in by clicking on the image using the mouse.

For all location memory experiments, following each response participants are asked to indicate their confidence in the accuracy of their response by clicking one of the following confidence descriptions (presented as text boxes on an otherwise blank screen in a random order for each image); *absolutely sure, fairly sure, hunch, not sure,* or *blind guess.* Should confidence be diagnostic of accuracy in recall, then this will have specific applied use in database design. For example, if confidence is low, then search parameters will need to be wide to maximise the probability of a desired return, whereas if confidence is high, these parameters can be narrowed to result in less returns and a more efficient search strategy. Previous investigations with real-world images suggest that for the recall of location information, confidence is predictive of the availability (A) of recall, but insensitive to recall precision (λ), Lansdale et al. (2005).

2.5 Glossary of terms

For the research presented in the subsequent experimental chapters, a number of terms are used which are pertinent to the particular analyses adopted within this thesis, and to the HELM analytical framework. For reader clarity, the definitions presented below should be used above any other connotations of the terms when they appear within subsequent chapters of this thesis.

Glossary of Terms

RMS	The magnitude of variation in location recalls from the correct location value (root-mean-square or RMS), calculated using the square root of the mean of the squares of the values.
RMS_c	Rescaled RMS values as a proportion of the (unequal) appropriate chance RMS value for each of the nine locations on the horizontal axis (root-mean-square [corrected]).
HELM	Hybrid Encoding of Location Memory as described by Lansdale (1998).
Exact recall (*E*)	A categorical response within HELM, for example "the cat was in the centre of the picture" (location L5), which represents all-or-none recall.
Inexact recall (*I*)	Information of an incomplete nature within HELM (resulting from a gradual information gain), which is likely to result in a degree of near-miss error.
Availability (*A*)	A parameter of inexact recall (*I*) within HELM. Depicts the amount of inexact information regarding the location of a target object in memory for a given image.

Precision (λ)	A parameter of inexact recall (*I*) within HELM. Depicts the accuracy of available inexact information regarding the location of a target object in memory for a given image.
Near-miss error	Errors in location recall which fall at neighbouring locations to the absolute correct location value.
Confidence	A participants' judgement of their own confidence in the accuracy of location recall on a 5 point scale; 1 = blind guess 2 = not sure 3 = hunch 4 = fairly sure 5 = absolutely sure
Bias	In the absence of any other information, participants' responses on a left-right continuum are not equally likely (e.g. Tversky & Schiano, 1989). Within HELM, bias represents a weighting parameter for each of the location responses derived from the data from all images presented within a given confusion matrix[15].

Ethical approval

Ethical approval was sought for the series of experiments presented within this thesis from both Nottingham Trent University and the University of Leicester, copies of which can be found in the appendices (17-18).

[15] The mathematical expressions of exact recall, inexact recall and bias are presented in Lansdale (1998).

Chapter three: exploring the HELM approach with novel stimuli

Abstract

Previous investigations drawing upon HELM (Lansdale, 1998) modelling techniques have demonstrate that memory for object location within real-world images can be quantified using two parameters of performance; *A*: the probability that a representation of an object location will be available in memory, and λ: the precision of recall (Lansdale, et al., 2005). A key finding of this research was that levels of λ vary significantly between individual stimuli, and levels of *A* appear to be strongly governed by experimental manipulations that influence whether or not the specific target object receives attention.

Two experiments are presented in which the applicability of the HELM model was assessed with a novel set of real-world images. Experiment 1 examined the nature of recall for location memory for the novel image set. Experiment 2 investigated the effects of drawing attention to the specific target object at encoding (through the provision of a verbal commentary).

Findings served to highlight some key similarities in the distribution of errors for the novel stimuli, with substantial levels of correct recall, the presence of near-miss errors, and increased levels of overall performance with the presence of additional verbal information at encoding. However, a novel variation in error distribution was highlighted for some images in both Experiments 1 and 2, with clustering of errors at locations distant to the correct value. The importance of these distant errors is discussed in relation to individual image properties.

3.1 Introduction

Prior to further investigations taking place, this first experimental chapter aims to make substantial links with previous research investigating the nature of memory for location in complex real-world pictures. The HELM model has been designed to estimate a set of parameter values to generate the best model-fit for an observed confusion matrix. The first use of HELM was to model confusion matrices representing location recall for target objects along 9 discrete horizontal location segments. Stimuli producing the recall responses were highly constructed images consisting of coffee mugs placed upon a shelf (Lansdale, 1998) which were devised to suit the experimental method. However, in real-world images, objects are not constrained. They tend to co-occur with other objects and function as part of the overall scene meaning and configuration. It is therefore reasonable to assume that memory for location of cued target objects in real-world images may be subject to different patterns of recall than was witnessed for highly constrained, artificial stimuli.

Research conducted by Lansdale and colleagues (2005) provided the first exploration into the feasibility of object location memory as a query language for real-world image retrieval. These novel empirical experiments explored the accuracy of cued-recall for the absolute location of objects in complex photographic images sourced from newspapers. Analysis using HELM suggested that it was possible to account for object location responses in real-world images using a model of inexact recall only, (exact recall (*E*) was not required to provide model predictions which were not significantly different to the data, unlike for artificial stimuli). Second, object location recall could be successfully described using two parameters of inexact recall performance, *A* (the probability that a representation of an object location will be *available* in memory) and λ (the *precision* of those responses). Third, participants' confidence in their accuracy of recall was a strong predictor of *A* for both individual participants, and aggregated across participants for individual stimuli, which suggests that individual real-world pictures vary in terms of either the accuracy of location recall, or the distribution of error they generate. Further analysis revealed that levels of both *A* and λ varied across the nine separate locations being tested. Yet despite this empirical evidence, little is actually known about the inherent properties of real-world images which serve to generate the variability of error distribution in location recall.

One particular aspect of the research presented by Lansdale, et al., (2005) attempted to address the effects of picture content and meaning on recall of location through the categorisation of target objects as either foreground (either the most semantically salient, or one of a few equally semantically salient objects within the image) or background (perceptually discriminable, but not among the semantically salient objects within the image) items. Recall data suggested that semantic saliency is important in predicting the availability of location memory, with foreground items demonstrating significantly higher levels of availability than background items, although precision was insensitive to this distinction. Lansdale, et al., (2005) concluded that foreground items were more likely to elicit viewers' attention during image viewing, and therefore were more likely to be available in memory. Furthermore, the authors demonstrated that this foreground item precedence could be suppressed through the provision of a verbal commentary at stimulus encoding which directed viewer's attention evenly between foreground and background items.

The present chapter seeks to apply the methodological approach of Lansdale, et al., (2005) to a novel set of twenty-seven newspaper images to identify whether similar patterns of error distribution are present for the novel stimuli, prior to further investigations taking place. This chapter provides the first step in a series of experiments which seek to investigate factors which impact upon the accuracy of location memory in real-world images, pertinent to the nature of image database design. The primary aim of this first experimental chapter is to create links with the previous research and establish the analytical methodology to be used.

Two experiments are presented which are based upon the experimental methodology of Lansdale and colleagues (2005). Experiment 1 seeks to explore the applicability of HELM to a novel set of complex real-world images (stimuli set A). A further experiment (Experiment 2) then aims to assess the effects of providing participants with additional verbal information at encoding on their subsequent memory for cued-target location for the same stimuli.

3.2 Experiment 1*:* Exploring memory for location using a novel set of real-world images

Introduction

Experiment 1 represents a partial replication of research conducted by Lansdale, et al., (2005). In the present experiment, participants were presented with 27 real-world images (varying in content) taken from newspapers (stimuli set A, Appendix 1). At recall, participants were presented with a grid comprising of 9 equally spaced columns (occupying the same dimensions as the previously viewed images) and were asked to mark the location of objects from those images on the grid. Each of the columns on the left-right array had an equal chance of representing the correct target location across the full stimuli set. This initial replication experiment aims to assess memory for the cued location of target objects in a novel set of real-world images, and assess the applicability of the HELM analytical method to these stimuli.

Method

Stimuli and materials

Please refer to the general methods (Chapter 2) for an overview of the stimuli and materials used within this experiment.

Participants

Sixty-eight undergraduate students (60 female, 8 male) from Nottingham Trent University, Nottingham, UK, took part in return for course research credits or £3 cash. Ages ranged from 18-49 years with a mean age of 19 years 7 months.

Procedure

Image presentation instructions:

> This Experiment is designed to identify which features or qualities of newspaper images make them effective pictures. You will be shown a series of 27 pictures taken from newspapers and will hear a title for each picture. As a final test of effectiveness of these images, we will test your ability to remember the location of one of the objects shown in the picture. Please click the mouse button to begin the Experiment.

Following a 5 minute distracter task (see Chapter 2 for full details), recall instructions read:

> You will now be presented with 27 response screens. Each screen will show the title of one of the newspaper images you have previously viewed, and a response grid representing the image. A target item will be named from the newspaper images in question and you will be asked to use the mouse to click the exact location in

> the response grid you believe you have previously seen the target item occupy. You will then be asked how confident you feel about the location response you have given. To resume the Experiment please click a mouse button.

Participants and were allowed as much time as required to complete the 27 response grids. After each response grid, participants were presented with a screen asking for a confidence judgement for their location recall.

Results

Table 3.1 shows the distribution of the object location responses to each of the 27 newspaper images presented as a confusion matrix. This table presents the recall data in terms of correct versus observed responses. Location responses on the diagonal (highlighted in bold) represent exact location recalls, and responses which fall off the diagonal represent inexact recalls. By examining the distribution of the data it is shown that, as with previous findings by Lansdale, et al,, (2005), the stimuli demonstrate substantial levels of correct location recall, with a clustering of errors around the correct location values. Similarly, the frequencies with which responses L1-L9 are used imply a bias against responding with location values at the periphery of the array (see column totals).

An indication of overall performance is generated within Table 3.1 using the average deviation presented as RMS_c (root-mean-square corrected) of all responses from the correct location value (see Chapter 2 for an overview of the RMS correction). RMS_c values for each stimulus, aggregated across participants, show a range from 0.28 (target location 6, stimulus B) indicating substantial levels of recall, to 1.06 (target location 5, stimulus C) indicating performance slightly below what would be expected by chance.

Parameter Estimates

Table 3.1 highlights a variation in the accuracy of recall (as indicated by RMS_c values) between stimuli sets A, B and C where recall is elicited for the same target location. For example, RMS_c scores for 5A, 5B and 5C are .57, .68 and 1.06 respectively. The homogeneity of location recall responses for those images testing recall of a target at location 5 for matrices A, B, and C were tested using a 3 (matrices) x 9 (location) matrix of observed vs. expected frequencies. The test of the homogeneity of responses across locations was statistically significant, $x^2(16, N = 204) = 92.25$, $p < .001$. This was replicated for all stimulus locations; with values of $p < .05$ for target location 7, and $p < .001$ for all other target locations. An aggregated test for homogeneity across all stimuli (the summed statistic from each of these individual tests) was also highly significant, $x^2(144, N = 1836) = 591.87$, $p < .001$. This therefore indicates that despite having the same target location, each of the three stimuli varied as a function of the distribution of recall responses they elicit.

Table 3.1: Frequency of locations given as response to each of the 27 stimuli and computed RMS_c scores in Experiment 1.

Target location and stimulus identifier		Location given as response									Total	RMS_c score	Mean confidence
		1	2	3	4	5	6	7	8	9			
1													
	A	**29**	15	5	4	5	2	2	5	1	68	0.45	3.76
	B	**3**	20	16	6	4	4	7	6	2	68	0.76	2.84
	C	**5**	6	17	10	3	16	8	3	0	68	0.85	2.37
2													
	A	5	**17**	10	15	8	8	3	2	0	68	0.58	3.19
	B	17	**32**	10	2	1	1	0	2	3	68	0.32	4.60
	C	2	**4**	21	17	6	6	8	2	2	68	0.75	3.18
3													
	A	1	4	**28**	18	4	4	3	1	5	68	0.50	3.10
	B	1	4	**9**	9	23	13	5	1	3	68	0.79	2.87
	C	2	0	**19**	34	6	3	1	1	2	68	0.44	3.94
4													
	A	3	2	7	**30**	14	6	3	2	1	68	0.43	3.24
	B	1	1	3	**37**	16	3	2	4	1	68	0.36	4.01
	C	2	2	2	**10**	39	10	0	3	0	68	0.52	3.09
5													
	A	1	3	4	14	**21**	12	5	3	5	68	0.57	3.01
	B	2	2	4	6	**18**	13	12	6	5	68	0.68	3.21
	C	7	21	22	6	**3**	4	2	1	2	68	1.06	3.99
6													
	A	0	1	3	6	14	**21**	13	9	1	68	0.46	3.12
	B	1	0	1	1	28	**31**	6	0	0	68	0.28	3.93
	C	0	4	8	14	14	**9**	13	3	3	68	0.69	2.38
7													
	A	0	4	8	6	8	21	**15**	4	2	68	0.63	3.15
	B	2	2	15	11	6	13	**8**	11	0	68	0.83	2.32
	C	2	3	24	7	7	11	**8**	6	0	68	0.97	2.81
8													
	A	1	3	3	1	6	30	17	**5**	2	68	0.64	3.74
	B	1	3	6	1	0	19	21	**16**	1	68	0.54	4.01
	C	3	4	14	16	5	7	8	**8**	3	68	1.00	3.15
9													
	A	1	3	6	5	6	18	17	8	**4**	68	0.77	3.10
	B	5	0	6	3	11	6	10	20	**7**	68	0.71	3.35
	C	3	10	10	7	5	12	17	2	**2**	68	1.03	2.28
	Total	100	170	281	296	281	303	214	134	57			
	Average											0.65	3.25

RMS_c = root-mean-square corrected, numbers in **bold** represent correct location responses.

For the purpose of analysis, and following the techniques of previous investigations into the nature of memory for object locations (Lansdale et al, 2005), responses for corresponding locations were arbitrarily separated into three separate stimuli groups; A, B and C, providing three sets of nine images, with each image representing target objects in each matrix at one of the possible target locations L1–L9 (Table 3.2). In order to gain a more detailed analysis of the recall data, HELM was used to model each of the three confusion matrices (A, B and C).

Analyses using HELM provided overall estimates for each of the target locations for the parameters of exact recall (*E*), inexact recall (*A* and λ) and an estimate of bias. Unlike previous findings by Lansdale, et al., (2005), the optimised HELM model applied to each of these matrices only provided a non-significantly different prediction of the data for matrix A, with respective goodness of fit statistics of A: $x^2(36, N = 612) = 38.62$, *ns*; B: $x^2(36, N = 612) = 90.95$, $p < .001$; and C: $x^2(36, N = 612) = 177.69$, $p < .001$[16] respectively, as opposed to non-significant predictions for all three matrices (A, B & C). But why should the model fits be any different for the present experiment?

[16] The G or 2I statistic is used in place of traditional Chi as it offers an exact test which is better able to deal with low cell frequencies (see Baguley et al. 2006 for a discussion).

Table 3.2: Confusion matrices displaying frequency of responses and correct location values (highlighted in bold) for each of the 9 stimuli in matrices A, B & C for Experiment 1.

Matrix A:
Location given as response

Target location	1	2	3	4	5	6	7	8	9	Total
1	**29**	15	5	4	5	2	2	5	1	68
2	5	**17**	10	15	8	8	3	2	0	68
3	1	4	**28**	18	4	4	3	1	5	68
4	3	2	7	**30**	14	6	3	2	1	68
5	1	3	4	14	**21**	12	5	3	5	68
6	0	1	3	6	14	**21**	13	9	1	68
7	0	4	8	6	8	21	**15**	4	2	68
8	1	3	3	1	6	30	17	**5**	2	68
9	1	3	6	5	6	18	17	8	**4**	68
Total	41	52	74	99	86	112	78	39	21	

Matrix B:
Location given as response

Target location	1	2	3	4	5	6	7	8	9	Total
1	**3**	20	16	6	4	4	7	6	2	68
2	17	**32**	10	2	1	1	0	2	3	68
3	1	4	**9**	9	23	13	5	1	3	68
4	1	1	3	**37**	16	3	2	4	1	68
5	2	2	4	6	**18**	13	12	6	5	68
6	1	0	1	1	28	**31**	6	0	0	68
7	2	2	15	11	6	13	**8**	11	0	68
8	1	3	6	1	0	19	21	**16**	1	68
9	5	0	6	3	11	6	10	20	**7**	68
Total	33	64	70	76	107	103	71	66	22	

Matrix C:
Location given as response

Target location	1	2	3	4	5	6	7	8	9	Total
1	**5**	6	17	10	3	16	8	3	0	68
2	2	**4**	21	17	6	6	8	2	2	68
3	2	0	**19**	34	6	3	1	1	2	68
4	2	2	2	**10**	39	10	0	3	0	68
5	7	21	22	6	**3**	4	2	1	2	68
6	0	4	8	14	14	**9**	13	3	3	68
7	2	3	24	7	7	11	**8**	6	0	68
8	3	4	14	16	5	7	8	**8**	3	68
9	3	10	10	7	5	12	17	2	**2**	68
Total	26	54	137	121	88	78	65	29	14	

As previously discussed within Chapter 2, the HELM model assumes that errors in recall will be clustered around the correct location value. For the present data it is clear that this assumption is violated on a number of occasions. For example, in matrix C, row 1 (single image with target object location at L1) demonstrates a large cluster of error responses at L6, and row 5 (single image with target object location at L5) indicates large numbers of error responses at L2 and L3. These clusters of responses which do not demonstrate near-miss errors, are in contrast to the patterns of error demonstrated within the data of Lansdale, et al., (2005), and result in statistically different models of the data using HELM.

Despite otherwise comparable trends in error distribution between the present data and the previous research by Lansdale and colleagues, (high levels of correct recall, near-miss errors, bias against responding at the periphery), the inability of HELM to model these matrices points to a substantial constraint with the model in that it makes an assumption that all errors in recall will be centred on and fall symmetrically around the correct location value. Although this was the case for artificial stimuli (Lansdale, 1998), and to some degree the real-world images selected by Lansdale, et al., (2005), the real-world pictures selected for the present research do not always conform to this trend, resulting in statistically different model predictions for 2/3 matrices. It is therefore imperative that, at this early stage, one questions whether analysis should proceed using the HELM model considering the model has failed to accurately account for the recall data.

In response to this question, it is imperative that analysis continues in the same manner as it was conducted within the original research on a number of grounds. First, it is important to maintain compatibility with the previous research methodology for purposes of direct comparison. Both the research by Lansdale, et al., (2005) and the present investigation examine location memory for real-world newspaper images on a discrete location segmentation of 9 horizontal locations. As such, any differences in the distribution of errors made by participants will be highly informative in terms of the effects of images content or construction on memory for location.

Second, and perhaps most importantly, simply looking at statistically significant models will not tell us everything we need to know about the data. An overall indication of recall performance is provided by RMS_c (a transformation of the raw data, with no imposed theoretical framework), and therefore analyses undertaken using HELM aim are undertaken simply to gain a deeper understanding of the likely state of memory which produced the observed recall data within this experiment.

Third, the analyses undertaken by Lansdale, et al., (2005) use the HELM model to estimate the requirement of its parameters in a process of cyclical constraint. By adopting this method, the importance lies within the *change value* of the x^2 model statistic when parameters are constrained. Each parameter which is constrained within the model removes 8df (each parameter represents 9 location values). These analyses therefore offer a rational test of the change imposed on the model as a result of removing free parameters (8df). Clearly these analyses do come with a heavy caveat, and it should always be born in mind that the model from which they are drawn from is not a perfect representation of the data observed. However, there are good reasons to suppose why the model is unable to accurately account for the data presented within this experiment (distant error clusters), and this specific issue will be returned to and examined both in the discussion, and in detail within Chapter 4.

Does HELM require exact recall (E) to model the data?

First, model estimations for each of the matrices (A, B and C) were obtained with all parameters unconstrained. Estimates of availability of inexact recall and precision are presented in Table 3.3. Estimated mean probabilities of exact recall (*E*) for each of the three matrices were low: A = 0.024, B = 0.031 and C = 0.071 respectively. The main question to address here is whether or not these probabilities give rise to frequencies above and beyond those we would expect from the distribution of inexact recall alone? This was examined through the constraint of the exact recall parameter (*E*) within the HELM model by fixing the value at zero[17]. A re-optimization of the remaining free parameters did not provide a significant increase in the x^2 statistic for any matrix when compared with the previous unconstrained model fits. Respective changes (Δ) were: ΔA: $x^2(9, N = 612) = 3.25$, *ns*; ΔB: $x^2(9, N = 612) = 0.38$, *ns*; and ΔC: $x^2(9, N = 612) = 3.93$, *ns*. It can be assumed that these data, as with the data in the

[17]Parameter subtraction analyses are undertaken with the consideration that non-significant model fits were not provided by HELM for two of the three stimuli matrices.

previous research, do not require exact recall (*E*) to model the data. Subsequently, all further HELM analyses for these data will be conducted with the assumption of no recall and therefore will all have the exact recall parameters (*E*) fixed at zero.

Is availability of inexact recall common for all stimuli?

Lansdale, et al., (2005) suggest that different real-world images offer different levels of inexact recall responses. To test whether the novel stimuli within the present experiment also vary in levels of inexact recall, the HELM model was re-optimised with the availability parameter (*A*) fixed to the mean matrix value for all stimuli in each matrix. This produced a significant decrease in goodness of fit for only one of the three matrices, matrix B, with respective changes in model fit of ΔA: $x^2(8, N = 612) = 9.64$, *ns*; ΔB: $x^2(8, N = 612) = 20.56$, $p < .05$; and ΔC: $x^2(8, N = 612) = 7.18$, *ns*. The findings therefore indicate some variation in the availability of inexact recall between stimuli, with one matrix failing to tolerate a fixed value of *A* (as opposed to two of the matrices within the original research).

Table 3.3: Parameter Estimates of Availability (A) and Precision (λ) for each stimulus derived from HELM in Experiment 1.

Correct target location and stimulus identifier		Parameter Estimates A	Parameter Estimates λ	Foreground or background target object
1				
	A	0.58	5.32	f
	B	0.53	3.00	b
	C	1.00	0.32	f
2				
	A	0.81	1.72	b
	B	0.80	4.65	f
	C	0.30	1.74	f
3				
	A	0.56	5.01	f
	B	0.63	1.00	b
	C	0.75	3.01	f
4				
	A	0.57	4.92	b
	B	0.67	5.72	f
	C	0.74	2.80	b
5				
	A	0.34	5.11	f
	B	0.22	2.24	b
	C	0.00	3.04	f
6				
	A	0.80	1.88	f
	B	0.91	4.12	f
	C	0.81	0.99	b
7				
	A	0.22	4.30	f
	B	0.00	2.84	b
	C	1.00	0.23	f
8				
	A	0.79	1.54	b
	B	0.59	2.30	f
	C	0.66	0.41	f
9				
	A	0.42	2.03	b
	B	0.35	3.50	f
	C	0.25	2.13	b

A = availability of inexact recall, λ = precision of inexact recall. f = target object is classified as a foreground item, b = target object is classified as a background item.

Is precision common for all of stimuli?

The final parameter to be constrained, precision (λ), looks specifically at the clustering of near-miss (inexact) recalls around the correct target value for each of the stimuli. In Lansdale et al, (2005), a common value λ could not be assumed, and it was therefore concluded that inexact recall was more precise for some object locations than others. By the same process, is this also the case for the present stimuli set? Re-optimizing the remaining free parameters with a common mean matrix value of *λ* applied to each of the matrices produced a significant decrease in goodness of fit for matrices A and B; ΔA: $x^2(8, N = 612) = 31.61$, $p < .001$; ΔB: $x^2(8, N = 612) = 44.78$, $p < .001$; but not for matrix C, ΔC: $x^2(8, N = 612) = 5.84$, *ns*. As such, it can be assumed that as with the previous research, inexact recall is more precise for some object locations than for others, although this parameter constraint failed to cause a significant decrease in model fit for one of the matrices (C).

Confidence Ratings

Findings by Lansdale, et al., (2005) suggested that participants' confidence in the accuracy of their location response was a good predictor of the availability (A) of inexact location memory, but insensitive to precision (λ). For the present experiment, a correlation was found between participants' mean confidence and the mean λ of their responses, $r\ (26) = 0.48$, $p < .05$, with higher levels of mean confidence correlating with higher levels of mean λ across the 27 stimuli, whereas no correlation was found between mean confidence and mean *A*, $r\ (26) = 0.13$, ns (Figure 3.1). However, when overall accuracy of recall is represented by the RMS_c deviation (where levels of performance are not split into availability and precision distinctions), lower RMS_c scores (higher levels overall performance) were found to be moderately correlated to participants confidence in the accuracy of their responses at a highly significant level, *r* (26) = -0.57, p < .01 (Figure 3.2).

Figure 3.1: Mean confidence with mean *A* and λ for each of the 27 real-world images in Experiment 1.

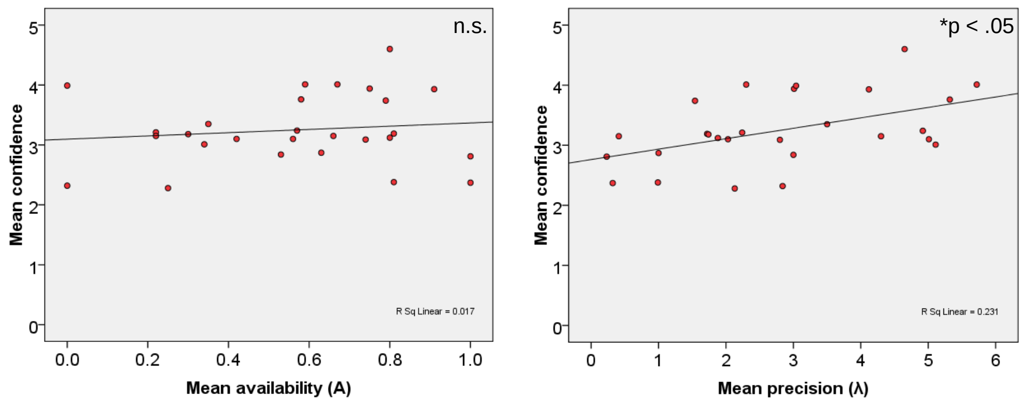
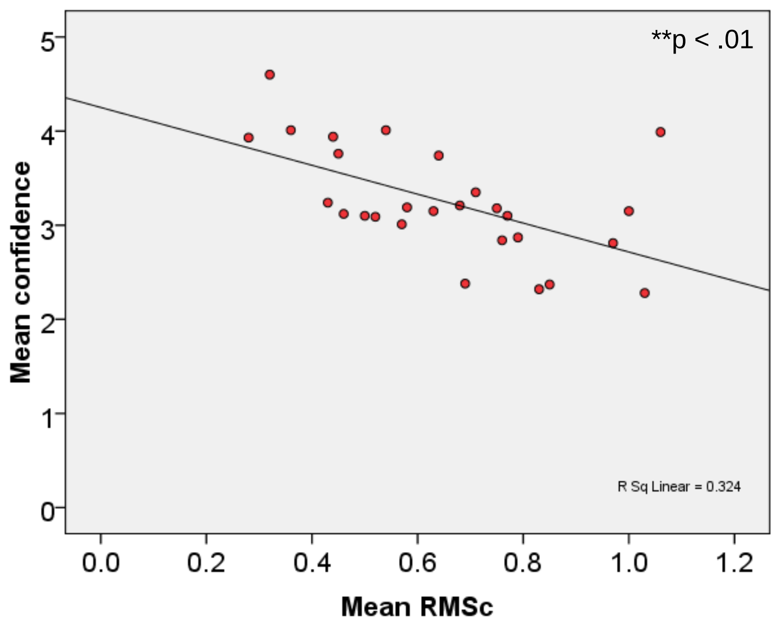


Figure 3.2: Mean confidence and RMS_c scores for all participants and all 27 pictures in Experiment 1.



Foreground and background items

Distinctions between semantically salient foreground, and non-salient background items within the research conducted by Lansdale, et al., (2005) suggested that semantic salience served to highlighted elevated levels of *A* for foreground items, whilst levels of λ remained unaffected by this distinction. In the present experiment, using the foreground/background stimuli distinctions as described by Lansdale et al, (2005), target objects were classified as foreground in sixteen of the stimuli images, and background items in the remaining eleven (foreground and background items were evenly distributed across recall locations L1-L9). Details of whether target objects were classified as foreground or background items are presented within Table 3.3.

Findings demonstrate that although overall mean levels of both *A* and λ were greater for foreground as opposed to background items (foreground: mean *A* = 0.60, *SD* = 0.29, mean λ = 3.17, *SD* = 1.86; background; mean *A* = 0.52, *SD* = 0.27, mean λ = 2.29, *SD* = 1.11), neither of these comparisons were statistically significant, as indicated by independent t-tests; *A*: t (25) = 0.64, ns, λ: t (25) = 1.53, *ns.* However, in a comparison of participants' confidence in their location judgements, mean confidence levels were higher for foreground than background objects (mean confidence for foreground items = 3.47, *SD* = 0.58, mean confidence for background items = 2.93, *SD* = 0.46), which did represent a statistically significant difference, t (25) = 2.56, $p < .05$.

Summary

Experiment 1 served to investigate the nature of memory for location using the HELM analytical model. This experiment provided a replication of the methodological approach adopted by Lansdale, et al., (2005) to examine the memory for location in a novel set of real-world images.

The first major point for consideration is the inability for HELM to provide non-significant model fits for two of the three confusion matrices (B & C) within this experiment. This is in contrast to non-significant model predictions for all matrices within the initial research conducted by Lansdale and colleagues (2005). The poorer model fits witnessed here may be indicative of clusters of error which are not centred on the correct location value.

Despite these poor model fits, the present experiment has made strong contact with the original experimental work conducted by Lansdale, et al., (2005). First, the stimuli demonstrate substantial levels of correct location recall for cued target object location, and reveal a clustering of near-miss errors which fall around the correct location value. Second, participants demonstrate a bias against responding with locations at the periphery of the array (locations L1 and L9). Third, despite recall being tested for the same absolute location, recall responses vary as a function of either the accuracy of recall or the distribution of error for the cued object.

Alike the findings of Lansdale, et al., (2005), no evidence was found for substantial levels of exact recall using the HELM model, suggesting that the distribution of location recall could be accounted for by parameters of inexact recall. Furthermore, variation in the availability and precision of inexact recall was demonstrated for some stimuli, suggesting that individual image properties may play a role in the accuracy of memory for object location. Participants' confidence in their accuracy of recall was found to correlate with both the precision of their responses (although not the availability of those responses as demonstrated by Lansdale et al., 2005), and with overall levels of performance as indicated by RMS_c values. As with the previous research findings, semantic saliency (indicated by target objects being categorised as foreground or background items) was shown to have an effect insofar as foreground items demonstrating greater mean levels of both availability and precision across the full stimuli set, yet this did not amount to a significant difference in either case. Nevertheless, in an analysis which wasn't conducted by Lansdale, et al., (2005), higher levels of mean confidence were demonstrated for foreground above background item recall.

3.3 Experiment 2: Effects of additional verbal information on memory for location

Introduction

Findings from Experiment 1 serve to highlight the degree to which memory for location varies across individual real-world images. A trend has been highlighted for which the semantic saliency of a target object affects levels of inexact recall, with foreground items demonstrating greater mean levels of both the availability and precision of location information. Despite this not being a statistically significant effect, mean confidence in participants' accuracy of recall was significantly greater for foreground items, which suggests that there may be a difference in the degree to which foreground and background objects are encoded.

In the earlier research conducted by Lansdale, et al., (2005) findings suggested that the status of a target object as foreground increased the likelihood that their location would be processed (greater mean availability), but did not necessarily increase the precision of the ensuing recall response. In a second experiment, the provision of a verbal commentary at stimulus encoding aimed to equalize attention between foreground and background objects. It was hypothesised that should attention be equalized, then this would serve to reduce, or perhaps even eliminate the differences observed in levels of availability between foreground and background objects. Findings revealed that additional verbal information at encoding resulted in an overall increase in the availability and precision of location recall across all images. Furthermore levels of availability were equalized across both foreground and background items.

The present experiment seeks to replicate the experimental procedure of Lansdale, et al., (2005) to identify whether overall levels of performance can be increased by specifically drawing participants' attention to the target object at encoding. In addition, this experiment serves to highlight whether the presence of a verbal commentary equalising attention across foreground and background target objects can serve to reduce the effects of semantic salience witnessed in Experiment 1.

Method

Stimuli and materials

The experimental design of Experiment 2 was exactly alike that of Experiment 1 (above) with the addition of verbal commentaries during stimulus presentation. Commentaries served to offer a verbal description of the image. All commentaries served to draw attention to the object location memory target item. The commentaries were constructed to be comparable in nature to those used within the original research (Lansdale, et al., 2005). Full details are presented within the general methods in Chapter 2, and full verbal commentaries for each of the 27 real-world images are presented within Appendix 6.

Participants

Eighty-five undergraduate students (69 female, 16 male) from Nottingham Trent University, Nottingham, UK, took part in return for course research credits, or a payment (£3). Ages ranged from 18-44 years, with a mean age of 18 years 10 months.

Procedure

The procedure was the same as that for Experiment 1 except for the addition of a spoken title and a verbal commentary during stimulus presentation. Instructions given to participants within Experiment 2 reflected this change:

> This Experiment is designed to identify which features or qualities of newspaper images make them effective pictures. You will be shown a series of 27 pictures taken from newspapers and will *hear a title and description* for each picture. As a final test of effectiveness of these images, we will test your ability to remember the location of one of the objects shown in the picture. Please click the mouse button to begin the Experiment.

Results

Table 3.4 shows the distribution of the object location recalls for each of the 27 newspaper images from stimuli set A. As with the data from Experiment 1, the stimuli showed substantial levels of correct location recall, with a clustering of errors around the correct location values, and participants demonstrate a bias against responding with location values at the periphery of the array.

Table 3.4: Frequency of locations given as response to each of the 27 stimuli and computed RMS_c scores in Experiment 2.

Target location and stimulus identifier		Location given as response									Total	RMS_c score	Mean confidence
		1	2	3	4	5	6	7	8	9			
1													
	A	**54**	18	3	2	2	1	2	2	1	85	0.45	3.76
	B	**3**	29	18	11	4	9	7	2	2	85	0.76	2.84
	C	**32**	19	6	4	2	6	9	5	2	85	0.85	2.37
2													
	A	6	**28**	28	12	4	1	2	1	3	85	0.58	3.19
	B	5	**38**	28	7	1	1	1	2	2	85	0.32	4.60
	C	2	**2**	34	30	6	3	4	3	1	85	0.75	3.18
3													
	A	1	5	**36**	33	4	3	1	0	2	85	0.50	3.10
	B	2	6	**40**	17	8	7	3	2	0	85	0.79	2.87
	C	3	3	**21**	43	8	4	3	0	0	85	0.44	3.94
4													
	A	1	0	5	**60**	13	1	3	1	1	85	0.43	3.24
	B	3	1	6	**46**	24	2	0	2	1	85	0.36	4.01
	C	3	1	2	**58**	16	2	1	1	1	85	0.52	3.09
5													
	A	1	1	12	27	**27**	11	5	1	0	85	0.57	3.01
	B	1	1	2	19	**29**	25	1	3	4	85	0.68	3.21
	C	7	24	31	13	**3**	3	0	1	3	85	1.06	3.99
6													
	A	3	1	1	3	13	**42**	21	0	1	85	0.46	3.12
	B	0	2	1	2	30	**36**	9	3	2	85	0.28	3.93
	C	3	3	2	7	23	**42**	4	0	1	85	0.69	2.38
7													
	A	6	5	8	1	3	10	**41**	7	4	85	0.63	3.15
	B	2	7	8	6	8	19	**27**	7	1	85	0.83	2.32
	C	2	4	4	6	4	54	**9**	0	2	85	0.97	2.81
8													
	A	1	4	1	3	5	26	42	**2**	1	85	0.64	3.74
	B	1	0	5	4	3	15	43	**12**	2	85	0.54	4.01
	C	4	1	6	5	4	9	23	**32**	1	85	1.00	3.15
9													
	A	4	0	5	3	10	14	14	23	**12**	85	0.77	3.10
	B	1	3	6	5	5	4	22	31	**8**	85	0.71	3.35
	C	0	4	7	4	3	6	4	20	**37**	85	1.03	2.28
	Total	151	210	326	431	262	356	301	163	95			
	Average											0.65	3.25

Parameter estimates

As with Experiment 1, a variation between responses is witnessed across stimuli from sets A, B and C testing the same target location. For example, RMS_c scores for 9A, 9B and 9C are .62, .58 and .44 respectively. A test of the homogeneity of these responses across location arrays was statistically significant, $x^2(16, N = 255) = 64.33$, $p < .001$, suggesting that despite having the same target location, each of the three stimuli varied as a function of either accuracy of recall, or distribution of recall errors. This was replicated for all stimulus locations, where significance levels were shown at either $p < .01$ (target locations 3 and 6) or $p < .001$ (all other target locations), with the exception of target location 4, which failed to show a significant result, $x^2(16, N = 255) = 16.10$, $p < .05$. An aggregated test for homogeneity across all stimuli remained highly significant, $x^2(144, N = 2295) = 618.07$ $p < .001$.

Optimised HELM model did not provide close predictions for any of the matrices (all observed matrix data were significantly different to the model predictions) A: $x^2(36, N = 765) = 77.78$, $p < .001$; B: $x^2(36, N = 765) = 66.36$, $p < .01$; and C: $x^2(36, N = 765) = 163.03$, $p < .001$. Although further analysis using parameter constraints, confirmed a comparable data trend as with Experiment 1, with no evidence of exact recall (*E*) ΔA: $x^2(9, N = 765) = 4.05$, *ns*; ΔB: $x^2(9, N = 765) = 0.73$, *ns*; and ΔC: $x^2(9, N = 765) = 1.71$, *ns*[18].

[18]In line with the analyses for Experiment 1, parameter subtraction tests are undertaken here with the consideration that non-significant model fits were not provided by HELM for all three matrices.

Effects of verbal commentary on overall recall performance

Comparisons of mean RMS_c values suggested levels of overall performance, aggregated across stimuli, were greater (lower RMS_c values) with the presence of a verbal commentary at encoding (mean = 0.46, *SD* = 0.17), when compared with performance in Experiment 1 (mean = 0.65, *SD* = 0.22). This was confirmed by a highly significant difference in the RMS_c scores for each stimulus provided by an independent samples t-test, $t\ (26) = 3.50$, $p < .001$. This trend is consistent with the findings of the previous research (Lansdale et al, 2005).

Effects of verbal commentary on availability (A)

A re-optimization of the remaining free parameters in HELM, with the availability parameter (*A*) assuming the same mean value (from the unconstrained matrices) for each stimuli, all matrices provided a significant decrease in the goodness of fit statistic; ΔA: $x^2(8, N = 765) = 26.34$, $p < .01$; ΔB: $x^2(8, N = 765) = 21.23$, $p < .01$; and ΔC: $x^2(8, N = 765) = 20.84$, $p < .01$, as opposed to just one (matrix B) in Experiment 1. When taking into consideration that the same stimuli set was used within each experiment, this suggests that the presence of a verbal commentary at encoding has the effect of increasing the extent to which the availability (*A*) of inexact recall is greater for some object locations than others.

Comparisons of the mean availability (*A*) predictions from HELM suggest a slight increase in the availability of information; (Experiment 2: mean = 0.65, *SD* = 0.18, compared with Experiment 1: mean = 0.57, *SD* = 0.28), although an independent t-test comparison of the scores for each stimulus did not reach significance, $t\ (26) = -1.36$, $p = .18$. This suggests that the mean *A* scores were not significantly different across experiments overall.

Table 3.5: Parameter estimates of availability (A) and precision (λ) for each stimulus in Experiment 2.

Correct target location and stimulus identifier		Parameter Estimates		Foreground or background target object
		A	*λ*	
1				
	A	0.82	5.38	f
	B	0.55	2.99	b
	C	0.41	5.54	f
2				
	A	0.60	4.36	b
	B	0.80	4.02	f
	C	0.57	1.77	f
3				
	A	0.80	4.19	f
	B	0.59	5.48	b
	C	0.69	2.67	f
4				
	A	0.86	5.75	b
	B	0.73	5.06	f
	C	0.77	5.30	b
5				
	A	0.87	2.56	f
	B	0.61	3.99	b
	C	0.00	4.79	f
6				
	A	0.78	4.81	f
	B	0.75	4.23	f
	C	0.75	4.31	b
7				
	A	0.46	5.71	f
	B	0.39	4.88	b
	C	0.76	3.15	f
8				
	A	0.78	2.14	b
	B	0.76	2.87	f
	C	0.62	4.72	f
9				
	A	0.56	3.27	b
	B	0.68	3.37	f
	C	0.70	5.03	b

Effects of verbal commentary on precision (λ)

Re-optimization of the remaining free parameters in HELM with precision (*λ*) assuming the same value for each stimuli resulted in a highly significant decrease in the goodness of fit statistic in all three matrices: ΔA: $x^2(8, N = 765) = 55.56$, p < .001; ΔB: $x^2(8, N = 765) = 42.90$, p < .001; and ΔC: $x^2(8, N = 765) = 47.01$, p < .001, as opposed to just two of the matrices (A and B) in Experiment 1. This suggests that the presence of a verbal commentary at encoding increases the extent to which inexact recall is more precise for some object locations than others.

Comparisons of mean *λ* predictions from HELM show a large increase in the precision of recalls in the presence of a verbal commentary (Experiment 2, mean = 4.16, *SD* = 1.16) when compared to the no commentary experiment (Experiment 1, mean = 2.81, *SD* = 1.63). This was confirmed by an independent t-test comparison of the precision predictions for each stimulus, $t(26) = -3.52$, p < .001. As the verbal commentary does not significantly increase the availability of recalls, this suggests that the main influence of the commentary is to increase the precision of the available location responses in memory.

Confidence ratings

Analysis of mean confidence ratings and mean *A* and λ parameter values revealed no significant correlations; *A*: $r(26) = 0.27$, ns[19], λ: $r(26) = 0.36$, ns (Figure 3.3). However, a moderate and highly significant correlation

[19] Removal of the outlier relating to the image *Speeding Protestors* results in a significant moderate positive correlation between mean confidence and mean *A*, $r(25) = 0.44$, p < .05.

was again witnessed between participants mean confidence ratings and their overall performance, indicated by RMS_c scores, r (26) = -0.69, p < .01 (Figure 3.4).

Figure 3.3: Mean Confidence with mean A and λ for each of the 27 real-world images in Experiment 2.

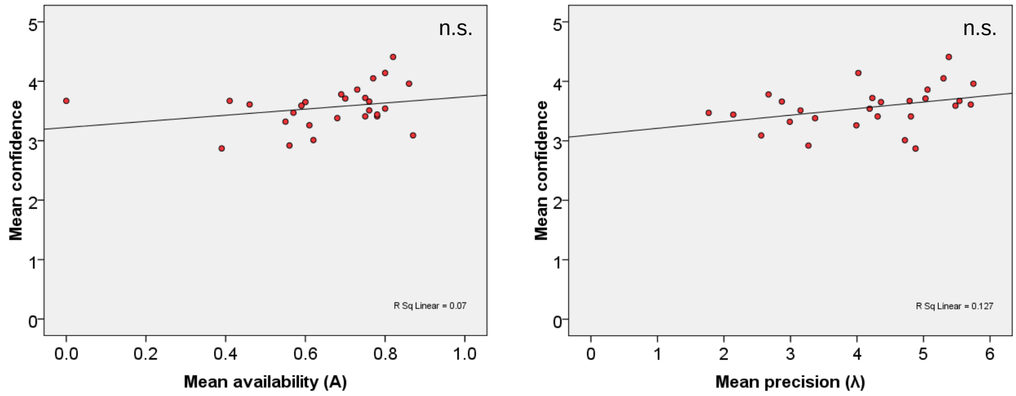
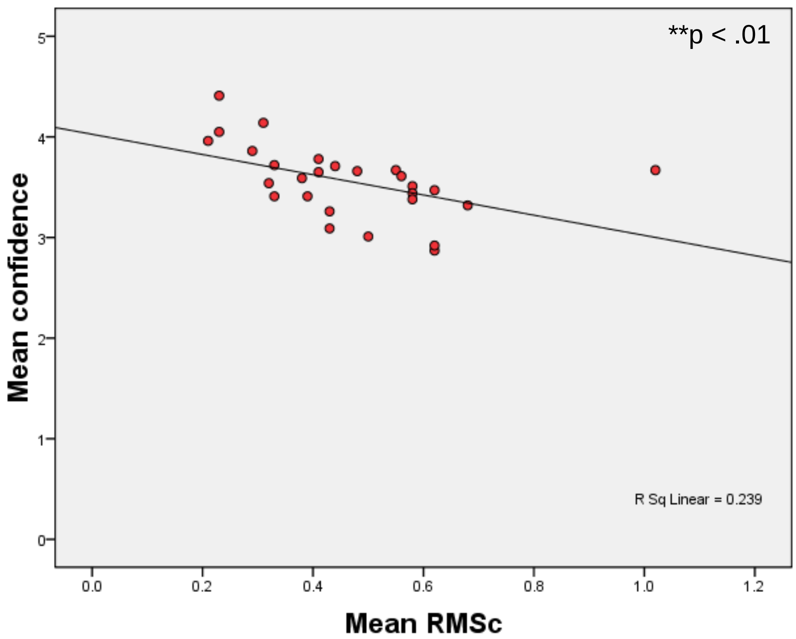
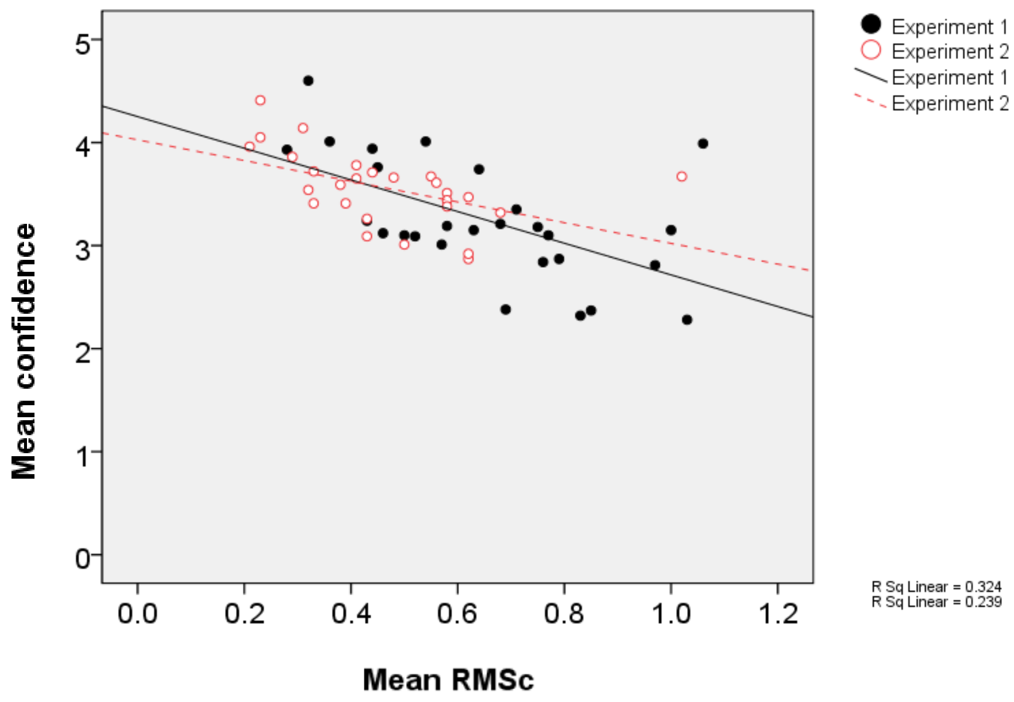


Figure 3.4: Mean confidence and RMS_c scores for all participants and all 27 pictures in Experiment 2.



By superimposing both sets of data from Experiment 1 (black) and Experiment 2 (red outline), one can see that the trend lines are very similar, as shown in Figure 3.5 below. The presence of additional verbal information at encoding is having the effect of improving overall performance (as shown by a general reduction in RMS_c scores). Furthermore, participants' mean confidence ratings across all 27 images are slightly higher for the verbal commentary condition of the present experiment (mean 3.56) than for the free-viewing condition of Experiment 1 (mean 3.25), a difference which is confirmed by an independent samples t-test, t (26) = -2.34, p < .05.

Figure 3.5: Mean confidence and RMS_c scores across all participants for each of the 27 pictures in Experiments 1 and 2.



Foreground and background items

Within the initial research by Lansdale and colleagues, mean levels of *A* were significantly higher in a free-viewing condition, yet with the provision of additional verbal information at encoding it was possible to eliminate this difference. The researchers concluded that visual attention was being focused on the most salient items within an image under conditions of free-viewing, resulting in an increase in the availability of location information, yet this availability benefit was eliminated in the presence of a verbal commentary, as it served to equalize attention across both foreground and background items.

Within Experiment 1 of this thesis, a mean increase in both *A* and λ was highlighted for target objects classed as foreground items, suggesting an effect of semantic saliency on levels of *A* and λ of inexact location information (although these differences were not statistically significant). With the presence of a verbal commentary at stimulus presentation, levels of availability were comparable between foreground and background target objects (foreground; mean A = 0.66, SD = 0.22, background; mean A = 0.65, SD = 0.13) t (25) = 0.07, *ns*. The foreground benefit was also eliminated in this second experiment for mean levels of precision, and in fact, precision was shown in this experiment to be slightly higher for background that foreground objects, (foreground; mean λ = 4.05, SD = 1.19, background; mean λ = 4.32, SD = 1.14) although did not represent a significant difference, t (25) = -0.58, *ns*. Furthermore, participants levels of confidence in their location judgements were significantly higher for foreground items in the free-viewing condition of Experiment 1, yet in the present experiment, although slightly higher for foreground items, confidence levels did not differ significantly (foreground; mean confidence = 3.62, *SD* = 0.35, background; mean confidence = 3.47, *SD* = 0.38), t (25) = 1.07, *ns*. These data suggest that the presence of a verbal commentary at stimulus encoding serves to equalize levels of both A and λ across foreground and background items, and also participants' confidence in the accuracy of their location judgements. In line with the previous findings, this is likely to be due to the verbal commentary having the effect of equalizing attention between both foreground and background items at encoding.

Summary

Experiment 2 served to investigate the nature of memory for location where attention was manipulated at encoding. The presence of a verbal commentary served to draw attention to the target object to be recalled, as well as equalise attention across objects classed as semantically salient (foreground items) or non-salient (background items). In line with previous research conducted by Lansdale, et al., (2005), it was hypothesised that the presence of a verbal commentary would serve to increase levels of performance (greater levels of both the A and λ of inexact recall) across all images and all participants, and reduce any effects of semantic saliency on recall performance.

The raw data revealed a substantial level of correct recall and near-miss error. A test of the homogeneity of responses across all images at each location value was statistically significant, suggesting that despite target objects residing in the same absolute location, individual images varied as a function of the accuracy of recall, or the distribution of recall error. Levels of both *A* and *λ* of inexact recall also varied across locations.

Alike the data from Experiment 1, HELM was unable to provide statistically significant model fits for the recall data elicited from the novel real-world images. As such, further analyses using the HELM model were conducted with an understanding that despite similar data trends, the responses elicited from the present stimuli were somewhat different for a number of images than responses gained in the previous study by Lansdale, et al., (2005). As hypothesised, the provision of a verbal commentary to participants at stimulus viewing served to increase overall levels of location memory performance. Mean RMS_c values for the present experiment were significantly greater than for Experiment 1. A slight increase in the *A* of inexact recall was noted, however, this was not significantly greater than for Experiment 1. However, levels of precision were substantially higher in this experiment, and represented a significant mean increase from 2.81 in Experiment 1, to 4.16 in Experiment 2. As the presence of a verbal commentary at encoding does not significantly increase mean availability of recall, the main influence of the commentary appears to be in the increase of the precision of the available location information in memory.

Participants mean confidence in the accuracy of their responses was higher with the presence of a verbal commentary. Data within Experiment 1 saw a correlation between participants' confidence in their accuracy of recall and the overall precision of their responses across each of the 27 real-world images. Although the present experiment revealed a similar pattern of results, the correlation between precision and confidence was non-significant. However, a highly significant correlation was demonstrated between overall performance levels (as indicated by RMS_c) and participants confidence ratings, and this was a slightly larger correlation than shown in Experiment 1 (r (26) = 0.69 as opposed to 0.57), which may be related to a tighter compression of RMS_c scores below 0.7 than was witnessed in the free-viewing condition of Experiment 1.

3.4 General discussion

Experiments 1 and 2 aimed to explore the nature of recall responses when testing memory for object location for a novel set of real-world images, and to assess the applicability of the HELM analytical methodology in quantifying the nature of location recall for these stimuli. What do these two experiments tell us about the nature of memory for location in complex real-world images? In a number of respects, the data strengthen much of what we already knew from previous investigations into memory for location in real-world images, as presented by Lansdale, et al., (2005). In other ways, however, the result pose some important questions regarding the variability of location memory as a function of individual image properties, and questions some of the fundamental assumptions of the HELM analytical model.

As a general trend, recall responses within these two initial experiments tend to be clustered both at and around the correct location value. In addition, participants demonstrate a bias against responding with location values at the periphery of the array. Both of these findings are in line with previous research testing cued-recall of object location for real-world images (Lansdale, et al., 2005). Also in line with the previous research, constraining exact recall (*E*) to zero did not significantly decrease model fits. Therefore the model does not require *E* to adequately model the location memory data derived from the present stimuli. Constraining both parameters of inexact recall (*A* and λ) was not tolerated by the model, confirming the initial that levels of both availability and precision are greater for some target object locations than others. Furthermore, the presence of a verbal commentary at encoding (Experiment 2) served to significantly increase the levels of inexact information available at recall, with greater mean levels of *A* and λ in the second experiment.

Also like the findings of the previous research by Lansdale and colleagues (2005), image composition in terms of the semantic salience of the target object (whether the target was classed as a foreground or background item) affected location recall, with higher mean availability and precision of recall for foreground over background items in the free-viewing condition of Experiment 1, although this was not a statistically significant difference.

Previous findings by Lansdale and colleagues (2005) highlighted an increase in the availability of inexact recall for foreground items, whereas findings of Experiment 1 suggested that the precision of recalls was marginally greater. For the free-viewing condition of Experiment 1, participants' confidence in the accuracy of their responses, were significantly greater for foreground as opposed to background items, an effect which was not replicated with the presence of a verbal commentary in Experiment 2. Unfortunately, as this comparison was not made within the original paper, it is not possible to make comparisons to the original data.

A fundamental difference is identified within the present research when compared to that of Lansdale, et al., (2005), in that model predictions are not as good as those for the original data. This may be attributable to individual differences in stimuli composition, which we know has a substantial impact on memory for object location (highlighted by the raw data of Experiments 1 and 2, as well as the previous analyses undertaken by Lansdale et al, 2005). Through an examination of the raw data for individual images, it becomes apparent that errors in location recall are not always near-miss in nature. For some images, clusters of errors are centred at locations distant from the target object location. For example in Experiment 1, some images offer recall errors concentrated either to the left (notably stimuli 2C and 3B) or to the right of the correct location (for example stimuli 5C, 8C and 7C). Stimulus 5C in particular shows a substantial bias towards errors being made at locations L2 and L3 as opposed to the correct location L5. As the HELM model assumes errors in recall will be clustered around the correct location, any violation of this assumption will reduce the goodness of fit of the model, substantially in some cases.

HELM was originally designed to model the location memory recall data elicited from highly artificial, carefully constructed simple stimuli such as a mug on a shelf (Lansdale, 1998). Although errors for simple stimuli may demonstrate near-miss errors centred on the correct target location value, why should we expect that this would also be the case for complex real-world pictures, which are highly dynamic in terms of the visual and semantic properties they contain? The assumption that HELM makes regarding the symmetrical distribution of errors around the correct location value is purely that, an assumption, although one which was also made by Huttenlocher, et al., (1991), based upon the recall of properties of simple stimuli. This is a perfectly valid assumption for that purpose, and enabled the data to be modelled adequately for these simplistic stimuli. Yet, the data from Experiments 1 and 2 suggest that memory for location may operate rather differently for complex natural stimuli.

Two important questions to pose at this point are; why should performance be *substantially* worse for particular images over and above other images? And, what is it about the nature of these images which impact upon the accuracy of ensuing location recalls? Upon closer inspection of the error distribution for a particular image in both Experiments 1 and 2 (image 5C, *Speed Campaigners*), it was evident that clusters of errors appear to coincide with the location of a large sign reading ‘Please drive slowly’ (Figure 3.6).

Figure 3.6: Image 5C: Image entitled *Speed Campaigners*, together with cued target location recall distributions from Experiments 1 and 2[20]. Correct target location is L5.

Image removed due to copyright restrictions

	L1	L2	L3	L4	L5	L6	L7	L8	L9	
Expt. 1	7	21	22	6	**3**	4	2	1	2	68
Expt. 2	7	24	3	13	**3**	3	0	1	3	85

Numbers in **bold** represent correct recalls.

Spatial judgements are known to be based upon information from multiple cues including relationships between objects, landmarks and boundaries, as well as prior schematic knowledge structures (Cheng, Shettleworth,

[20] Comparisons are made with the location memory data from Experiment 1 (normal viewing conditions) and Experiment 2 (additional verbal commentary at encoding).

Huttenlocher, & Rieser, 2007; Wang, Johnson, Sun, & Zhang, 2005). From a purely visual perspective, image 5C (*Speed Campaigners*) may offer viewers with a memory trace of a truncated image, whereby the poster redefines the image boundary. We know from previous research that fixations are likely to be made to informative regions of an image (Antes, 1974; Buswell, 1935; Mackworth & Morandi, 1967). Due to the size of the poster, following initial identification of this object, participants may allocate their attention to the remaining (perhaps more visually informative) region to the right of the poster, thereby assessing the image as a subsection of the overall scene. If this is the case, then the boy's face would be located towards the left of this subsection, which may account for errors in recall being made towards the left of the overall location array at recall.

Similarly, for stimulus 3B (*Dinosaurs at Buckingham Palace*) in Experiment 1, we would expect the target object (a chandelier at location L3) to generate near-miss errors at locations L2 and L4, yet in Experiment 1, clusters of errors are witnessed at locations L5 and L6. These locations correspond to an area occupied by large dinosaur sculpture in the image foreground. Interestingly for this image, in Experiment 2 (where a verbal commentary specifically draws the viewers attention to the target object for recall), the clustering of errors at L5 and L6 are eliminated (Figure 3.7) and recall becomes much more accurate for the target object. For image 5C (*Speed Campaigners*), however, the clusters of errors made by participants in Experiment 1 are not eliminated in the presence of a verbal commentary drawing attention to the target object in Experiment 2, which suggests that the processing of image 5C is somehow different to image 3B, an effect which may be related to visual cues and inherent allocentric representations within this particular image.

Figure 3.7: Image 3B: Image entitled *Dinosaurs at Buckingham Palace*, together with cued target location recall distributions from Experiments 1 and 2. Correct target location is L3.

Image removed due to copyright restrictions

	L1	L2	L3	L4	L5	L6	L7	L8	L9	
Expt. 1	1	4	**9**	9	23	13	5	1	3	68
Expt. 2	2	6	**40**	17	8	7	3	2	0	85

Numbers in **bold** represent correct recalls.

Recall data from these two images in particular suggests that in the absence of sufficient information being encoded, participants may, in error, make a location judgement based upon an object other than the target at recall. Yet why such confusions occur is less clear from the limited evidence offered by these two examples.

Ultimately, what is remembered from an image is closely linked to regions attended to during image encoding. Looking at dominant theories of attentional deployment, there are two main hypotheses which may account for the far-miss errors witnessed in location memory for real-world images. First, the visual saliency hypothesis states that attention is captured by areas of images whose local, low-level visual attributes differ significantly from the surrounding image attributes (Itti & Koch, 2000; Koch & Ullman, 1985; Treisman & Gelade, 1980). For image 5C (*Speed Campaigners*), should the poster be a visually salient object within the image, this would result in an increased likelihood that it will capture viewers' attention, which in turn may lead an increase in the likelihood of the location of this object being encoded and subsequently given as a response at recall. However, image 3B (*Dinosaurs at Buckingham Palace*) has a target object which is visually salient (a lit chandelier), yet the distribution of errors demonstrate very low levels of exact recall for this object (just 9 out of 68 responses), suggesting that visual saliency is not a key factor in influencing memory for location.

Equally plausible is the idea that the poster in image 5C may be highly semantically salient within the image. As discussed in detail within the introduction (Chapter 1), meaningful objects may provide a more psychologically plausible process of attention deployment over real-world, semantically rich images (Einhäuser, et al., 2008). Evidence from Experiment 1 demonstrates that foreground items elicit significantly higher levels of confidence in the accuracy of recall than background items, suggesting that these objects may be encoded to a greater degree (although this conclusion should be taken with some caution due to higher levels of mean availability and precision for foreground items failing to reach significance).

The contextual relevance hypothesis (Henderson, et al., 2009) places primary emphasis on knowledge-based control for the deployment of attention across a visual display. Within image 5C, the poster provides viewers with important information regarding the nature of the ‘protest’ taking place. As such, this object may capture viewers’ attention over and above other objects due to its contextual significance within the image, thus increasing the likelihood of this location being encoded and selected at recall. Similarly, image 3B demonstrates clusters of errors which fall at the location of a large dinosaur which is central to the nature of the scene the image is portraying (*Dinosaurs at Buckingham Palace*), as such, if cognitive relevance is driving viewers attention, this object is likely to be attended to more than the target object itself (a chandelier). Indeed, when a verbal commentary is presented at image viewing (Experiment 2), specifically directing viewers’ attention to the chandelier, levels of correct recall substantially increase (47% of all responses in Experiment 2 as opposed to just 13% in Experiment 1).

In summary, location memory for complex real-world stimuli is significantly more variable than that for simple stimuli (Lansdale, 1998), and to some degree, the complex stimuli selected for the present research appear to demonstrate greater levels of variability than the previously studied complex real-world stimuli of Lansdale, et al., (Lansdale, et al., 2005). These experiments highlight the discovery error distribution whereby for some images in particular, errors are centred on and around locations *other* than the target location. As a consequence, the HELM model has been shown to be inadequate to model location data derived from these complex real-world images. This finding is not surprising when we consider that the HELM model was originally designed to model location recall elicited from highly constructed stimuli, which exclude the range of possible semantic and visual dynamics involved in complex real-world pictures. For this reason, a reinterpretation of the way in which HELM is used to quantify the data for real-world stimuli is required. Furthermore, a detailed analysis of the way in which the visual and semantic content and complexity of naturalistic images affects memory for location should be pursued. The following chapters (4 & 5) aim to explore some of these specific theoretical issues in further detail.

Chapter four: effects of image content on memory for location

Abstract

To assess the impact of image content on memory for location, Experiment 3 sought to establish the 5 items or objects participants rated as being most ‘interesting’ within a set of complex real-world images. Analyses aimed to identify whether any relationship exists between these interesting items and errors participants make in cued-object location recall.

Data revealed substantial agreement amongst participants on the selection of interesting items. Comparisons between interesting item clusters and location recall data revealed a larger degree of concordance between interesting item clusters and the free viewing data of Experiment 1. Where accuracy of location recall was improved with additional verbal information at encoding within Experiment 2, levels of concordance between errors in recall and item clusters was reduced. A model of memory performance which considers interesting item clusters was shown to perform best when the cluster data were relevant to the corresponding images, rather than taken from a random image. These findings offer some limited suggestion that errors in location recall may correspond to the location of other interesting items at recall, particularly when location recall accuracy is poorer.

A fundamental assumption of the HELM model prescribes that errors in recall will be centred on the correct location value. Data from Experiments 1 and 2 both demonstrate that this is not always the case for the recall of object locations from complex real-world images. This novel discovery has indicated the need for reconsideration of the way in which HELM accounts for the distribution of recall error for object locations in real-world stimuli.

4.1 Introduction

Can 'interesting' items predict errors in recall?

One major consideration when modelling memory for object location is the variability in responses generated by individual images. Memory for location has been shown to vary across individual images in previous studies, even when target objects reside at the same absolute location (Lansdale, 1998; Lansdale, et al., 2005). Yet, the magnitude of error distribution highlighted within experiments presented in the previous chapter (Experiments 1 and 2) is far greater than in previous research with real-world images (Lansdale, et al., 2005). This in turn led to the inability of HELM to model the data for a number of the confusion matrices generated by these initial experiments. One particular hypothesis which may explain some of the variance in error distribution (based upon the observed data from Experiments 1 and 2) postulates participants may make errors in recall which correspond to other significant objects in previously viewed images.

A key advantage of the human visual system is the ability to rapidly understand the meaning of a previously unattended image, even if given only a single fixation (Potter, 1975). A single glance at an image has been shown to enable the extraction of information regarding objects (I. Biederman, Mezzanotte, & Rabinowitz, 1982; Fei-Fei, Iyer, Koch, & Perona, 2007; Rensink, 2000b; Wolfe, 1998) semantic information , for example emotional valence (Maljkovic & Martini, 2005) and spatial properties (Biederman, 1995; Biederman, Rabinowitz, Glass & Stacy1974; Oliva & Torralba, 2001; Schyns & Oliva, 1994).

Theories of eye guidance for the viewing of natural images have historically focused on low-level features or saliency to predict where fixations are likely to be made (Itti, Koch, & Niebur, 1998; Koch & Ullman, 1985; Parkhurst, et al., 2002). More recent evidence suggests that for real-world scenes, it is likely that the semantic content of the scene, the co-occurrence of objects, and task constraints all play a role in the modulation of attention and eye movements (Chun & Jiang, 1998; De Graef, 1992; Henderson, 2003; Oliva, Torralba, Castelhano, & Henderson, 2003; Torralba, Oliva, Castelhano, & Henderson, 2006a; Yarbus, 1967). Although saliency may predict initial fixations, cognitive mechanisms are likely to override this with eye movements directed towards informative objects during scene viewing (Foulsham & Underwood, 2008; Henderson, et al., 2009; Land & Hayhoe, 2001; Torralba, et al., 2006a; G. Underwood, Foulsham, van Loon, Humphreys, & Bloyce, 2006). As viewing times within the experiments presented throughout this thesis are substantial enough (between 10-20 seconds) to warrant detailed inspection, it is important to consider where attention will be deployed across images over time.

It has long been demonstrated that when viewing a scene, observer fixations will be directed upon informative foreground objects, including people (Buswell, 1935; Yarbus, 1967) and areas of interest (Mackworth &

Morandi, 1967). What is encoded and retained in memory however is less clear. A number of studies have demonstrated our immense capacity to recognise substantial numbers of previously viewed images, even when presented only for a brief period, (Nickerson, 1965; Shepard, 1967; Sperling, 1960; Standing, 1973; Standing, et al., 1970). As such, our visual memory is clearly capable of quickly extracting sufficient information regarding images to enable recognition on second presentation. One hypothesis which has been pursued by a number of researchers investigating scene recognition memory is the extraction of scene gist. Gist is often defined as the essence or identity of a scene (Rensink, 2000a), or its central theme, (Potter, Staub, & O'Conner, 2004).Oliva (2005) suggests that the gist of an image contains information regarding the spatial layout of the scene, whereas Henderson & Hollingworth suggest that gist can encompass, "layout, and perhaps the abstract identities of recognized objects" (Henderson & Hollingworth, 2002, p.116). The extraction of gist from an image or scene is fast, stored within memory, and available for comparison should the task require (see van Montfort, 2006 for a review). Furthermore, the gist of an image has been shown to remain within memory for up to eight weeks from initial image viewing (Homa & Viera, 1988). The concept of scene gist highlights the importance of spatial layout for rapid scene understanding.

Object-centred theories of visual processing suggest that objects form the basis of scene analysis (Biederman, 1987; Biederman, Blickle, Teitelbaum, & Klatsky, 1988; Marr, 1982; Pylyshyn, 1999), with scene recognition emerging through the local processing of object identities, object co-occurrence and the spatial arrangements between them. Objects are entities which deliver meaning. They are central to the understanding of scenes (Oliva & Schyns, 2000; Potter, 1975; Schyns & Oliva, 1994) and the spatial regularity between them has been shown to play an important role in the retrieval of visual information from memory (Alvarez, Konkle, & Oliva, 2007). Jiang and colleagues demonstrated that when the spatial layout of a display is disrupted between study and test phases, this interferes with the retrieval of both location and object information (Jiang, Olson, & Chun, 2000).

A study conducted by Lansdale, Underwood & Davies (2010) examined experts and non-experts eye movements when undertaking the highly specialised task of inspecting Ordinance Survey maps for changes, and making spatial location judgements about particular map sections. Findings suggested that while novice viewers tended to use salient features to guide fixations, experts relied upon semantically salient features such as roads or geographical boundaries, to guide fixations. It is argued that these features provide experts with specific landmark information from which the spatial location of objects could be cognitively represented, resulting in significantly better location memory performance on the task than the untrained viewers. The way in which experts represented these semantically salient features within memory is unknown, yet the authors propose that salient features are spatially encoded with little effort when inspecting an image, enabling more accurate judgements of location to be made with reference to these landmarks at recall (M. W. Lansdale, et al., 2010). It could be argued that we are all experts in viewing natural real-world scenes, and as such, it may be the case that we are able to store previously viewed real-world images in a manner which preserves the layout of semantically salient features within memory. Should this be the case, then it could be argued that target object retrieval failure may result in participants select the wrong feature of a previously viewed image in place of the target object at recall.

Although it is clear from previous research that memory for location is subject to a number of influencing factors and biases, only near-miss errors have been previously encountered within the literature surrounding complex real-world images (Lansdale, et al., 2005). The location recall data from Experiments 1 and 2, however, demonstrate clusters of error at locations distant to the target location value across a number of individual real-world images. It is hypothesised that these clusters of error (or far-miss errors) correspond to the locations of other key objects within real-world images, and that the errors are as a result of participants confusing these key objects with the target object at recall. Should object confusions take place in Experiments 1 and 2, then *a priori* knowledge of the locations of the key features (objects) in real-world images may allow us to predict (at least to some degree) where the observed ‘far-miss’ errors may fall.

To this end, the present chapter aims to specifically address this issue with a comparison of the key objects in an image and the distribution of error in Experiments 1 and 2. To identify the key objects within the present stimuli, Experiment 3 asks participants to select the 5 most interesting objects or items within each of the 27 real-world pictures (stimuli set A). Through the examination of the errors distributions for location recall in Experiments 1 and 2 and the objects viewers deem to be ‘interesting’ in the present experiment, it may be possible to inform the distribution errors people make in their judgements of target object locations.

4.2 Experiment 3:

Methods

Stimuli and Materials

Image set A (27 complex real-world images) were provided to participants in the form of laminated, full-colour picture cards, each measuring 9.5cm x 14.5cm. Participants were also provided with an answer booklet in which to record the 5 most interesting objects within each of the images. An example of the answer booklet is presented within Appendix 7.

Participants

19 undergraduate students (2 male, 17 female), age range 18-35, mean = 21 years 10 months, from Nottingham Trent University, Nottingham, UK, took part in return for course research credits, or a payment (£3). All

participants were screened for normal/corrected to normal vision, and none had taken part in previous experiments using the same stimuli set.

Procedure

Participants were provided with the picture cards and an answer booklet. The front page of the answer booklet contained the following instructions to participants:

> This study is designed to identify which features or qualities of newspaper images make them effective pictures. You will be given a set of 27 pictures taken from newspapers, in the form of picture cards. Please view each picture in turn; there will be no time limit for the viewings. After looking carefully at each picture, please use the answer booklet attached to write down the 5 most interesting items or objects in that picture. Please ensure you have 5 items for each of the 27 pictures and that no spaces are left blank.

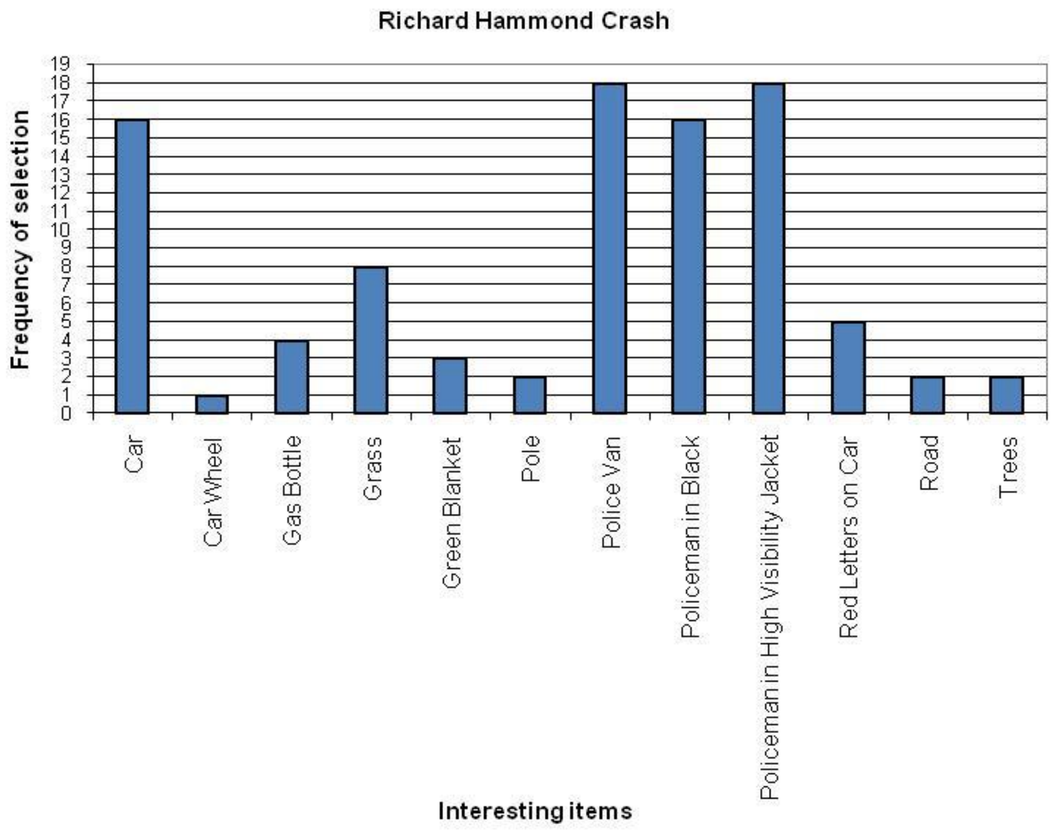
Prior to commencing, participants were told they could use this time to ask any questions regarding their participation in the study. Participants were then asked to complete a consent form containing full details of the Experiment, their right to withdraw, and the anonymous nature of the collected data. Participants were then asked to complete the response booklet in their own time.

Results

Selection of interesting items

Data were collated for each individual image based upon the items selected as interesting and the frequency of their selection. A chart indicating the selected items and frequency of selection was generated for each of the 27 images (Appendix 9). The first point to note is that the frequency bar charts demonstrate a high concordance between participant selections for a small number of objects for each of the images. For the present example, which will be used throughout this chapter for consistency, (see Figure 4.1, which represents image 7C, entitled *Richard Hammond Crash*), there are four notable objects (a car, a police van and two police officers), which almost all participants select as being interesting items (minimum 16, maximum 18, mean 17 participants). The number of objects selected by more than 50% of participants (frequencies of 10 +) across all 27 stimuli ranges from 3 to 6 items, (mean = 4.6, SD = 0.97).

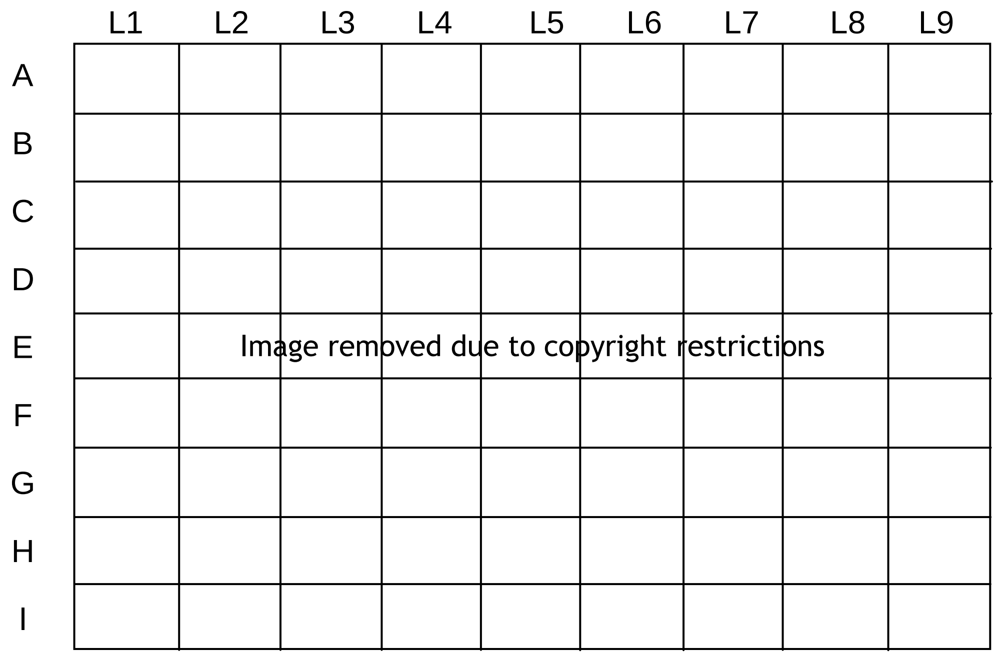
Figure 4.1: Exemplar bar chart indicating items selected as interesting and frequency of selection across all participant responses for image 7C entitled *Richard Hammond Crash*.



Location of interesting items

Images were sub-divided into 9 equal partitions on the horizontal and vertical axes for the purpose of analysis. This provided a total of 81 location segments for each image. An example of this segmentation is provided in Figure 4.2.

Figure 4.2: Exemplar image 7C entitled *Richard Hammond Crash* divided into 81 equal location segments. The target location for this image in Experiments 1 & 2 was L7.



The objects rated by participants as interesting were then collated in a frequency matrix representing these 81 cells (Figure 4.3). Where a named object spans a number of these image segment cells, then the cell representing the absolute centre of that object was selected in order to maintain consistency of cell selection among responses from individual participants. A total of 19 participants each rated the five most interesting objects within each image, resulting in a total of 95 individual selections per image. Frequency matrices for all 27 stimuli are presented within Appendix 10.

Identification of interesting item clusters

Assuming a random distribution of interesting item locations, the binomial distribution indicates that observed frequencies of more than 3 responses per cell are unlikely, with a cumulative probability of $p = .02$. Therefore, we assume frequencies of 4 and above to represent significant levels of agreement between participants. Nevertheless, we know that memory for location is subject to various forms of bias, the most common being a bias against responses at the periphery of the array (centripetal bias). To make allowances for these considerations and to ensure that estimates are conservative, the number of cells we assume to operate was generously reduced to 45 (in effect excluding the two peripheral location columns on either side of the array), and the binomial recalculated based upon the reduced range of cells. Based upon 45 cells operating, the binomial distribution indicates cell frequencies of 5 or more would constitute significantly more responses than would be expected by chance ($p = .04$). Cells demonstrating frequencies of selections greater than would be expected by chance will subsequently be referred to as interesting item clusters (see Figure 4.3).

Figure 4.3: Exemplar table representing interesting item selection frequencies in image 7C entitled *Richard Hammond Crash*. Figure in red corresponds to selections which fall on the target for recall in Experiments 1 & 2, shaded squares represent the locations of the 5 most salient image features.

	L1	L2	L3	L4	L5	L6	L7	L8	L9
A									
B							18		
C		3							
D			1						
E		15	3		5		16		
F		2		2	1	1			
G				2	10	2	1	3	
H	1		1						1
I					5		2		

Analysis 1: Interesting item clusters and saliency

It is conceivable that participants' selection of interesting items may be dictated by highly salient regions of an image. Indeed it would be surprising should key objects within an image not be salient (Elazary & Itti, 2008). For this reason, an additional level of analysis was conducted on each of the 27 real-world images in stimuli set A to investigate any relationships between interesting items and highly salient regions in the present stimuli. Using the Matlab Saliency Toolkit (Walther & Koch, 2006) which was based upon the Itti, Koch & Niebur (1998) implementation of the saliency map-based model of bottom-up attention by Koch & Ullman (1985), saliency maps were created for each of the 27 images. These saliency maps (computed using Matlab 2008a) identified the 5 most salient regions of each image as defined by colour, intensity and orientation. The saliency maps and the 5 computed salient regions can be found within Appendix 11. The saliency predictions were than attributed to relevant cells of the 81 image segments of each image. As with the selection of interesting items, should a salient region span cells, then the cell representing the central point of the salient region was selected. Computed frequency tables representing the saliency regions in relation to the 81 cell segments for each image are presented within Appendix 10 (see example in Figure 4.3).

Cells indicating interesting item clusters (frequencies of 5+) were compared with cells containing salient features in order to identify whether any relationship could be demonstrated between the two. For each image, 2 x 2 matrices were generated which identified the frequencies of cells containing neither salient features nor interesting item clusters, cells containing a salient feature, cells containing a cluster and cells containing both. An example 2 x 2 matrix, together with the predicted frequencies assuming homogeneity, is presented within Figure 4.4.

Figure 4.4: Exemplar 2 x 2 matrix showing frequencies of the 81 cells for image 7C entitled *Richard Hammond Crash* adopted by nothing, interesting item clusters, salient features, or both, together with predicted frequencies assuming homogeneity.

		Salient features: Absent	Salient features: Present	Total
Interesting item clusters	Absent	72	5	77
	Present	4	0	4
	Total	76	5	81

Predicted frequencies assuming homogeneity

70.37	4.63
5.63	0.37

A test of homogeneity across all image matrices only reached significance for 4 of the 27 stimuli (Image 9B *Camel Train*; x^2 (1, N = 81) = 4.05, p < .05, Image 7A *Climbing Frame*; x^2 (1, N = 81) = 4.05, p < .05, Image 8C *Training*; x^2 (1, N = 81) = 4.05, p < .05 and image 2B *Lipstick*; x^2 (1, N = 81) = 6.64, p < .01), all other matrix tests produced non-significant results. A summed test for homogeneity across all images however did just reach significance, x^2 (27, N = 2187) = 44.17, $p < .05$. Nevertheless, should interesting item clusters and saliency be related, then this should be most evident in comparisons between saliency and highly significant clusters. As such, the analysis was conducted again with clusters defined as cells containing frequencies of 7 or more selections (binomial distribution p = .01). For the highly salient clusters and saliency, a test for the homogeneity of responses across all image matrices only reached significance for 2 out of the 27 stimuli (Image 4B *Marie Antoinette*; x^2 (1, N = 81) = 5.53, $p < .05$, and image 7A *Climbing Frame*; x^2 (1, N = 81) = 6.64, $p < .01$), with all other tests producing non-significant results. A summed test for homogeneity across all images remained non-significant, x^2 (27, N = 2187) = 35.76, *ns*, suggesting no association between saliency and highly significant clusters of interesting items. As such, analyses suggest that it is unlikely that clusters of interesting items are related to the 5 most salient regions of an image.

Analysis 2: Interesting item clusters and error in location recall

In order to examine whether any relationships exist between interesting item clusters and errors in recall, the degree of concordance between interesting item clusters in Experiment 3 and the location recall data from Experiments 1 and 2 was determined. It should noted however that this is a substantially difficult task giving that we presume the recall data from Experiments 1 and 2 consists of three key elements; memory for the correct location, response bias, and responses based upon locations of other objects within the scene (clusters). The present analysis was therefore conducted with the understanding that clusters may only account for a proportion of the observed responses.

Data revealed, unsurprisingly, that the recall data from Experiments 1 (free viewing) and Experiment 2 (verbal commentary), although significantly different from one another, offered the most similarity (concordance between Experiments 1 and 2 location recall: x^2 (216, N = 4131) = 683.89, p < .001; concordance between Experiment 1 recall and Experiment 3 clusters: x^2 (216, N = 4131) = 1292.58, p < .001; concordance between Experiment 2 recall and Experiment 3 clusters: x^2 (216, N = 4131) = 1921.39, p < .001). However, for four of the 27 images, the degree of concordance was greatest between the recall data from Experiment 1 and clusters from Experiment 3; Images 1A: Charity Run, x^2 (8, N = 153) = 39.25, p < .001; 4C: Taiwan Toilet Restaurant, x^2 (8, N = 153) = 36.15, p < .001; 7A: Climbing Frame, x^2 (8, N = 153) = 19.20, p < .001; and 9C: Horse Racing, x^2 (8, N = 153) = 40.37, p < .001, which suggests that clusters are most predictive of the distributions of error in recall for these particular images in the free viewing condition of Experiment 1.

Analysis 3:Which experimental data best represent target location values?

In an attempt to identify which set of data (recall data from Experiments 1-2 or cluster data from Experiment 3) best represents the target location value being elicited for each of the stimuli at recall (Experiments 1 and 2), the distribution of the data was represented in terms of the RMS_c deviation of the data from the correct location value for each image in each

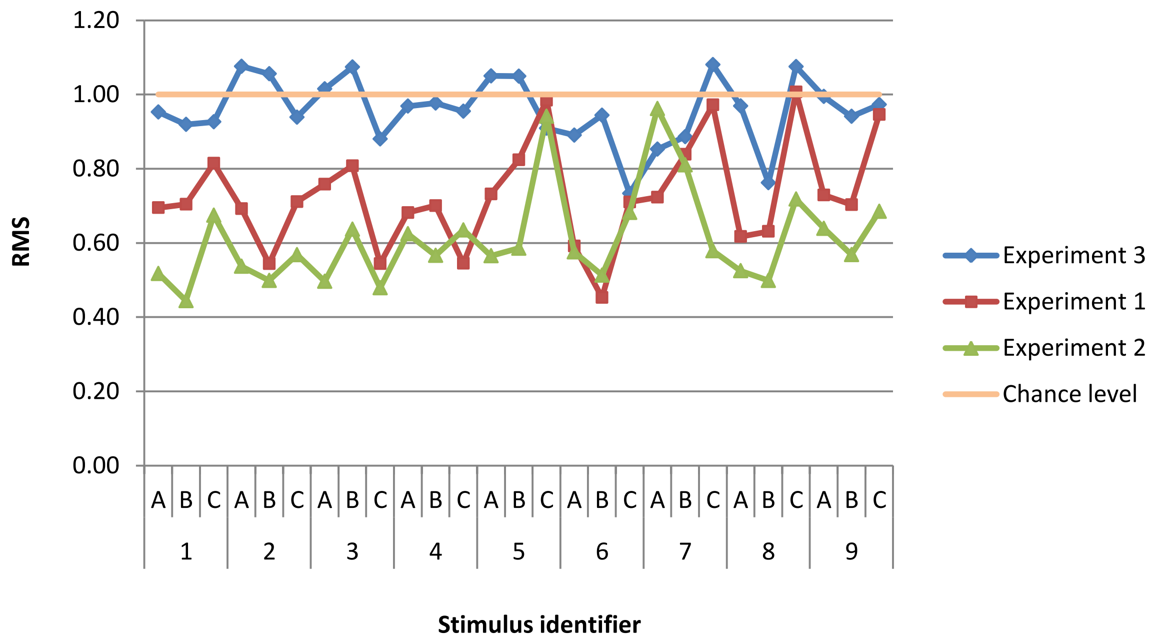
Experiment (see Table 4.1). An overall comparison of these RMS_c scores was made for each image, which were then ranked in terms of their accuracy to the correct location value. Data revealed that 24/27 of the pictures showed the largest level of concordance to the correct location value in the data elicited from Experiment 1. The second largest level of concordance with the correct target location was Experiment 2, with 4/27 images demonstrating data distributions which closely matched the correct location value. The lowest levels of concordance were witnessed between the correct location value and the cluster data from Experiment 3, with just 1/27 images demonstrating data distributions which were closest to the correct location value. This suggests that interesting item clusters are not predictive of correct location responses, and that the recall data from Experiment 2 (which we know is more accurate than the data from Experiment 1 from analyses conducted within Chapter 3) offers the best concordance with correct location values.

Table 4.1: RMS_c deviation from the correct location value for interesting item clusters (Experiment 3) and location recall in Experiments 1 and 2 for each of the 27 images in stimuli set A.

Target location and stimulus identifier		RMS		
		Experiment 3	Experiment 1	Experiment 2
1	A	0.95	0.70	0.52
	B	0.92	0.70	0.44
	C	0.93	0.81	0.67
2	A	1.08	0.69	0.54
	B	1.06	0.54	0.50
	C	0.94	0.71	0.57
3	A	1.02	0.76	0.50
	B	1.07	0.81	0.64
	C	0.88	0.54	0.48
4	A	0.97	0.68	0.62
	B	0.98	0.70	0.57
	C	0.95	0.55	0.63
5	A	1.05	0.73	0.57
	B	1.05	0.82	0.59
	C	0.91	0.98	0.94
6	A	0.89	0.59	0.58
	B	0.94	0.45	0.51
	C	0.73	0.71	0.68
7	A	0.85	0.72	0.96
	B	0.89	0.84	0.81
	C	1.08	0.97	0.58
8	A	0.97	0.62	0.53
	B	0.76	0.63	0.50
	C	1.08	1.01	0.72
9	A	0.99	0.73	0.64
	B	0.94	0.70	0.57
	C	0.97	0.95	0.69
Average		0.96	0.73	0.61

Data distributions in Experiment 1 fall somewhere between Experiments 2 and 3, which is what we would expect given that overall levels of performance are greater with the presence of a verbal commentary in Experiment 2. This may therefore suggest that where performance is lower (Experiment 1), errors in recall may sometimes adopt the locations of interesting item clusters. This can be visualised within figure 4.4. Yet it should be clear that these analyses are far from conclusive, given the complexity of the location recall data and the numerous factors thought to impact upon memory for location. It therefore cannot be ruled out that these results may have occurred purely by chance.

Figure 4.5: RMS_c deviation from the correct location value for interesting item clusters (Experiment 3) and location recall data from Experiments 1 & 2 in each of the 27 images from stimuli set A.



Analysis 4: Do interesting item clusters influence recall?

Although interesting item clusters are not predictive of correct target locations, where performance is lower (Experiment 1) data suggests that performance lies somewhere between the more accurate performance of Experiment 2, and the interesting item clusters within Experiment 3. An example of this may be witnessed within image 7C (*Richard Hammond Crash*). Figure 4.3 (above) highlights the largest interesting item selection frequencies at horizontal locations L2, L5 and L7, with the target object being the police officer dressed in black at location L7 (Figure 4.6). When we compare this to the location recall data from Experiment 1 (free-viewing condition), we can see that a number of far-miss errors are observed at L3 (count = 24). Interestingly, this also corresponds to a high interesting item frequency of selection within Experiment 3. Yet, the majority of these far-miss errors are eliminated in Experiment 2, where recall performance becomes much more accurate (the majority of responses fall as near-miss errors at location L6). It may therefore be the case for this particular image that participants are confusing the two police officers in memory, and selecting the wrong officer (albeit with some level of near-miss error resulting in responses centred at L3 instead of L2) when cued for recall in the free viewing condition of Experiment 1, a confusion which is prevented within Experiment 2 with the provision of additional information in the form of a verbal commentary.

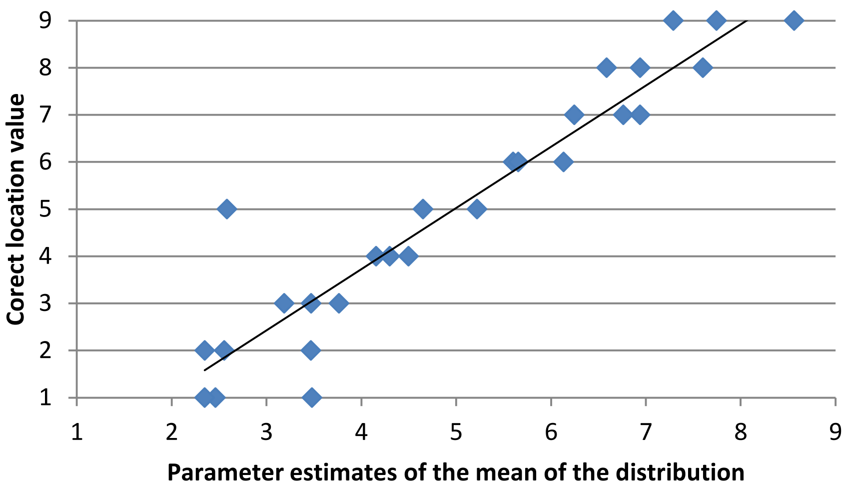
Figure 4.6: Exemplar image 7C (*Richard Hammond Crash*) together with location memory data from Experiments 1 and 2 (target location = L7) and interesting item selections across locations L1-L9 for each of the 27 images (stimuli set A).

Image removed due to copyright restrictions

	L1	L2	L3	L4	L5	L6	**L7**	L8	L9
Experiment 1	2	3	24	7	7	11	**8**	6	0
Experiment 2	2	4	4	6	4	54	**9**	0	2
Experiment 3	1	20	5	4	21	3	**37**	3	1

A second stage of analysis sought to examine the influence of interesting items on errors in location recall through a process of modelling recall performance in Experiments 1 and 2 using an estimate of the mean of the distribution of responses and its standard deviation (SD). Using a relatively small number of parameters, this cluster model provides estimates of the mean location for recall which are close predictions of the correct location value (Figure 4.7).

Figure 4.7: Correspondence between correct location value and parameter estimates of the distribution mean, for each of the 27 images in stimuli set A, as generated by the cluster model.



The model was used to generate estimates of the proportion of information available to participants in Experiment 1 (parameter PM1) and how much of the subsequent remaining information is added by the verbal commentary in Experiment 2 (parameter PM2). The remaining responses were then modelled as a proportion of guesses based upon the distribution of interesting item selections from Experiment 3 (parameter Pcluster,). The balance of guesses based upon bias and interesting items is optimised by the model to achieve the best sum of squares fit for each of the 27 images. Pcluster parameter values which are positive indicate there is some recall of the locations of other objects taking place. Where Pcluster values are zero, recall is deemed to be too high for those particular stimuli for the errors to demonstrate any correspondence to other significant objects. Model parameter estimates are presented within Table 4.2.

Table 4.2: Cluster model parameter estimates for each of the 27 images in stimuli set A and goodness of fit statistics for models with true and false cluster estimates applied.

Target location and stimulus identifier		Parameter estimates					Goodness of fit x^2	
		Mean	SD	PM1	PM2	Pcluster	True	False
1	A	2.46	1.10	0.35	0.93	1.00	531.86	624.94
	B	2.35	0.62	0.43	0.61	0.20	36.33	39.92
	C	3.48	0.32	0.09	0.59	0.00	118.80	118.81
2	A	2.55	0.92	0.32	0.72	0.37	83.50	101.99
	B	2.35	0.77	0.51	0.73	1.00	158.14	222.79
	C	3.47	0.39	0.33	0.44	0.00	21.89	21.89
3	A	3.47	0.53	0.54	0.46	0.38	30.22	48.08
	B	3.19	0.50	0.00	0.53	0.00	267.02	267.01
	C	3.76	0.60	0.74	0.00	0.00	20.16	18.88
4	A	4.15	0.48	0.45	0.78	0.10	28.36	28.62
	B	4.30	0.52	0.74	0.15	0.00	29.53	25.91
	C	4.50	0.05	0.00	0.79	1.00	724.31	1036.29
5	A	4.65	0.93	0.53	0.41	0.04	78.54	59.07
	B	5.22	0.90	0.40	0.66	0.00	177.44	166.72
	C	2.58	0.94	0.78	0.21	0.37	35.00	32.88
6	A	6.13	0.73	0.46	0.80	0.61	58.90	79.42
	B	5.60	0.72	0.92	0.00	0.11	46.55	31.25
	C	5.65	0.46	0.00	0.66	0.18	79.80	94.88
7	A	6.94	0.48	0.17	0.45	0.60	191.67	208.42
	B	6.76	0.69	0.05	0.43	0.00	109.02	475.30
	C	6.24	0.34	0.00	0.64	0.00	230.28	214.07
8	A	6.59	0.54	0.51	0.59	0.72	195.49	211.38
	B	6.94	0.69	0.53	0.57	0.55	134.99	160.07
	C	7.60	0.47	0.06	0.55	0.00	85.18	85.18
9	A	7.29	1.99	0.53	1.00	0.43	160.65	162.58
	B	7.74	0.58	0.39	0.29	0.38	83.23	95.02
	C	8.56	0.32	0.00	0.62	0.24	118.42	153.31
	Average						142.05	177.21

Comparisons were then made between optimised model fits generated using Pcluster values which were true (relating to the same image), or false (relating to a random image). The data reveal better model fits when the Pcluster data being matched was relevant to that picture (average goodness of fit across all images: $x^2 = 142.05$) than when the cluster data was from an image selected at random (average goodness of fit across all images: $x^2 = 177.21$). This was the case for 19 of the 27 individual images; data is presented within Table 4.2. A paired t-test confirmed that the two sets of model estimates were significantly different from one another t (26) = -2.01, $p < .05$.

4.3 General discussion

Examinations of the raw recall data for images with the lowest overall levels of performance in Experiments 1 and 2 suggest that errors which do not constitute near-miss errors may fall at the location(s) of other significant objects within an image. This led to a consideration that far-miss errors in recall may be attributable (at least to some degree) to image content.

Suppose when presented with an image under free-viewing conditions, a viewer generates a mental representation of the spatial locations of key objects within that image (a form of spatial-map of the scene), yet does not always encode sufficient detail regarding object identities. Far-miss errors may reflect instances whereby if sufficient information is not available to make an accurate selection from this spatial map, participants select the location of an object other than the target object at recall. The experiment presented within this chapter aimed to assess whether the objects participants define as key interesting items within a scene demonstrate any relationship to the errors participants make in the recall of cued target object locations in Experiments 1 and 2.

Initial analyses of the items selected by participants as interesting drew three broad conclusions. First, participants demonstrate high levels of agreement in their selection of interesting items, with the majority of participants selecting the same 3-6 objects per image. Second, these object selections could not simply be attributed to highly salient regions of an image. Third, clusters of interesting items do not correspond to correct location values.

An examination of the levels of concordance between interesting object clusters and Experiments 1 and 2 suggest that location recall data from Experiment 1 are *most* like the interesting item selections, whereas recall performance in Experiment 2 is more accurate and demonstrate less concordance with interesting item selections. Further analyses using a model of recall performance for the location recall data within Experiments 1 and 2 suggests that models adopting image-relevant cluster data perform significantly better than models using cluster data from a random image. These analyses offer (albeit limited) suggestion that errors made in the recall of location may adopt the location of other interesting objects within real-world images, especially in situations where recall performance is reduced (Experiment 1). It is important to note at this point that this finding was demonstrated despite comparisons being made to the absolute location of interesting item selections made within Experiment 3, without taking into account that location recall responses to interesting items are themselves likely to be prone to error. Given time, an interesting additional analysis would be to replicate these model estimates, substituting the parameter Pcluster for a parameter based upon the salient regions of each image. Although unlikely, it is not possible to identify from the analyses conducted so far whether salience plays a role in the distribution of location recall error witnessed within Experiments 1 and 2.

A reconsideration of the HELM model

The findings presented within this chapter offer limited support to account for the origins of far-miss errors witnessed in Experiments 1 and 2. However, the issue still stands that the presence of errors distant to the correct location value result in the inability for HELM to adequately model the location memory recalls generated by the present set of complex real-world stimuli. The assumption that errors in recall will be centred on the correct location value results in statistically different model fits for the majority of the data observed within Chapter 3, and as such, a reconsideration of the way in which HELM accounts for the distribution of location recall error for real-world images was required. This is not surprising when we take into consideration the HELM model was initially designed to model location recall data from highly simplistic stimuli. The distribution of error for these simple stimuli have been shown to manifest themselves as correct responses or near-miss errors. Subsequently, HELM model estimations for such data have been shown to be highly robust (Lansdale, 1998). For complex real-world images however, the presence of errors which do not constitute near-misses pose a substantial problem to this model, rendering it unable to provide estimations which were not significantly different from the observed error distributions.

A new version of HELM is therefore proposed, which will be referred to as HELM2. This model allows for the mean of the error distribution to vary away from the target location where required based upon an optimisation of the mean value of the error distribution. As with HELM, HELM2 provides an estimation of the availability of location information in memory, yet due to the ability for the mean to vary, this estimate is often higher in HELM2 as it may sometimes include information from locations other than the correct location value.

Whereas the distribution of error in HELM was modelled using a Poisson distribution of gradual information gain, it was identified through the application of a number of model variations that a Gaussian distribution of error was fit for the purpose of modelling the data derived from complex real-world images. As such, for the purposes of computational simplicity, HELM2 addresses the quantification of precision in recall using the standard deviation (SD) of the data distribution from the mean value. A larger SD of the distribution is indicative of a decline in the precision of those responses. It should be noted that the estimates of precision within this model hold less psychological meaning than the estimates within HELM, yet still provide an indication regarding the spread of responses relative to the centre of the error distribution. Implementations of HELM2 to model the recall data of both complex and simple real-world images are presented within subsequent chapters of this thesis.

Chapter five: effects of image complexity on memory for location

Abstract

When presented with a complex image, individuals can often have very different interpretations of the same visual scene (O'Connor & O'Connor, 1999). The spatial properties of an image, however, are universal, and it has been demonstrated that the cognitive cost of encoding location information is low (Hasher & Zacks, 1979). As such, we may expect the relative semantic and visual complexity of an image to have little effect on memory for location. Nevertheless, there is a substantial body of evidence to suggest that both emotional valence and image complexity affect memory for visual detail (e.g. Hamann & Cahill, 1997; Mandler & Parker, 1976). Furthermore, it has been identified within literature (Goldstein & Chance, 1970; J. M Mandler & Johnson, 1976) and in previous chapters of this thesis, that memory for location is affected by image-specific features.

Four experiments are presented in which the effects of semantic complexity (Experiments 4a & 4b), and object density (Experiments 5 and 6) on subsequent memory for the location of cued objects within real-world scenes are examined. Findings from Experiments 4a & 4b demonstrate that for scenes displaying threatening relationships, participants foreshorten the estimation of space between two objects significantly more than for scenes displaying neutral object-relations. Data from Experiments 5 and 6 reveal that both the availability of location information and the precision of object-location responses are greater for simple, single-object images as opposed to multiple-object complex real-world scenes. Taken together, these findings suggest that both the semantic and visual complexities of images impact upon memory for the cued location of target objects within them.

5.1. Effects of semantic complexity on memory for location

Introduction

In evolutionary terms, an important role of our attention system is to focus on information relevant for dealing with critical demands (Eccleston & Crombez, 1999; Lang, Bradley, & Cuthbert, 1990). Studies investigating the interaction between emotion and memory have largely been concentrated on the impact of either *valence* (the stimuli's subjective emotional value) or *arousal* (participants' subjective opinion of how intense or exciting the stimuli are). Both of these attributes have been linked to memory enhancement (Hamann & Cahill, 1997; Phelps, 2004).

Enhanced memory for emotional events has been linked to four main factors, all of which are suggested to be associated with a heightened state of emotion or arousal:

1. Increased activation of the amygdala (Windmann & Kutas, 2001).

2. The capture of attention (Cahill, Babinsky, Markowitsch , & McGaugh, 1995; Cahill & McGaugh, 1995, 1998; Estes & Adelman, 2008; Hamann, 2001).

3. Binding of emotional stimuli to context (MacKay et al., 2004; Mather & Nesmith, 2008).

4. The distinctiveness of the stimuli (Ochsner, 2000).

In a study of induced valence, Cahill & McGaugh (1995) presented participants with 12 images (slides) including a picture of badly scarred legs. As they viewed the slides, taped narratives were played to the participants, which were either neutral or arousing in nature. In the neutral condition, the image of the scarred legs was described in the narrative as an actor made-up for a disaster drill, whereas in the arousal condition, the image was described as a boy who has had to have his feet reattached by surgeons. Findings showed that participants in the arousal condition recalled more story elements than participants in the neutral condition.

It may be the case that memory for negative material may be enhanced due to the attention-grabbing nature of the stimuli. Rapid detection of relevant threat stimuli have been shown with faster detection times for fear-relevant (snakes) than fear-irrelevant (flowers) pictures (Öhman, Flykt, & Esteves, 2001). Evidence suggests that the processing of threatening and arousing information is prioritised within our attentional system; with processing of such stimuli is fast (Globisch, Hamm, Esteves, & Öhman, 1999), and it interferes with the ongoing processing of other information (Hartikainen, Ogawa, & Knight, 2000; Tipples & Sharma, 2000; Vuilleumier, Armony, Driver, & Dolan, 2001).

Studies into memory for neutral and negative words, however, are highly variable in their findings. Some of the studies report that memory for negative words is greater than for neutral words, (Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004; Hamann, 2001; Kensinger & Corkin, 2003; Ochsner, 2000; Pesta, Murphy, & Sanders, 2001), whereas others report that negative words are remembered less accurately (Danion, Kauffman-Muller, Grange, Zimmermann, & Greth, 1995; Dougal & Rotello, 2007; Maratos, Allan, & Rugg, 2000). Dougal & Rotello (2007) argue that negative stimuli simply produce a larger response bias than neutral stimuli which, they argue, may account for the inconsistencies in reported effects.

One set of experiments conducted by Mather and Nesmith (2008), focused on the effects of arousal on memory for the location of pictures. Following an incidental encoding task, participants were more likely to remember the locations of positive and negative arousing pictures than non-arousing pictures (Figure 5.1). Yet, findings from their four separate experiments suggest that this arousal-enhanced location-picture binding is not due to the arousing stimuli drawing attention for longer than non-arousing stimuli. The authors therefore argue that emotionally arousing stimuli might be more effectively bound with their features in initial perception.

Figure 5.1: Examples of matched pairs of similar non-arousing (left column) and arousing (right column) pictures from the negative high arousal set used by Mather & Nesmith, (2008)[21]. Images were sourced from the International Affective Picture System (IAPS: Lang, 1995).

Frames of reference

Representations of space are often referred to being either egocentric, where objects are judged relative to the viewer, or allocentric, where judgements are made regarding the location of objects relative to other items in the scene in which they occur (e.g. Pani & Dupree, 1994). The majority of work in spatial cognition to date has been concerned with the role of *landmarks* in the allocentric estimation of location. Landmarks represent salient objects or features which can facilitate the encoding of

[21] Image reproduced with the permission of Elsevier.

location by serving as reference points from which spatial knowledge can be organised (Sadalla, et al., 1980). Research has shown that landmarks do not have to be explicit. Subjective landmarks such as horizontal and vertical quadrant divides within a circle (Huttenlocher, et al., 1991) have been shown to influence memory for the relocation of a dot. Boundaries have also been shown to influence spatial memory. For example, in the dot relocation task, position of the dot is likely to be placed closer to the border of the circle. Nelson and Chaiklin (1980) proposed the weighted-distortion theory explaining the effects of the border on memory for position. The theory postulates that boundaries or borders lead to more accurate coding of dots proximal to them, there is a systematic bias in memory for position towards such features (the *attraction effect*), and that the magnitude of this bias increases relative to the distance away from the border.

Inter-object relations

Some more recent work by Green & Hummel (2006), suggests that object pairs which demonstrate interactive relationships may be perceptually grouped. The *functional relationship hypothesis* suggests that the identification of objects within a scene may be influenced by the relationships between them (Green & Hummel, 2004, 2006). Experiments demonstrated that object identification was better for those objects which were shown to be related and working together (for example, a jug orientated towards a glass) than objects which were unrelated and did not demonstrate an interaction (e.g. a jug orientated away from a nail). It has been identified in previous work that the encoding of location accompanies object identification (Henderson, Weeks, & Hollingworth, 1999; Hollingworth & Henderson, 2002a; Mandler, Seegmiller, & Day, 1977; Mou, Zhang, & McNamara, 2004), and although the functional relationship hypothesis is yet to be tested in real-world stimuli (the authors used line drawings of household objects), the authors argue that object detection in multi object scenes cannot be solely in terms of semantics or object layout. Perceptional and/or attentional grouping processes governed by observer's knowledge about the functional relationships between objects should also be considered.

Experiments 4a and 4b explore the effects of inter-object relationships on memory for object location. Specifically these experiments assess whether negative threat-victim relationships between two objects within an image affect judgements of cued objects locations over and above a spatially matched neutral object interaction (Figure 5.2). In light of the known evidence suggesting an attentional bias to threat, and an object identification benefit for interacting objects, should top-down attentional factors play a role in the encoding of location, then it would be expected that different patterns in the distributions of error will be demonstrated between the two conditions at recall.

Figure 5.2: Exemplar image pair entitled *Dog and Hare* with objects (spatially matched on the horizontal axis) demonstrating neutral (top) and threat (bottom) relationships.

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5.2. Experiments 4a & 4b: Semantic complexity

Methods

Stimuli and materials

Full details of the experimental stimuli and methods employed within Experiments 4a and 4b are presented in Chapter 2.

Participants: Experiment 4a

A total of one hundred and twenty six participants took part in the Experiment. Participants (108 female, 18 male) were either undergraduate students from the University of Leicester, or University staff/affiliates recruited using the University of Leicester's eBulletin weekly news email. Participants took part in return for course research credits or a payment of £3. All participants were screened for normal/corrected to normal vision. Participants were randomly allocated to either the threat or the neutral stimuli conditions providing sixty-three participants per condition. For the threat condition, 7 participants were male and 56 were female, with an age range of 18-45 years and a mean age of 19 years 10 months. For the neutral condition, 11 participants were male and 52 were female, with an age range of 18-32 years and a mean age of 19 years 7 months.

Participants: Experiment 4b

A total of one hundred and twenty participants (83 female, 37 male) took part in the Experiment. Participants were either undergraduate students from the University of Leicester, or University staff/affiliates recruited using the University of Leicester's eBulletin weekly news email. Participants took part in return for course research credits or a payment of £3. All participants were screened for normal/corrected to normal vision. As with Experiment 4a, participants were randomly allocated to either the threat or the neutral stimuli conditions providing sixty participants per condition. For the threat condition, 22 participants were male and 38 were female, with an age range of 18-51 years and a mean age of 24years 11 months. For the neutral condition, 15 participants were male and 45 were female, with an age range of 18-74 years and a mean age of 25 years 7 months.

Procedure

In Experiment 4a, the target object for the threat stimuli was randomly selected to be either the threat object or the victim object. A spatially matched counterpart image cued for location of one of two neutrally related objects occupying the same absolute location as the target in the threat image. Cued target objects were reversed in Experiment 4b to ensure that both the threat and the victim objects within the threat stimuli were elicited for recall across the two experiments. This was necessary to ensure that any effects of target object selection were able to be adequately assessed.

For both Experiments 4a and 4b, participants were instructed as follows:

> This experiment is designed to identify which features or qualities of real-world images make them effective

> pictures. You will be shown a series of nine pictures, and as a final test of effectiveness of these images, we will test your ability to remember the location of one of the objects shown in the picture. Please click a mouse button to begin the experiment

Dependent on the allocation to condition, either the nine threat or neutral images were shown to participants, in a random order, for a duration of 20s per image. Following a 5 minute Sudoku puzzle distracter task participants were asked to recall the location of a missing target item from an edited version of the stimuli where the target object had been removed (recall stimuli are presented in Appendix 4: Experiment 4a, and Appendix 5: Experiment 4b). Instructions for the recall task were as follows:

> You will now be presented with nine response screens. Each screen will show one of the images you have previously viewed with one item missing. The missing item will be named at the top of the screen. Please use the mouse to click on the exact point in the image where you believe the missing item appeared. You will then be asked how confident you feel about the location response you have given. To resume the experiment, please click a mouse button.

Participants were allowed as much time as required to complete the 9 location responses. Following each location response, participants were presented with a screen asking for a confidence judgement for the location they had chosen on a scale of 1 (blind guess) to 5 (absolutely sure).

Results

Analysis 1: The impact of testing for missing objects

As the stimuli used within the present experiments were largely un-complex in nature (containing only two salient objects), and given that participants had a vast amount of contextual information presented to them at recall, it is likely that participants judgements of the location of target objects will be more accurate than, for example, the target object location responses generated for complex real-world images within Experiment 1, where responses were elicited by way of an empty response grid.

In order to assess levels of accuracy relative to complex real-world images, comparisons of the overall recall performance, as indicated by RMS_c scores, were made between the recall data from the present experiments and that from Experiment 1. Not all target locations were represented within Experiments 4a and 4b, and as such, comparison of the mean RMS_c were only made for those locations tested.

As anticipated, location judgements were more accurate in the present experiments than for the complex images presented in Experiment 1 (for the same target locations) as demonstrated in Tables 5.1 and 5.2[22]. Data were screened for any extreme outliers, none of which existed.

Table 5.1: Comparison of Mean RMS_c Scores for Experiment 1 (Stimuli Set A: Complex images) and Experiment 4a (Stimuli Set C: Threat and Neutral images) for all images with target locations of L2, L4, L5, L6 and L7[23].

Experiment 1	Experiment 4a	
	Neutral	Threat
0.61	0.12	0.23

Table 5.2: Comparison of Mean RMS_c Scores for Experiment 1 (Stimuli Set A: Complex images) and Experiment 4b (Stimuli Set C: Threat and Neutral images) for all images with target locations of L2, L3, L4, L7 and L8.

Experiment 1	Experiment 4b	
	Neutral	Threat
0.62	0.21	0.20

[22] For purposes of comparison, values reported are average RMS_c scores across all images testing location recall at each of the relevant locations in Experiments 1, 4a and 4b.
[23] The experimental design of Experiments 4a and 4b dictate that not all locations are occupied by target objects. As such, comparisons are made only across those locations tested in Experiments 4a and 4b, as indicated in the Table captions.

Effect of inter-object relationships on judgements of location

In order to identify whether the threat-victim relationship between objects affected memory for location the mean distance of the target object location response (in locations) relative to the remaining cue object at recall was calculated for each of the images in the threat and neutral conditions as follows:

$$mean\ distance = \frac{Number\ of\ responses\ x\ distance\ from\ cue\ in\ locations}{total\ number\ of\ responses}$$

Comparisons of mean distances for each condition in both Experiments 4a and 4b are presented in Figures 5.3 and 5.4. Figure 5.3 indicates that judgements of the location of the target object in both the neutral and the threat condition are placed closer to the remaining cue object at recall that is physically true (mean distances for each condition are lower than the actual distance). Yet the mean distances of target object location responses from the cue are consistently lower in the threat condition (green bars) than the neutral condition (red bars) for responses to all stimuli within Experiment 4a. Data from Experiment 4b, however, (Figure 5.4) differ somewhat from this trend, with just five out of nine stimuli demonstrating smaller mean distance from the cue in the threat condition, and four of the stimuli (highlighted in bold) demonstrating the reverse effect. Actual and mean distances to the remaining cue object for location responses for both Experiments 4a and 4b are presented in Tables 5.3 and 5.4.

Figure 5.3: Chart showing actual distance and mean recall response distance from cue for each of the 9 stimuli in Experiment 4a

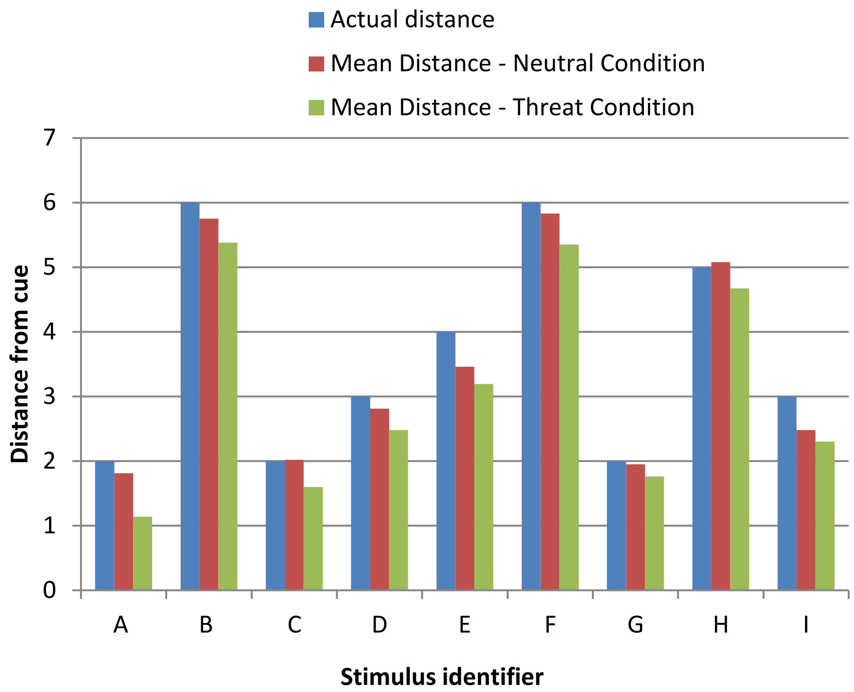


Figure 5.4: Chart showing actual distance and mean recall response distance from cue for each of the 9 stimuli in Experiments 4b.

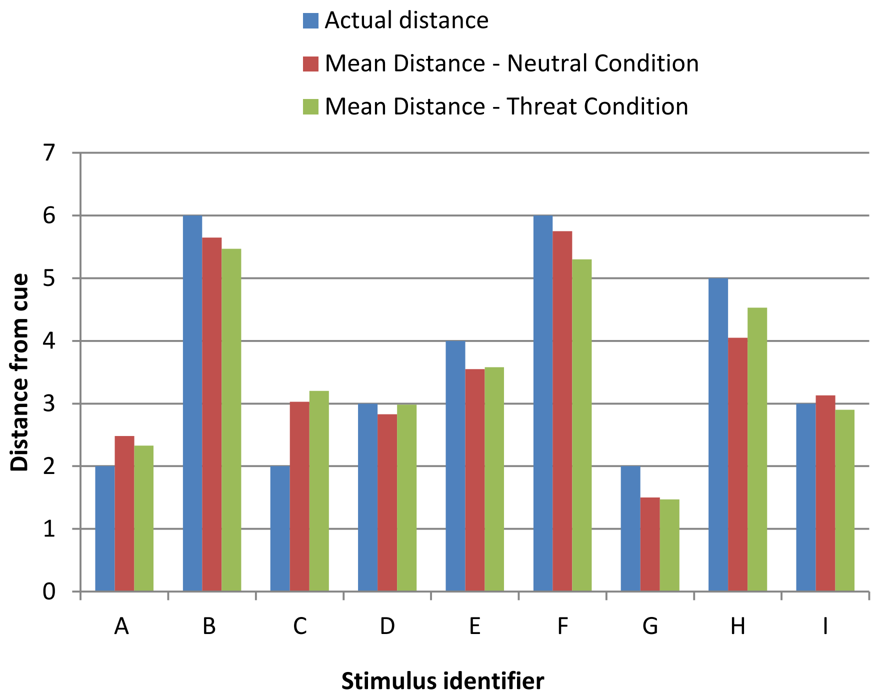


Table 5.3: Mean distance of target location response from the cue object in Experiment 4a.

Stimulus identifier and title	Actual distance	Neutral condition	Threat condition	Difference
1 Arrested	2	1.81	1.14	0.67
2 Bird Shoot	6	5.75	5.38	0.37
3 Dog and Hare	2	2.02	1.60	0.41
4 Fighting Silhouette	3	2.81	2.48	0.33
5 Knife Chase	4	3.46	3.19	0.27
6 Lion and Gazelle	6	5.83	5.35	0.48
7 Matador	2	1.95	1.76	0.19
8 Rabbit and Fox	5	5.08	4.67	0.41
9 Surfing	3	2.48	2.30	0.17
Average	3.67	3.46	3.10	0.37

Table 5.4: Mean distance of target location response from the cue object in both neutral and threat conditions for Experiment 4b.

Stimulus number and title	Actual distance	Neutral condition	Threat condition	Difference
1 Arrested	2	2.48	2.33	0.15
2 Bird Shoot	6	5.65	5.47	0.18
3 Dog and Hare	2	3.03	3.20	**-0.17**
4 Fighting Silhouette	3	2.83	2.98	**-0.15**
5 Knife Chase	4	3.55	3.58	**-0.03**
6 Lion and Gazelle	6	5.75	5.30	0.45
7 Matador	2	1.50	1.47	0.03
8 Rabbit and Fox	5	4.05	4.53	**-0.48**
9 Surfing	3	3.13	2.90	0.23
Average	3.67	3.55	3.53	0.02

In 14/18 cases across the two experiments, the mean distance of location judgements are lower for recall of target objects in threat images. Due to the fact that all participants in each experimental condition (4a and 4b) were tested for the recall of location in both threat and neutral images, paired samples t-tests were used to identify whether this difference was statistically significant. For experiment 4a, where all of the mean distance of location judgements were lower for the threat images than for the neutral images, a paired samples t-test revealed a highly significant difference between responses for threat and neutral counterbalanced images, $t(8) = 7.52$, $p<.001$. However, for Experiment 4b, where 4 of the 9 comparisons demonstrate mean distance of location judgements to be lower in the neutral images, the difference between judgements for neutral and threat images did not reveal a significant difference, $t(8) = 0.26$, $p=.803$. These data therefore suggest that participants foreshorten the estimation of space between the two objects within the threat condition more often than would be expected by chance in Experiment 4a, although this effect is not witnessed in the reversed image recall scenarios of Experiment 4b. It is clear that this effect cannot be attributable to the type of object selected as the cue for recall in the threat condition (i.e. cue being either the "threat" or the "victim" object) as both threat and neutral objects are equally represented within these four images (as shown in Table 5.5). It may therefore be the case than individual image composition has resulted in the variability in results witnessed here, an issue which will be returned to in detail within the discussion.

Table 5.5: Cued target object identity in Experiments 4a and 4b.

Stimuli	Experiment 4a	Experiment 4b
1 Arrested	Threat	Victim
2 Bird Shoot	Victim	Threat
3 Dog and Hare	Victim	Threat
4 Fighting Silhouette	Victim	Threat
5 Knife Chase	Threat	Victim
6 Lion and Gazelle	Threat	Victim
7 Matador	Victim	Threat
8 Rabbit and Fox	Threat	Victim
9 Surfing	Threat	Victim

Comparisons of the mean distance of location judgements relative to the cue across all stimuli were shown to be lower for the neutral condition in both Experiments 4a (mean actual distance = 3.67 locations, mean for the neutral condition = 3.46, mean for the threat condition = 3.10) and 4b (mean actual distance = 3.67 locations, mean for the neutral condition = 3.55, mean for the threat condition = 3.53). However independent t-tests revealed that neither these (Experiment 4a: t (16) = 0.47, *ns*; Experiment 4b: t (16, N = 9) = 0.49, *ns*) nor a summed comparison of the responses across both experiments (t (34, N = 18) = 0.40, *ns*) resulted in a statistically significant difference.

Effects of threat on the accuracy of location recall

Indications of performance were generated across the two conditions of each experiment using RMS_c. RMS_c values are presented within Table 5.6.

Table 5.6: RMS_c values for all stimuli across both threat and neutral conditions in Experiments 4a and 4b.

	Experiment 4a		Experiment 4b	
Stimuli	Neutral	Threat	Neutral	Threat
1 Arrested	0.14	0.28	0.21	0.18
2 Bird Shoot	0.09	0.20	0.17	0.23
3 Dog and Hare	0.09	0.17	0.46	0.51
4 Fighting Silhouette	0.08	0.22	0.13	0.11
5 Knife Chase	0.20	0.32	0.17	0.22
6 Lion and Gazelle	0.05	0.23	0.10	0.23
7 Matador	0.07	0.21	0.21	0.27
8 Rabbit and Fox	0.14	0.21	0.29	0.16
9 Surfing	0.21	0.23	0.24	0.14
Average	0.12	0.23	0.22	0.23

Average RMS_c values shown in table 5.6 reveal that overall location memory performance is greater for the neutral condition in both experiments, although comparisons in Experiment 4b are marginal (neutral condition mean RMS_c = 0.22, threat condition = 0.23). This was confirmed by independent t-tests demonstrating a highly statistically significant difference in Experiment 4a, t (16) = -4.60, $p < .001$, but no significant difference in Experiment 4b, *t* (16) = -0.15, *ns*. 5.5 and 5.6[24] indicate performance across both conditions of the two experiments. However a summed comparison of RMS_c values between neutral and threat conditions across the two experiments remained statistically significant: *t* (34) = -1.94, p < .05, indicating that overall, recall performance was better for object locations in the neutral images.

Figures 5.5 and 5.6 demonstrate the RMS_c values for each stimulus in each experiment. Individual stimuli tested are represented by an identifying number along the x-axis of each figure. It is evident from the RMS_c scores that overall levels of performance are very similar in nature across each of the stimuli in the neutral and threat conditions of each experiment. This is important as although we are testing the same absolute location in each condition, it should be emphasised that memory is being elicited for two different images in the neutral and threat conditions.

For Experiment 4a (Figure 5.5), there is a clear difference between levels of performance, with consistently lower RMS_c values (greater overall accuracy of recall) for stimuli demonstrating neutral relationships. For Experiment 4b (Figure 5.6), this effect is seen for stimuli 2, 5, 6 & 7, although there are high levels of variability in performance across individual stimuli tested here. Stimuli 3 (*Dog and Hare*) poses a particular issue in each condition within this experiment (two images representing either a dog and a rock, or a dog chasing a hare). Location recall

[24] Note that the x-axis relates to individual stimuli and not locations tested for recall in Figures 5.5 and 5.6.

performance for the target object in each condition is substantially lower than for any of the other stimuli. Yet, data suggest that this may be an artefact of particular image properties of this stimuli pair, an issue which will be returned to in detail within the general discussion.

Figure 5.5: RMS_c deviation of responses from the correct location value for each of the stimuli within Experiment 4a.

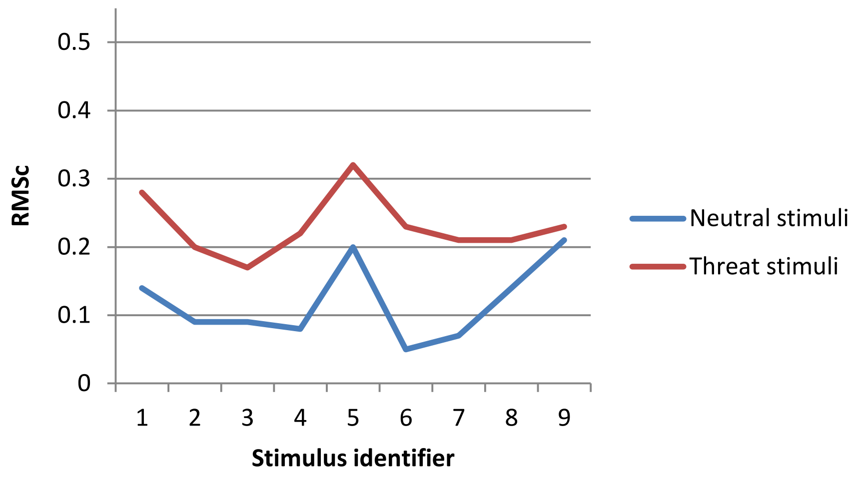
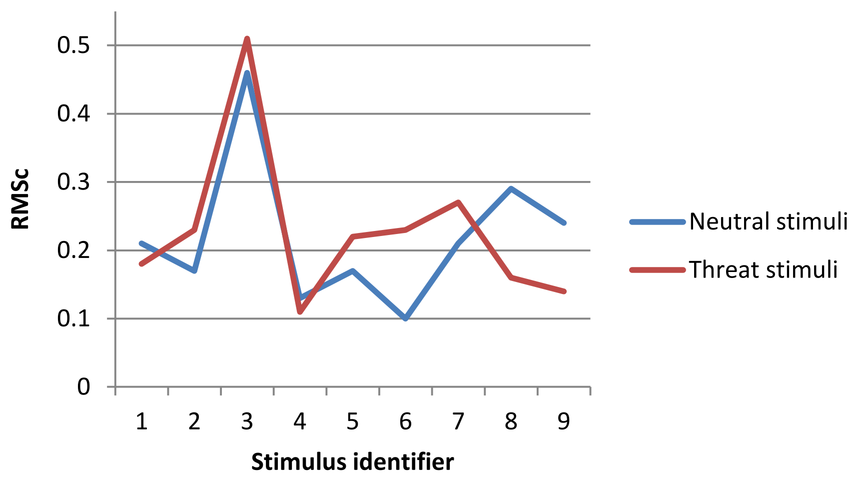


Figure 5.6: RMS_c deviation of responses from the correct location value for each of the stimuli within Experiment 4a.



Confidence in recall accuracy for neutral and threat stimuli

It has been suggested that judgements in levels of remembered information and confidence at recall are higher for emotional stimuli than neutral stimuli, despite no increase in accurately remembered detail (Talarico & Rubin, 2003). Data in Table 5.7 shows that participants' average confidence in the accuracy of their location recall was lower for the threat stimuli in both Experiments 4a (neutral = 4.21, threat = 3.94) and 4b (neutral = 4.26, threat = 4.10). This indicates that over all of the 18 image comparisons across the two experiments, participants were, on average, less confident in their location judgements in the condition in which their performance was less accurate (closer to the cue object at recall).

Table 5.7: Mean confidence for both neutral and threat conditions in Experiments 4a and 4b.

	Experiment 4a		Experiment 4b	
Stimuli	Neutral	Threat	Neutral	Threat
1 Arrested	3.94	3.95	4.20	4.58
2 Bird Shoot	4.29	4.22	4.12	3.80
3 Dog and Hare	4.33	4.37	3.97	3.92
4 Fighting Silhouette	4.06	3.84	4.28	4.03
5 Knife Chase	3.84	3.81	4.47	4.00
6 Lion and Gazelle	4.67	4.02	4.58	4.17
7 Matador	4.41	2.90	4.33	4.03
8 Rabbit and Fox	4.19	3.98	4.37	4.42
9 Surfing	4.19	4.35	4.03	3.93
Average	4.21	3.94	4.26	4.10

This was confirmed in Experiment 4a with an independent t-test, t (18) = 1.82, $p < .05$, yet for Experiment 4b, the test did not quite reach significance, t (18) = 1.73, $p = .053$. Further tests revealed that confidence was comparable across both experiments, with no significant differences displayed between the confidence ratings for individual stimuli in either the neutral (t (18) = -0.50, *ns*) or threat conditions (t (18) = -1.06, *ns*).

Comparisons of mean confidence and overall levels of performance (as indicated by RMS_c) revealed that for the neutral stimuli within each experiment, mean confidence was moderately negatively correlated with RMS_c for each of the stimuli, yet only reaching significance within experiment 4a (Experiment 4a: r (18) = -0.69, $p < .05$; Experiment 4b: r (18) = -0.64, *ns*) which indicates, as previous experiments have suggested, that participants are more confident in their location judgements as they become more accurate in recall. However, for the threat stimuli, this was not the case, the negative correlations between RMS_c were small, and did not reach significance in either case (Experiment 4a: r (18) = -0.16, *ns*; Experiment 4b: r (18) = -0.32, *ns*). These correlations are visualised within Figures 5.7 and 5.8. This suggests that although confidence in recall is related to recall performance for the neutral stimuli, participant's confidence is not a good predictor of their performance for those images which display threat-victim relationships between the target and cue objects.

Figure 5.7: Comparisons of mean RMS_c and mean confidence per stimulus in both threat and neutral conditions of Experiment 4a.

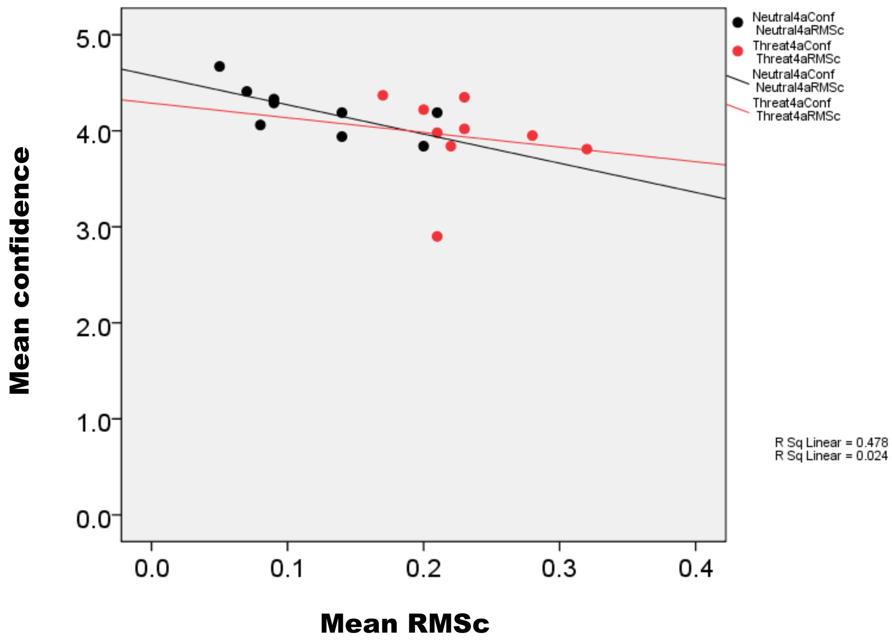
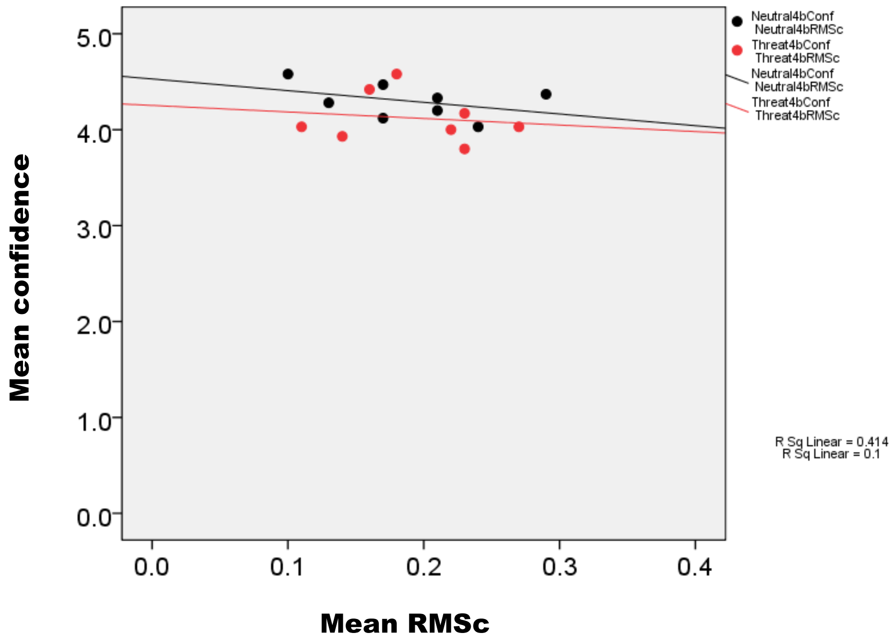


Figure 5.8: Comparisons of mean RMS_c and mean confidence per stimulus in both threat and neutral conditions of Experiment 4b.



Summary

The present experiment sought to identify whether the semantic inter-object relationships in an image affect memory for the recall of target objects relative to the remaining cue object at recall. The findings from these initial exploratory studies are three-fold.

1. 14/18 comparisons highlight an effect of participants foreshortening the estimation of space between threat-victim objects over and above that witnessed for the estimations of space between neutral objects at recall.

2. Comparisons of mean RMS_c scores across all stimuli and both experiments indicate lower levels of recall performance for threat stimuli.

3. Although confidence and recall accuracy are moderately correlated for location recall within the neutral relationship condition, the relationship between these two factors is substantially lower for threat-victim images.

Findings highlight an effect of semantic image complexity on memory for the recall of cued-target object location in real-world images, whereby the presence of threat-victim inter-object relationships diminish both overall levels of recall accuracy, and also the relationship previously witnessed between confidence and location memory performance in natural stimuli. A full consideration of these theoretical findings is presented within the general discussion at the end of this chapter.

5.3 Effects of object density on memory for location

Introduction

One of the key findings by Lansdale et al. (2005) regarding memory for real-world images was that increase in stimulus duration from short (5-10 seconds) to long (20-30 seconds) resulted in an increased number of object locations available in memory. The researchers attribute this increase in available memory to an increase in picture attributes eliciting attention with longer viewing times. This interpretation follows a well-established trend within the literature which points to increased exposure to a stimulus leading to increased memory because more information about the details of the picture are encoded and retained at the longer intervals, (Loftus & Bell, 1975a; Potter & Levy, 1969; Potter, et al., 2004; B. Tversky & Sherman, 1975).

In order for any type of spatial memory to be formulated, some kind of reference frame must be available to the viewer from which to make a judgement. *Egocentric* frames of reference refer to those in which location is specified with reference to the viewer. *Allocentric* frames of reference on the other hand are those in which location is specified with reference to other objects, features or landmarks in which the location is specified (Bryant & Subbiah, 1994). In both the present and previous experimental chapters of this thesis, individual image content has been shown to play a major role in the variation of errors in recall for cued target locations at both a visual (Experiments 1 and 3) and a semantic (Experiments 4a and

4b) level. Furthermore, Experiments 4a and 4b serve to highlight differences in the accuracy of location recall as a function of the semantic relationship between the objects. Previous (unpublished) work by Lansdale & Cole (2006) concludes that the manipulation of real-world picture content to include more objects has the effect of enhancing the accuracy of location memory . These findings suggest that objects within images are coded and remembered relative to each other (allocentric frames of reference), and that an increase in the number of reference frames available increases the likelihood of an object location being more accurate. Nevertheless, research by Baguley, et al., (2006) concludes that individuals are unable to use two reference frames simultaneously when judging the relative location of an object in memory.

Published data is currently confined to the examination of location memory in terms of complex real-world images (Lansdale, et al., 2005), and we know from data derived from the experiments conducted thus far that the content of complex real-world images may in fact have a detrimental effect on memory for cued target location. Experiments 1 and 3 highlighted the possibility for object confusions within complex real-world images at recall, and Experiments 4a and 4b suggest that semantic properties of an image may affect recall, resulting in biased responses for images demonstrating threatening relationships. By examining memory for location in simple real-world images which contain only one specific object (the target object for recall), one would assume that by removing the possible biasing effects of semantics and object confusions, recall for the location of these individual objects may demonstrate greater levels of accuracy than objects in complex counterpart images. On the other hand, the content of an image provides viewers with allocentric frames of reference from which to form a spatial representation. By presenting viewers with a relatively simple image (for example, a real-world image containing only one definable object), opportunities to form allocentric frames of reference are reduced, which may in turn lead to less accurate location recall (Wang, et al., 2005).

The experiments presented within this section of the present chapter aim to examine the effects of object density on memory for location. Experiment 5 aims to identify effects of image complexity on levels of availability and precision using stimuli which are highly simplistic in nature. Stimuli chosen for the purposes of Experiment 5 contain only one target object, with a relatively undifferentiated (yet naturalistic) background. Data are compared with the location recall data for multiple-object, complex images (Experiment 1) in order to identify any effects of image complexity (in the form of object density) on levels of availability and precision of location memory. The definitions of simple and complex images are discussed further within Chapter 2, and were selected by the researcher. Independent analysis of simple and complex images was not deemed necessary due to the simplicity of these definitions. A further Experiment (Experiment 6) provides a within-participant direct comparison of location memory for both simple and complex stimuli in order to ensure that the data generated by Experiment 5 (simple images) are not simply an artefact of adopting a slightly different experimental design to that in Experiment 1 (complex images).

5.4 Experiments 5: Memory for simple real-world images

Method

Stimuli and Materials

This experiment uses 27 single-object real-world images (stimuli set B) as described in Chapter 2. The 27 simple real-world images were arbitrarily split into 3 sets of 9 at random, with each set representing target items at L1-L9. The 3 sets of images were shown to participants at varying time points; 2 weeks prior to recall (week 1), 1 week prior to recall (week 2) and on the day of the recall test (week 3)[25].

Images were loaded into a pre-timed PowerPoint presentation, with each picture residing on the screen for 10 seconds. Images were presented to participants using a 3m x 3m PC projection screen in a 180 seat lecture theatre, with viewing angles no greater than 30^{o} from the perpendicular, as part of an undergraduate Introduction to Psychology lecture series at Nottingham Trent University. Two Experimental conditions were employed, incidental and intentional learning paradigms. These two conditions served to identify whether the instructions given to participants prior to stimuli presentation altered location memory performance for simple real-world images in light of an increased memory performance for

[25] For the purposes of the present chapter focus (image complexity), only data from week 3 (immediate recall) will be presented. Data from the two delayed recall image sets will be explored within Chapter 6 (effects of delay).

complex real-world-images under intentional learning conditions within previous published research (Lansdale, et al., Lansdale, et al., 2005; 2003).

Participant responses were collected at the end of the three week presentation period using paper answer booklets. The booklet included space for demographic information on the front cover, together with full participant instructions, participant consent form and 27 response grids on which to indicate the location of the target item from each of the three weekly sessions of 9 images. An example answer for the location of an image which was not previously included in the stimuli set was presented within the response booklet in order to ensure participants fully understood the nature of the task. An example answer booklet can be found within Appendix 7. The order in which each image target was presented in the response booklet was randomised 10 times throughout the population using the random function in Microsoft Office Excel. These were then distributed systematically to participants by their seated location. This ensured that images were recalled in a random order, and that participants were not responding to images in the same order as any of their neighbouring participants.

Participants

Two Experimental conditions were employed, incidental, and Intentional learning paradigms. The first participant set (incidental learning paradigm) were obtained as an opportunity sample during a first year undergraduate

Psychology lecture at Nottingham Trent University. A total of 67 students (9 male, 58 female), age range 18-39, mean = 20 years 2 months, completed the study. The second participant set (intentional learning paradigm) were obtained from a separate combined-honours undergraduate Psychology lecture at Nottingham Trent University, and were again first year students. 44 students completed this condition of the study, (14 male, 30 female), age range 18-40, mean = 20 years exactly.

Procedure

Images were shown to the students over a three week period, during the first few minutes of their lecture. For the incidental learning condition, participants were instructed as follows:

> Please view the following slides in silence…

For the intentional learning condition, participants were instructed as follows:

> This study is designed to identify which features or qualities of images make them effective pictures. You will be asked to view, over a period of 3 weeks, a total of 27 images. Each of the images has a unique content and title. As a test of the effectiveness of these images, we will test your specific ability to remember the location of

the objects shown in the pictures at the end of the 3 week test period.

Following the instructions, the images were presented on the lecture theatre projection screen by way of a PowerPoint presentation, at a rate of one every 10 seconds. After image presentation, participants received their Psychology lecture as per usual. In week 3 of testing (which represents the data to be presented here), following image presentation and the subsequent Psychology lecture, participants were presented with an answer booklet in which they were asked to indicate the location of the target item named within each of the 27 images previously viewed over the 3 week period.

Results

Analysis 1: Effects of instruction on memory for location

For the immediate recall data (images presented in week 3), a two-way mixed design ANOVA was conducted on the pooled data from both intentional and incidental groups. The test revealed a significant effect of time (F (2, 218) = 42.51, $p < .001$). But not for condition (F (2, 109) = 0.22, p = *ns*) nor time*condition interaction (F (2, 109) = 2.53, *ns*).Therefore data from the intentional and incidental conditions were combined giving a total location memory recall dataset for 111 participants (67 participant responses from the incidental and 44 from the intentional learning paradigm). Table 5.8 shows the distribution of the immediate recall object location responses to each of the 9 simple real-world images representing target object locations L1-L9. An overall indication of performance is provided by the RMS_c values in the right hand column, all of which represent performance at levels greater than would be expected by chance (RMS_c values less than 1).

Table 5.8: Frequency of locations given as a response to each of the 9 simple real-world images tested for immediate location recall and computed RMS_c scores in Experiment 5.

Presentation week and target location		Location given as response									Total	RMS_c Score
		1	2	3	4	5	6	7	8	9		
		Immediate recall										
3												
	1	**22**	19	31	15	4	9	7	4	0	111	0.58
	2	2	**22**	31	17	7	16	10	4	2	111	0.67
	3	0	9	**38**	25	13	8	12	5	1	111	0.55
	4	4	19	32	**17**	12	8	13	4	2	111	0.68
	5	1	6	10	11	**37**	17	19	7	3	111	0.57
	6	0	7	10	12	28	**25**	20	7	2	111	0.58
	7	0	2	5	13	23	19	**33**	15	1	111	0.51
	8	0	10	16	20	7	19	23	**15**	1	111	0.85
	9	0	4	8	10	9	8	12	19	**41**	111	0.52
	Total	29	98	181	140	140	129	149	80	53		
Average												0.61

Like the data previously presented for complex real-world images (Experiment 1), some key similarities can be identified from the raw data. First, recall for each of the stimuli demonstrate considerable levels of exact recall, with response frequencies falling on the correct location value being greater than the majority of other locations. Column totals for responses by location also suggest a bias against responding at the periphery of the array (locations L1 and L9). Additionally, the data indicate a clustering of errors which fall around the correct location values (near-miss error). Interestingly, data for these simple real-world images also highlight clusters of errors which fall at locations distant to the target location (far-miss errors) particularly for stimuli target locations L2 (clusters of error at locations L6 and L7) and L8 (clusters of error at locations L3 and L4), an issue which will be returned to within the discussion.

Analysis 2: Comparisons of recall performance with recall for complex images in Experiment 1.

Overall levels of performance across all 9 stimuli, as indicated by the mean RMS_c value of 0.61 suggests that performance is comparable with that for the complex real-world images in Experiment 1 (matrix A: 0.52, matrix B: 0.49, matrix C: 0.80, average = 0.62). However, it should be considered that not only are these different images, the presentation methods between these two Experiments vary (individual PC presentation of images for 20s each in Experiment 1 versus lecture theatre presentation of 10s each in Experiment 5), therefore it cannot be assumed that levels of stimulus encoding and participant engagement were comparable across these two experimental designs.

Parameter estimates using HELM

Due to the relatively simple nature of these stimuli, and taking into account that confusions between multiple items would not be possible for the present stimuli, it was hypothesised that the distribution of error demonstrated by the present stimuli would not be as variable as that produced by the complex real-world images of stimuli set A. For this reason, analysis using the original HELM model was undertaken[26]. This therefore enables direct comparisons to be made between HELM parameter estimates in Experiment 1[27] and the present experiment. With exact recall (*E*) fixed at zero (assuming no significant levels of exact recall within the dataset), HELM was able to accurately model the location recall data presented by these simple stimuli, x^2 (36, n = 999) = 41.19, *ns*. The ability for HELM to provide non-significant model fit for this data confirms that error distributions were less variable for these simple stimuli than was witnessed for the data derived from complex real-world images in Experiment 1. Parameter estimates of Availability (*A*) and Precision (λ) are presented within table 5.9.

[26] Note the interchangeable use of HELM and HELM2 within this thesis. Model selections are based upon the comparisons being drawn.
[27] Comparisons are made to the data from Experiment 1 with the awareness that model fits were non-significant for two of the three matrices modelled by HELM.

Table 5.9: Individual parameter estimates of Availability (*A*) and precision (λ) generated by HELM for the 9 simple real-world images representing target locations L1-L9 in Experiment 5.

Week 3 images: Target location	Parameter Estimates	
	A	λ
L1	0.53	2.52
L2	0.25	3.43
L3	0.29	2.64
L4	0.53	0.90
L5	0.11	1.86
L6	0.51	3.18
L7	0.87	1.31
L8	0.19	2.28
L9	0.39	4.45
Average	0.41	2.51

Comparing the parameter estimates to those generated by HELM for the complex real-world image location recall within Experiment 1, it is noted that average levels of availability and precision appear to be slightly lower across the present stimuli (mean *A* = 0.41, mean λ = 2.51) than those witnessed for complex real-world images, with the exception of mean precision in matrix C (Experiment 1, matrix A: mean *A* = 0.57, mean λ = 3.54, matrix B: mean *A* = 0.52, mean λ = 3.26, matrix C: mean *A* = 0.61, mean λ = 1.63).

Is availability precision of inexact recall common for all stimuli?

Constraining parameter values to a common level of mean Availability resulted in a significant decrease in model fit demonstrates an inability to account for the data assuming common levels of availability for all stimuli and locations $\Delta\, x^{2}(8, n = 999) = 117.69, p > .001$. Furthermore, assuming a common mean level of Precision also results in a significant decrease in the fit of the model $\Delta\, x^{2}$ $(8, n = 999) = 70.03, p > .001$. The significant decreases in model goodness of fit statistics indicate that location responses for each of the stimuli vary in terms of the accuracy of recall and the distribution of recall error, as was the case for complex real-world images in Experiment 1. Simple though these images may be, they still demonstrate levels of idiosyncrasy.

Nevertheless, these comparisons are made with the consideration that HELM could only provide initial non-significant model fits for one of the three matrices offered by Experiment 1. As such, further investigations are required to directly compare the location recall performance between simple and complex stimuli. For this reason, analysis was also conducted using the modified version of HELM (HELM2), which accounts for distributions in error which may be centred on locations other than the correct location value (which we know is specifically an issue for complex real-world images).

Parameter estimates using HELM2

HELM2 provided a sufficient model fit of the data x^2 (36, n = 999) = 39.61, *ns*. Estimates of inexact recall are quantified using the parameters of availability (*A*) and precision (*SD*), presented within Table 5.10. Parameter estimates suggest a similar mean level of availability of location information (0.43 across all stimuli) to that witnessed for the analyses conducted using HELM, and an optimised mean *SD* of responses averaging 0.65 from the mean value. As methods of quantifying the precision of responses varies between HELM and HELM2 it is not possible to provide direct comparisons of these two measures.

Table 5.10: Individual parameter estimates of Availability (*A*) and Precision (*SD*) generated by HELM2 for each of the 9 simple real-world images representing target locations L1-L9 in Experiment 5.

Week 3 images: Target location	Parameter Estimates	
	A	*SD*
L1	0.67	1.46
L2	0.43	0.77
L3	0.50	0.74
L4	0.50	1.02
L5	0.27	0.10
L6	0.26	0.10
L7	0.73	1.35
L8	0.06	0.10
L9	0.49	0.25
Average	0.43	0.65

Is availability precision of inexact recall common for all stimuli?

Applying a common mean value of Availability to each stimulus resulted in a highly significant decrease in the goodness of fit of the model, Δ x^2 (8, n = 999) = 84.48, p > .001. Similarly, the application of a common mean *SD* value was not tolerated by the model, Δ x^2 (8, n = 999) = 44.58, p > .001. This confirms the analyses conducted with the original version of HELM in that different stimuli testing cued location recall for target objects across each of the different locations vary in both the accuracy of responses and the distribution of error they generate[28].

Summary

Two experimental conditions, incidental and intentional learning paradigms, were employed in order to identify the effects of instruction when viewing images on subsequent location memory for target objects in simple images. Previously, data has suggested that for complex images, participants who were anticipating a memory test demonstrate higher levels of availability (more target locations being recalled) and precision (the remembered locations being more accurate) when compared with participants who were not anticipating a test (Lansdale, et al., 2005). For the present stimuli only one object (and therefore only one target location) is presented, and as such, it would be reasonable to assume that the effect of instruction will not impact as highly upon these simple images, and that levels of availability and precision may even be comparable

[28] As only one image tests memory for each of the target locations L1-L9, a test of the homogeneity of responses across multiple images for each of the locations is not possible within this experiment. This would be an interesting analysis to be included in future research in order to identify whether single object images demonstrate variance across images when testing the same absolute location as is the case for complex real-world images.

between the two conditions. Indeed, data from Castelhano and Henderson (2005) suggest that there is no difference in visual memory performance between incidental and intentional learning paradigms providing the comparisons are made between objects which have previously received attention during stimulus presentation. In the present stimuli set it is reasonable to assume that if the participant is paying attention to the image then this implies that they are also paying attention to the single item within that image. Findings confirmed equivocal performance rates across the two learning conditions, and as such, data from the two conditions were pooled for the purpose of analyses.

The first point to note is that the recall data from the present experiment (simple real-world images) is not directly comparable with the recall data from Experiment 1 (complex real-world images), and as such, it is reasonable to assume that overall levels of engagement and attention will not be comparable across the two experiments. All comparisons made between the data from Experiments 1 and 5 are therefore undertaken with this constraint in mind.

The present data highlight some key similarities in the distribution of error for simple real-world images when compared to complex real-world images. Responses demonstrate considerable levels of exact recall, with frequencies of responses for the correct location value being greater than the majority of other locations across all stimuli. Errors in recall tend to be clustered around the correct location value, and column totals suggest a bias against participants selecting locations at the periphery of the array, as is the case for complex stimuli. However, it is somewhat surprising that alike the data for complex real-world images, data for two simple images in the present experiment demonstrate clustering of error at locations distant from the correct location value (far-miss errors). Previous analyses (Chapter 4) have suggested that for complex real-world images, far-miss errors may indicate some level of confusion in memory between the target object and other interesting objects within a scene at recall. Yet for the simple stimuli used within this experiment, only the target object is present within the scene, thus eliminating any opportunity for object confusions to occur within the image. This therefore suggests that far-miss errors witnessed within the present experiment may be attributable to factors other than inter-image object confusion in memory.

The two images which show a trend for far-miss errors are those testing recall for locations L2 and L8 (Figures 5.9 and 5.10). An important point for consideration is that these two images are very similar in terms of the overall content of the image, both show vessels on an expanse of water. Yet the target object locations are diametrically opposed (L2 vs. L8). It may therefore be possible that participants sometimes confuse the two *images* themselves in memory, with the resulting error distribution demonstrating far-miss error clusters at opposite ends of the location array.

Figure 5.9: Image entitled *Windsurfer* testing recall for the location of a windsurfer at location L2 and location recall responses in Experiment 5.

Image removed due to copyright restrictions

L1	**L2**	L3	L4	L5	L6	L7	L8	L9
2	**22**	31	17	7	16	10	4	2

Figure 5.10: Image entitled *Boat* testing recall for the location of a boat at location L8 and location recall responses in Experiment 5.

Image removed due to copyright restrictions

L1	L2	L3	L4	L5	L6	L7	**L8**	L9
0	10	16	20	7	19	23	**15**	1

Despite the differences in experimental design between Experiments 1 and 5, which are likely to sway in favour of performance in Experiment 1 (individual viewing conditions and increased viewing times), overall levels of performance, as indicated by RMS_c scores are still comparable between the two experiments. Parameter estimates from HELM do suggest however, that mean levels of both availability (*A*) and precision (λ) are slightly lower for the simple stimuli in Experiment 5. Whether this is attributable to differences in the relative complexity of the stimuli, or to differences in individual experimental design, remains untested.

Analyses using both HELM and HELM2 highlight that as for memory for location in complex images, parameter estimates of both availability and precision (*SD*) identify that for different stimuli testing cued location recall for target objects across each of the different locations, responses vary in terms of both the accuracy of those responses and the distribution of error they generate. As confidence ratings were not elicited at recall in Experiment 5, no comparisons can be drawn at this point with regards to the effect of image complexity on confidence in location recall.

In summary, location memory for simple images appears to result in similar error distributions to location memory for complex images. Memory for the location of target objects in simple real-world images is significantly better than chance for all 9 stimuli (with RMS_c values of substantially less than 1 in all cases) despite the impoverished viewing conditions in the present experiment. Yet no effects of instruction (incidental or intentional) were demonstrated for the simple stimuli, perhaps because the target object will always gain the viewers attention. As with memory for the location of target objects in complex real-world images, the distribution of error across different locations and different stimuli varies for simple images. However, comparisons drawn between the findings of Experiment 5 and the complex image data from Experiment 1 are not optimal due to substantial differences in experimental design between the two studies. For this reason, Experiment 6 (to follow) aims to assess memory for simple and complex real-world images in a manner which will allow for direct comparisons between the two stimuli sets.

5.5 Experiment 6: Within-participant comparisons of the effects of image complexity

Method

Stimuli and Materials

9 images were randomly chosen from stimuli set A (complex real-world images) and stimuli set B (simple real-world images), taking care to represent each target object location L1-L9[29]. This gave a total stimuli set of 18 images. For full details of the stimuli and materials used in this experiment are presented within Chapter 2.

[29] Complex images = 1A *Charity Run*, 2A *Football Manager*, 3A *Boozy Commentators*, 4A *Army Cadets*, 5B *Heron*, 6B *Kneeling Protestor*, 7B *Earthquake Refugees*, 8A *Classroom*, 9C *Horse Racing*; Simple images = 1.1 *Pylon*, 2.3 *Windsurfer*, 3.1 *Lightning*, 4.3 *Hiker*, 5.1 *Buffalo*, 6.3 *Dog*, 7.1 *Monkey*, 8.2 *House*, 9.1 *Man in shade*.

Participants

A total of one hundred and sixty three undergraduate students (134 female, 29 male) from the University of Leicester, Leicester, UK, took part in return for course credits. All participants were screened for normal/corrected to normal vision, and none had taken part in previous Experiments using either of the stimuli sets included within this experiment. Participants were randomly assigned to one of three recall groups: group 1 = immediate recall following a 5 minute Sudoku distraction task (57 participants; 47 female, 10 male, age range 18-23, mean 19 years 2 months); group 2 = recall after exactly 1 week delay (53 participants; 45 female, 8 male, age range 18-27, mean 19 years 10 months) and group 3 = recall after exactly 2 weeks delay (53 participants; 42 female, 11 male, age range 18-58, mean = 20 years 2 months) [30].

Procedure

Participants were instructed as follows:

> This experiment is designed to identify which features or qualities of real-world images make them effective pictures. You will be shown a series of 18 pictures, and as a final test of effectiveness of these images, we will test your ability to remember the location of one of the objects shown in the picture.

[30] For the purposes of the present chapter focus (complexity), only data from the immediate recall group (group 1) will be presented and discussed. The delayed recall data from groups 2 and 3 will be presented within Chapter 6 where an examination of the effects of delay on memory for location takes place.

The 18 images (9 simple and 9 complex) were then shown, in random order, for a duration of 20s per image via PC. After a 5 minute Sudoku puzzle task, participants in group 1 (immediate recall condition) were asked to complete 18 response grids, each reflecting a previously viewed image. Participants in the delayed recall conditions were instructed that part 1 of the study was now complete, and they would return in either 1 (group 2) or 2 weeks (group 3) to complete the recall phase of the study. Instructions for the recall phase were:

> You will now be presented with 18 response screens. Each screen will show a grid the same size as the images you have previously viewed, together with a title of one of the images. An object from a previously viewed image will be listed as the target item at the top of each screen. Imagining that the grid is the original image, please click on the exact point in the grid where you believe the missing item appeared in the original picture. You will then be asked how confident you feel about the location response you have given.

Participants and were allowed as much time as required to complete the 18 response grids. After each response grid, participants were presented with a screen asking for a confidence judgement for the location decision they had just made on a scale of 1-5 (1 = blind guess, 5 = absolutely sure).

Results

Target object location responses for each image are presented in Tables 5.11 (9 simple real-world images) and 5.12 (9 complex real-world images) for all 57 participants. A comparison of the frequency of selection of each of the 9 locations across all simple and all complex images are presented in Figure 5.11. This graph indicates similar patterns of response for both simple and complex stimuli, whereby there is a tendency for participants not to select locations at the periphery of the array for both types of image.

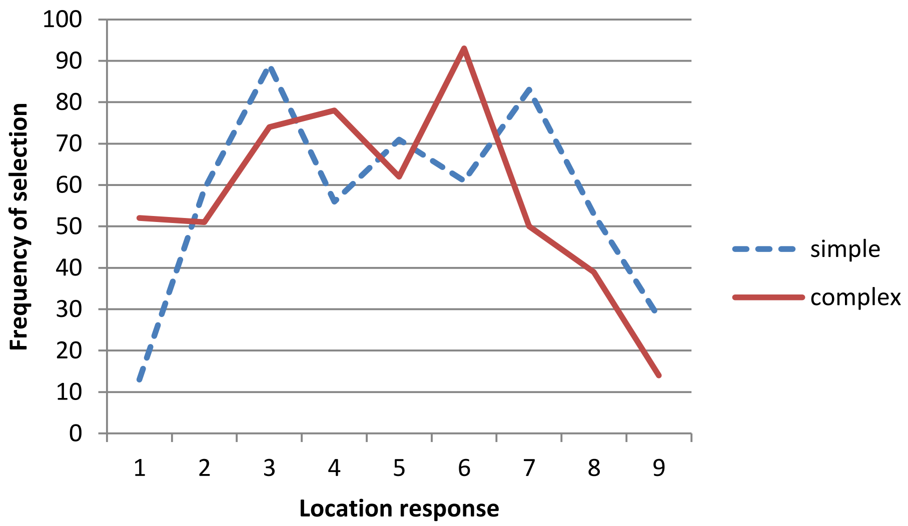
Table 5.11: Frequency of locations given as a response to each of the 9 simple stimuli and computed RMS_c scores in Experiment 6.

Participant group and target location	Location given as response									Total	RMS_c score	Mean confidence
	1	2	3	4	5	6	7	8	9			
	Immediate recall											
1												
1	**13**	18	11	4	2	0	4	3	2	57	0.53	3.09
2	0	**23**	24	4	2	3	0	1	0	57	0.30	3.67
3	0	13	**34**	10	0	0	0	0	0	57	0.15	4.26
4	0	0	11	**31**	12	2	0	0	1	57	0.24	3.95
5	0	1	3	2	**38**	7	6	0	0	57	0.24	3.82
6	0	1	1	3	11	**32**	8	0	1	57	0.26	4.02
7	0	0	0	0	3	12	**35**	7	0	57	0.16	4.18
8	0	1	2	2	1	3	24	**21**	3	57	0.33	3.88
9	0	2	3	0	2	2	6	21	**21**	57	0.35	3.68
Total	13	59	89	56	71	61	83	53	28			
Average											0.28	3.84

Table 5.12: Frequency of locations given as a response to each of the 9 complex stimuli and computed RMS_c scores in Experiment 6.

Participant group and target location	Location given as response									Total	RMS_c score	Mean confidence
	1	2	3	4	5	6	7	8	9			
	Immediate recall											
1												
1	**38**	12	2	2	0	0	0	2	1	57	0.19	3.89
2	9	**24**	8	6	5	3	2	0	0	57	0.36	3.37
3	0	4	**28**	14	1	2	0	5	3	57	0.45	3.56
4	1	3	7	**31**	9	4	2	0	0	57	0.29	3.60
5	1	0	4	14	**19**	10	3	5	1	57	0.48	3.05
6	0	0	0	2	16	**31**	7	0	1	57	0.23	3.84
7	0	2	16	4	7	11	**9**	8	0	57	0.78	2.70
8	0	1	3	0	2	28	15	**8**	0	57	0.53	3.61
9	3	5	6	5	3	4	12	11	**8**	57	0.79	2.63
Total	52	51	74	78	62	93	50	39	14			
Average											0.46	3.36

Figure 5.11: Summed frequencies of location selections across all simple and complex images within Experiment 6.

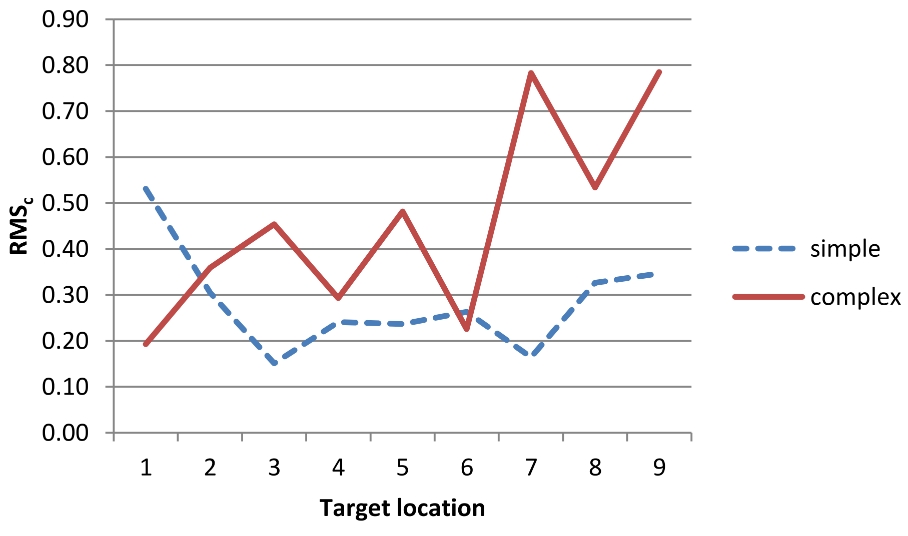


Overall levels of performance as a function of image complexity

A comparison of mean RMS_c scores indicated that overall levels of performance were greater for simple as opposed to complex real-world images (mean RMS_c for simple images = 0.28, complex images = 0.46). This was confirmed by an independent sample t-test for RMS_c values for the 9 simple and 9 complex images t (16) = -2.08, $p < .05$.

For the simple stimuli, responses demonstrate either correct or near-miss recalls. No far-miss errors are demonstrated. For the complex stimuli however, far-miss errors in recall are noted for the responses to stimuli testing memory for target object recall at locations L7, L8 and L9. This results in lower levels of performance for these particular stimuli, which can be seen in the higher RMS_c values at these locations in Figure 5.12.

Figure 5.12: RMS_c scores for each of the 9 target locations in simple and complex real-world images within Experiment 6.



Parameter estimates from HELM2

Analyses using HELM2 provided a good model fit for the simple stimuli, x^2 (36, N = 513) = 41.72, *ns*, but a statistically different fit for the complex stimuli, x^2 (36, N = 513) = 64.96, $p < .001$. By looking at the raw data in the confusion matrix (Table 5.9) the reason for the poor fit may be governed by the poor performance witnessed for those images testing recall of locations L7, L8 and L9 (see high RMS_c values in Figure 5.6 above), where errors distributions are substantially different for other locations tested, and tend to be directed to the left of the correct location value in each case. Although HELM2 is better able to deal with errors which are not centred on the correct location value, these data demonstrate that substantial variations in the distribution of error will not be tolerated by the model.

Estimates of availability (*A*) and precision (*SD*) were generated by the model for each of the target locations for both simple and complex real-world images (Table 5.14) with all parameters unconstrained. Mean estimates of availability and precision across all stimuli suggest that levels of location information in memory are comparable for both simple and complex real-world images, however, the distribution of error witnessed in complex real-world images is almost 2.5 times greater for the complex images (as shown by *SD* estimates).

Table 5.13: Parameter Estimates of Availability (A) and Precision (*SD*) for each of the 9 complex and 9 simple stimuli in Experiment 6 derived from HELM2.

Correct target location	Simple Image Parameter Estimates		Complex Image Parameter Estimates	
	A	*SD*	*A*	*SD*
1	0.65	0.96	0.87	0.10
2	0.75	0.10	1.00	2.28
3	1.00	0.64	0.60	0.66
4	0.95	0.71	1.00	1.11
5	0.73	0.10	0.80	0.95
6	0.83	0.61	0.98	0.70
7	1.00	0.71	0.49	0.96
8	0.82	0.65	0.81	0.62
9	0.78	0.78	0.90	5.30
Average	0.83	0.58	0.83	1.41

However, from the data presented within Table 5.13, predictions of availability appear to be artificially high for some of the complex images, perhaps due to a large spread of the data (as demonstrated by large standard deviations of the distributions for some locations). For this reason the models were re-optimised using the mean *SD* across all stimuli in each of the respective models in order to examine whether a mean *SD* would a) be tolerated by the model, and b) provide more accurate estimates of the availability of location information. The re-optimised models demonstrated statistically significant changes in x^2, therefore a fixed *SD* was not tolerated by either model; simple images Δx^2 (8, N = 513) = 21.52, p < .01, complex images Δx^2 (8, N = 513) = 105.83, p < .001 (parameter estimates are presented in Table 5.13). As such, it was concluded that the model was unable to provide suitable estimations for these particular data. As such, these parameter estimates should be treated with some caution.

Table 5.14: Parameter Estimates of Availability (A) and Precision (*SD*) for each of the 9 complex and 9 simple stimuli in Experiment 6 derived from HELM2 (fixed precision taken as mean *SD* from unconstrained model).

Correct target location	Simple Image Parameter Estimates		Complex Image Parameter Estimates	
	A	*SD*	*A*	*SD*
1	0.56	0.58	0.92	1.41
2	0.82	0.58	1.00	1.41
3	1.00	0.58	0.07	1.41
4	0.89	0.58	1.00	1.41
5	0.76	0.58	0.94	1.41
6	0.81	0.58	1.00	1.41
7	0.94	0.58	0.60	1.41
8	0.78	0.58	0.94	1.41
9	0.73	0.58	0.61	1.41
Average	0.81	0.58	0.79	1.41

Confidence as a function of image complexity

Mean confidence was slightly higher for the simple stimuli (3.84) than the complex stimuli (3.36), and an independent samples t-test revealed that this was a statistically significant difference t (16) = 2.47, p < .05. Furthermore, for both simple and complex stimuli, a large negative correlation was identified between levels of overall performance (as indicated by RMSc) and confidence in the accuracy of recall (simple; r (8)

= -0.96, p < .001, complex; *r* (8) = -0.91, p < .001, see Figures 5.13 and 5.14).

Figure 5.13: Mean confidence and RMS_c scores for all participants across the 9 simple images in Experiment 6.

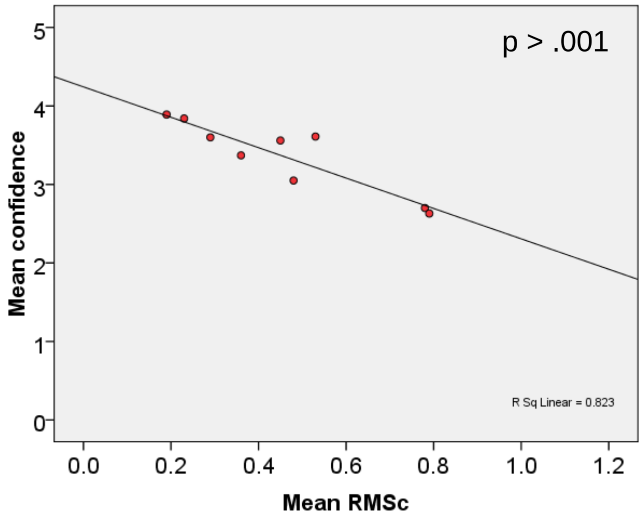
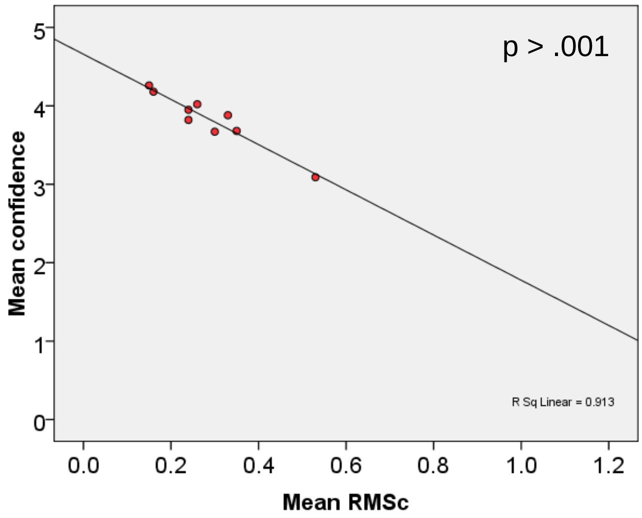


Figure 5.14: Mean confidence and RMS_c scores for all participants across the 9 complex images in Experiment 6.



Summary

Following on from an initial investigation into the effects of object density on memory for location, Experiment 6 offered a within-participant direct comparison of recall performance in single- and multiple-object real-world images. Initial examinations suggest that participants generally select locations with similar frequency for both simple and complex real-world images. However, the accuracy of recall, as demonstrated by RMSc, was greater for simple than for complex images, which is in direct contrast to the findings of Experiment 5, suggesting that the findings of the previous experiment may have been confounded by comparisons being made with results from a methodologically different experiment (Experiment 1).

Analyses using HELM2 confirmed that levels of availability and precision vary across individual stimuli and locations tested for both simple and complex images. Furthermore, estimates of mean availability of location information in memory across both stimuli conditions were comparable. However, precision in recall (as dictated by the optimised *SD* of the responses from the distribution mean) was far lower for the recall of object locations from complex stimuli. This suggests that higher RMS_c values (i.e. lower performance) for location recall within complex real-world is a result of lower levels of precision in the responses these stimuli elicit.

Finally, examinations of confidence ratings suggest that for both simple and complex real-world images, participant’s confidence provides large correlations with performance (RMS_c), whereby increased performance is indicative of higher mean confidence in recall.

5.6 General discussion

Four experiments presented within this chapter examined the effects of image content, in terms of the semantic complexity (Experiments 4a and 4b; threat-victim versus neutral inter-object relationships) and object density (Experiments 5 and 6; single- versus multiple-object images), on memory location in real-world scenes.

Effects of semantic complexity on memory for location

Data from both Experiments 4a and 4b suggest that judgements of object locations relative to other objects are reduced in the threat condition. This was observed in 14 out of the18 comparisons across two experiments. Furthermore, these errors in location recall are made despite participants being provided with an information-rich visual scene at recall. As such, these results suggest that participants pay attention to more than the mere spatial arrangement of objects within real-world images. The semantic properties of an image appear to affect memory for location whereby participants foreshorten the estimation of space between objects demonstrating a threat-victim relationship to a greater degree than objects demonstrating neutral relationships, and this occurs significantly more often than would be expected by chance.

Of the four comparisons which demonstrate the reverse effect, one comparison represents a marginal difference (-0.01 for stimuli number 5: Knife Chase). For the other three comparisons may be attributable to individual effects of picture composition only evident in a particular cue-target scenario. We know from previous work by Lansdale and colleagues (2005), as well as from the experiments in Chapters 3 and 4 that individual image composition can affect the distribution of error for the cued location of objects in real-world images. It may therefore be the case that for these comparisons in particular, the images used to cue location recall of the missing target object demonstrate unique properties which affect participants' responses in a different manner than is being observed for the other comparisons. For example, for stimuli 3 (Dog and Hare) in Experiment 4a, the target object is either a rock (neutral condition) or a hare (threat condition), with a dog as the cue (see Figure 5.5). This target object occupies one target location, L8, and results in a foreshortening of the estimation of space between the target and the cue at recall. However when the target and cue are reversed in Experiment 4b, the target object is the dog's head. Although the head of the dog within each image only occupies one target location (L6), the body extends a further 1.5 (threat condition) to 2.5 (neutral condition) locations to the left of the target. The fact that the dogs occupy a larger area of the image may have resulted in participants location responses being directed at locations to the left of the correct location value more often (see Figure 5.15). This particular comparison (found only within Experiment 4b) provides substantially larger

RMS_c values that any of the other stimuli (indicative of lower overall recall performance), suggesting that participants are indeed responding with incorrect locations more often than for any of the recall scenarios.

Figure 5.15: Exemplar image pair entitled *Dog and Hare* with objects (spatially matched on the horizontal axis) demonstrating neutral (top) and threat (bottom) relationships, together with location distinctions on the horizontal array.

Image removed due to copyright restrictions

L1 L2 L3 L4 L5 L6 L7 L8 L9

Image removed due to copyright restrictions

Both the findings of Experiment 2 within this thesis, and previous data from Lansdale et al. (2005) suggest that increased levels of attention result in increased accuracy for the recall of location information. Yet the findings of the present experiments paint a somewhat different story. Memory for the location of cued objects in images depicting threatening relationships, which we may assume from the literature would attract greater levels of attention (Öhman, et al., 2001), or more effective binding of features within memory (Mather & Nesmith, 2008), in fact demonstrate lower levels of recall accuracy than counterpart neutral images. There is however, evidence to suggest that threatening and arousing stimuli are prioritised within our attentional system (Globisch, et al., 1999) and that this can interfere with the ongoing processing of other information (Hartikainen, et al., 2000; Tipples & Sharma, 2000; Vuilleumier, et al., 2001). As such, it could be argued that the threat relationships *are* prioritised attentionally within the threat condition and that information regarding the absolute location of objects within these images *suffers* as a result. Nevertheless, this is in contrast to the findings of Mather & Nesmith, (2008), who suggest that the binding of location for emotional pictures does not result in reductions in encoding of other stimuli.

Data from the present experiments revealed that participants' average confidence in the accuracy of their location recall was in fact lower for the threat stimuli in both Experiments 4a (neutral = 4.21, threat = 3.94) and 4b (neutral = 4.26, threat = 4.10), which indicates that on average, across each of the 18 image comparisons in the two experiments, participants were less confident in their location judgements in the condition in which their performance was reduced. However, correlations revealed that although confidence was moderately related to higher overall levels of performance for the neutral stimuli across both experiments, confidence for the recall accuracy of targets from threat stimuli provided either small (Experiment 4b) or negligible (Experiment 4a) correlations. Previous literature has suggested that emotional stimuli demonstrate elevated levels of confidence in recall despite a correspondence in recall accuracy (Talarico & Rubin, 2003). Although the threat stimuli within the present experiment do not demonstrate higher mean levels of confidence in recall relative to neutral stimuli, the correlation between confidence and recall is reduced, suggesting that there is something different regarding the representation of target locations for these stimuli in memory. Further investigations regarding the relationship between recall accuracy and confidence are unfortunately beyond the time constraints of the present research, but may provide important insights into the nature of this effect.

Effects of object density on memory for location

Data from Experiment 5 highlight some key similarities in the distribution of error for simple real-world images when compared to complex real-world images in that responses demonstrate considerable levels of exact recall, with errors which tend to be clustered around the correct location value, and a bias against participants selecting locations at the periphery of the array. Although far-miss errors were demonstrated for two of the nine stimuli, examinations of these particular images revealed that they were highly similar in content, testing recall for opposite locations on the array (L2 and L8), and as such, it is conceivable that the far-miss errors may relate to participants recalling the location of the target object from the other image.

Parameter estimates using HELM suggested an increase in both the availability and precision of recall for simple real-world images when compared with the complex image recall data of Experiment 1. Yet, as HELM failed to provide non-significant model fits for 2 of the 3 matrices in Experiment 1, these estimates may not be optimal. Furthermore, as these two experiments differed in terms of both the mode of stimuli presentation and duration, a further experiment was required by which to directly compare memory for location across both simple and complex real-world images.

Findings from Experiment 6 offered a within-participant examination of the effects of object density on memory for location. Findings revealed slightly lower levels of overall performance for simple over complex real-world images. This result is in line with previous suggestions that multiple reference frames cannot be used simultaneously to enhance memory for location (Baguley, et al., 2006). As such, it may be argued that the image background or boundaries of simple real-world images are sufficient detail from which to formulate a frame of reference by which to location target objects, and that an increase in the number of objects within a scene adds nothing more to this representation other than the possibility for increases in error (see Chapter 4 for a discussion).

There were no far-miss errors witnessed within the data elicited from the recall of object locations in simple real-world images, which may be due to the possibility for object confusions being eliminated within these stimuli, and HELM2 was able to provide a non-significant model fit of the data. However, for the complex stimuli, far-miss errors were witnessed for images testing recall for locations L7 (*Earthquake Refugees*), L8 (*Classroom*) and L9 (*Horse Racing*) as shown in Figures 5.16-5.18.

Figure 5.16: Complex real-world image entitled *Earthquake Refugees* testing recall for the location of a toddler’s face at location L7, together wtih the location recall responses in Experiment 6.

Image removed due to copyright restrictions

L1	L2	L3	L4	L5	L6	**L7**	L8	L9
0	2	16	4	7	11	**9**	8	0

Figure 5.17: Complex real-world image entitled *Classroom* testing recall for the location of a drawing of an apple at location L8, together with the location recall responses in Experiment 6.

Image removed due to copyright restrictions

L1	L2	L3	L4	L5	L6	L7	**L8**	L9
0	1	3	0	2	28	15	**8**	0

Figure 5.18: Complex real-world image entitled *Horse Racing* testing recall for the location of a jockey in blue and white silks at location L9, together with the location recall responses in Experiment 6.

Image removed due to copyright restrictions

L1	L2	L3	L4	L5	L6	L7	L8	**L9**
3	5	6	5	3	4	12	11	**8**

Upon closer inspection of the far-miss errors within these three images, error clusters once again appear to coincide with the locations of other key objects within the scene (as with the data from Experiments 1 and 2). In the case of *Earthquake Refugees* (Figure 5.16) this is a boy dressed in red, for *Classroom* (Figure 5.17) clusters of errors adopt the same location as a girl wearing a blue shirt and in *Horse Racing* (Figure 5.18), errors are witnessed at the location of a jockey in purple and yellow silks. Although HELM2 was designed to allow for distributions of error which are not centred on the correct location value, due to the degree of variation generated by these far-miss errors, which are sometimes substantially further away from the correct location value than would be expected, HELM2 was unable to provide a non-significant model prediction for the recall data generated by these complex real-world images. Furthermore, the parameter estimates for the complex images appear to demonstrate some incipient instability. As a result, these findings should be treated with some caution.

Like the findings of Experiments 1 and 2, confidence was demonstrated to be related to overall levels of performance for both the simple and the complex real-world images. In both cases, large negative correlations revealed a strong relationship between higher levels of confidence and lower RMS_c scores.

In summary, the findings of the Experiment 6 offer a within-participant comparison of location memory for simple and complex real-world images.

Data suggest, in contrast to Experiment 5, that memory performance is greater for the location of cued-target objects in simple as opposed to complex real-world images, as demonstrated by lower RMS_c scores. As such, the comparisons drawn between Experiment 1 (complex images) Experiment 5 (simple images) may have been confounded by differences in the experimental design. Parameter estimates generated by the HELM2 model suggest that levels of availability of location information in memory are comparable between simple and complex real-world images. However, the precision of the responses is far greater for simple images. This suggests that the density of objects within a scene does not affect whether or not a participant will have information regarding the location of objects available in memory, however, it will affect how precise their location responses are at recall.

Overall conclusions

Across the four experiments presented within this chapter, findings highlight effects of both semantic complexity and object density on memory for location in real-world scenes. Key findings suggest that the semantic inter-object relationships between objects result in a foreshortening of the estimation of space between them at recall when a threat-victim relationship is witnessed significantly more than occurs when the objects display neutral relations. Additionally, threat images result in substantially lower correlations between participant's confidence in the accuracy of recall and their actual recall performance. Examinations of object density on the other hand suggest that availability of memory is not defined by the number of objects present within an image. However, the precision of recall is reduced when multiple target objects are present. These findings offer evidence to suggest that memory for the spatial properties are governed by both bottom-up visual image features and top-down semantic contextual factors regarding scene meaning and understanding.

Chapter six: effects of delay on memory for location

Abstract

Theoretical explorations within previous experimental chapters of this thesis provide evidence to support that the representations of object locations in memory are subject both visual and semantic influences. The content and complexity of real-world images are shown to effect accuracy of recall in terms of the both levels of location information available in memory and the precision of recall. Research thus far has been confined to testing memory for the location of cued-objects in real-world images following a short recall delay (e.g. 5 minute distracter task). When considering the feasibility of utilising memory for image retrieval, it is unlikely that image retrieval from picture databases will take place on the same day as initial viewing. As such, should spatial cognitive processes offer potential for image retrieval, a critical consideration should be to investigate how memory for location changes over periods of time.

The present chapter aimed to further the theoretical issues already explored to consider the effects of forgetting on memory for cued-target object location. Four experiments are presented in which memory for simple and complex real-world images area examined after delay periods of 1 and 2 weeks. Findings revealed that the effects of recall delay on memory for location for both single- and multiple-object real-world images manifests itself, as a general rule, as a decrease in the availability of location information, and a decline in the precision of recall. Memory for location declines in a non-linear fashion, with the majority of forgetting occurring within the first 7 days. Findings are discussed relative to the wider implications these data present to opportunities for image retrieval applications.

6.1 Forgetting

The applied issue of the effects of delay on memory for location

When considering the feasibility of using memory for location to aid the retrieval of images from picture databases, a key issue is that recall of an image is unlikely to occur on the same day that it is initially viewed. Despite a number of theoretical (Lansdale & Coates, 1999; Lansdale, et al., 2005; Lansdale, Scrivener, & Woodcock, 1996) and applied investigations (Jose, et al., 1998) into the feasibility of using location memory to inform picture database design, a critical omission in each of these articles is the failure to address the critical issue of how memory for location is affected by time. A number of theoretical issues regarding the nature of memory for location have been considered within previous chapters of this thesis. The present chapter aims to develop these theoretical findings with a consideration of the applied issue of memory for location following periods of delay.

A brief history of forgetting

Historically, forgetting has been accounted for through the consideration of three main processes,

1. Interference, either from prior learning (proactive interference/PI), or subsequent learning (retroactive interference/RI).
2. Retrieval failure due to changed or otherwise inadequate retrieval cues.
3. Information decay.

Gates (1930) attributed forgetting to a deterioration of the molecular underpinnings of the memory trace, which was governed by natural, metabolic processes (*information decay*). Yet, the amount of prior lists of items an individual had been asked to learn within an experimental setting (*proactive interference*) was shown by Underwood (1957) to affect the number of items successfully memorised at a later date, with more learning leading to less items remembered. Furthermore, Underwood's work was able to account for a vast range of published experimental data showing retention rates ranging from 20-80%. More recently, Wixted (2004) argues that forgetting is primarily due to retroactive interference, caused by mental exertion (not necessarily related to the memory task), perhaps drawing upon hippocampal resources, resulting in a disruption of the consolidation of newly formed memories.

Early work by Jenkins and Dallenbach (1924) established the importance of *retroactive interference* (RI) through the phenomenon of the positive effects of sleep on retention. It was shown that sleep eliminates the possibility for retroactive interference to occur. Furthermore, a number of studies testing the RI hypothesis have provided evidence to show that there is a greater retention of memory when the gap between learning and recall is not filled with subsequent learning activity (Fenn, Nusbaum, & Margoliash, 2003; Minami & Dallenbach, 1946; Walker, Brakefield, Hobson, & Stickgold, 2003).

The prevalent view of forgetting within contemporary neuroscience is that memories are initially formed through a long-lasting increase, typically days or weeks (Abraham, Logan, Greenwood, & Dragunow, 2002), in the probability that postsynaptic neurons in the hippocampus fire in response to neurotransmitters released from presynaptic neurons, otherwise known as long-term potentiation (LTP). A number of animal studies have shown that the induction of new LTP interferes with previously induced LTP (Izquierdo, Medina, Vianna, Izquierdo, & Barros, 1999; Xu, Anwyl, & Rowan, 1998) irrelevant of whether the new learning LTP is similar or different to the previous memory formed, or whether the learning was real or virtual (Brun, Ytterbo, Morris, Moser, & Moser, 2001). Wixted (2004) argues that it is the *amount* of mental exertion (i.e. LTP induction) which is important,

> ‘What the exact variables are that govern the degree to which prior memories are degraded is not known, but one obvious possibility is that the greater and more variable the new learning is, the greater the interfering effect will be’ (Wixted, 2004, p.262).

The age of the memory trace has been shown to play an important role in the vulnerability of that trace to interference, as highlighted by Jost’s (1897) second law, which holds that if two associations are of equal strength but of unequal age, the older association will decay less rapidly that the younger one. Forgetting functions have been proposed based on logarithmic (Ebbinghaus, 1885), power law (Wickelgren, 1974), or power and logarithmic forms (Wixted & Ebbesen, 1991, 1997). More recently, White (2001) has argued that a modified exponential (the exponential-power function) performs better than the sole exponential. What each of these functions has in common is that they are all characterised by a decreasing proportional rate of decay over time. Wixted (2004) argues that this might be expected if memories are consolidating, therefore the memory trace becomes more resistant to interference the longer they survive.

In 2008, Lansdale & Baguley proposed a model of long-term forgetting based on the principles of memory trace population dilution (PD). The authors suggest that memory for a stimulus can be described as a population of accessible traces, and that the probability of retrieval following a delay can be predicted by the proportion of traces within this population that will be defined as ‘correct’ if sampled. They argue that over time, this population is diluted by null traces that, if accessed, block retrieval. The model adheres to the fundamental principles of Jost’s Law, in that two (unequal) populations representing memories of different ages will have different rates of change depending on the size of their trace populations. Younger memories will have smaller trace populations resulting from fewer learning opportunities (M. W. Lansdale & Baguley, 2008). This model has been successfully applied to five published cued recall experiments (Postman & Riley, 1959; Rubin, Hinton, & Wenzel, 1999; Runquist, 1983; Shepard, 1967; Slamecka & McElree, 1983).

Forgetting of memory for location

Surprisingly, it appears that only one set of Experiments have investigated the role of forgetting in relation to long-term human spatial memory to date (Tlauka & Donaldson, 2008). The research by Tlauka and colleagues examined the effects of RI through varying levels of mental exertion between learning and recall of the spatial arrangement of photographs on the walls of a room. In Experiment 1, participants learned a virtual (displayed on a computer screen), or an equivalent real-world environment consisting of four walls, on which were colour photographs of household objects (e.g. hammer, brush, candle). Previous research has suggested similarities between real and virtual spatial memories (e.g. Foreman et al., 2000; Kaplan, Yannis, & Wilson, 1999). After learning the (virtual or real) environment, participants were then asked to mark on a circle (indicating the study location and initial viewing direction in the centre) the directional locations of eight household items on the circular array. Participants were then asked to mark the location of the eight items on a drawing of the room itself (showing all four walls). The spatial knowledge task was repeated after a delay of 1 week.

The authors found that directional errors were higher at the second test phase (after a delay of 1 week) with initial test highlighting a mean error score of 34^{o} and mean error in the second test of 50^{o} highlighting a significant forgetting effect. In the second test phase there was also a marginally significant difference between the accuracy of estimates in the real group (mean error = 36^{o}) when compared with the virtual group (mean error = 48 ^{o}) despite a comparable decline over the 1 week period in both groups.

Experiment 2 used only virtual environments and aimed to investigate whether the degree of mental exertion following learning had an effect on recall, as suggested by Wixted (2004). Again participants were asked to learn a virtual environment with photographs of household objects. They then completed the directional location judgement task using the circle as in Experiment 1. Participants spatial knowledge of the virtual environment was tested before and after (2-hour retention interval) the administration of a battery of interference tasks, split into three experimental groups of low, intermediate and high mental exertion (ranging from easy to increasingly more complex versions of: inference, backwards-counting, verbal comprehension, backwards word-span, backwards digit-span, basic arithmetic, completed arithmetic and search tasks).

Data revealed that participants were more accurate in the first than the second spatial knowledge task (mean error: time 1 = 31 ^{o}, time 2 = 36 ^{o}), although no significant differences were found between levels of exertion groups. This suggests that a greater level of mental exertion did not lead to an increase in forgetting where spatial location memories were derived from a virtual environment.

Investigating the effects of delay on memory for location

Important theoretical insights into the character of memory for object locations have been presented in the previous chapters of this thesis. It has been shown that memory for object location varies in accuracy across individual images and locations tested. The accuracy of recall varies according to both individual properties of an image (Chapters 4 & 5) and the amount of information made available to participants at encoding (Chapter 3). The previous chapters of this thesis have explored the nature of object location memories for cued recall in terms of availability and precision using the HELM2 approach, but tell us nothing about whether (and if so, how) these memories change over time.

The present chapter offers an investigation of the applied issue of how people remember about the spatial configuration of pictures over time, and explores the kinds of information which might be useful to the applied issue of document recovery. Four experiments are presented in which the nature of delayed recall for location information is examined across a range of real-world pictures.

6.2 Experiments 7 and 8: Effects of recall delay on memory for complex images

Experiment 7

The purpose of Experiment 7 was to replicate the experimental findings of Experiment 1 (location memory for complex images), and to further these investigations with the examination of the effects of forgetting over periods of 1 and 2 weeks recall delay. These delay periods were chosen as they were the most feasible periods of delay achievable within the timescales of the present thesis.

Method

Stimuli and materials

Stimuli and materials used within this experiment are presented in full within Chapter 2.

Participants

47 undergraduate students (10 male, 37 female) from Nottingham Trent University volunteered in return for course research credits, or a payment (£3). All participants were screened for normal/corrected to normal vision, and none had taken part in previous experiments concerned with visual memory. Participants were randomly assigned to either the 1 week or 2 week delay condition, resulting in two sets of within-participants data, with group 1 = 20 participants (7 male, 13 female), age range 18-28 years, mean = 19 years 10 months, completing the recall phase of the

experiment both immediately and after a 1 week delay period, and group 2 = 27 participants (3 male, 24 female), age range 18-49 years, mean = 21 years 5 months, completing the recall phase both immediately and after a 2 week delay period.

Procedure

The procedure for Experiment 7 was exactly alike that of Experiment 1 with the addition of a second recall phase following either a 1 or 2 week delay[31]. Stimulus presentation consisted of the same 27 complex real-world images (stimuli set A), viewed via a PC (see Chapter 2 for full details of the stimuli and materials used).

Following their initial participation in the study, participants were invited back after a period of exactly 1 (group 1) or 2 weeks (group 2) to recomplete the recall phase of the experiment.

Results

Analysis 1: Experimental reliability

As a first stage of analysis, should the experimental findings presented within this thesis be reliable, then they should be easily replicated. In order to establish that the data elicited from the immediate recall condition of both experimental groups (groups 1 and 2) of Experiment 7 is comparable to data from the methodologically identical Experiment 1, contrasts were

[31] An important methodological consideration within this Experiment is that location recall was elicited from all participants on two occasions.

made between the overall recall performance as indicated by mean RMS_c scores for each location tested. This confirmatory analysis is presented within Appendix 14.

Findings revealed that the immediate recall responses in Experiment 7 were very similar in terms of location recall accuracy to the responses witnessed in Experiment 1 (group 1: r (26) = 0.951, p < .01; group 2: r (26) = 0.934, p < .01), and as such, the participants are responding in a highly similar manner across the two experiments.

Analysis 2: Effects of delay on memory for location

Confusion matrices and RMS_c values for each image are presented within Appendix 12. An examination of the RMS_c values from delayed recall suggest that RMS_c increases (i.e. overall levels of performance decrease) as a function of time; 0.62 for group 1: immediate recall, rising to 0.65 following a 1 week recall delay, and 0.70 for group 2: immediate recall, rising to 0.77 for following a two week recall delay. Paired samples t-tests revealed that for group 1, the differences in RMS_c values between immediate and delayed recall were not significantly different from one another, t (26) = -1.60, *ns*, yet the for group 2, RMS_c scores were demonstrated to be significantly different between the two recall tests, t (26) = -2.51, p < .01.

These results suggest that overall levels of recall performance are significantly lower for the 2 week delay data relative to immediate recall, yet the overall performance data for 1 week delayed recall is not significantly lower than for initial recall. It is worth noting at this point the methodological consideration that participants complete the recall phase of the experiment twice, both immediately after a distracter task, and again following a delay period of either 1 (group 1) or 2 weeks (group 2). It has previously been acknowledged that a memory test serves to aid the accessibility of information in memory (Lansdale & Laming, 1995; Roediger & Karpicke, 2006; Runquist, 1983), and as such, we cannot rule out the possibility that participants may be (at least in part) recalling some of their previous responses above and beyond the stored representation of the stimuli.

Figures 6.3 and 6.4 present immediate recall versus 1 week and immediate recall versus 2 week delay mean RMS_c scores respectively. A parity line representing equal scores (0 =0, 1.2 = 1.2) was fitted to each of these plots. Data points falling above this line indicate an increase in mean RMS_c scores for individual stimuli tested between immediate and delayed recall.

Figure 6.3: Group 1: Comparison of mean RMS_c scores for each of the 27 stimuli in Experiment 7 for immediate and delayed recall.

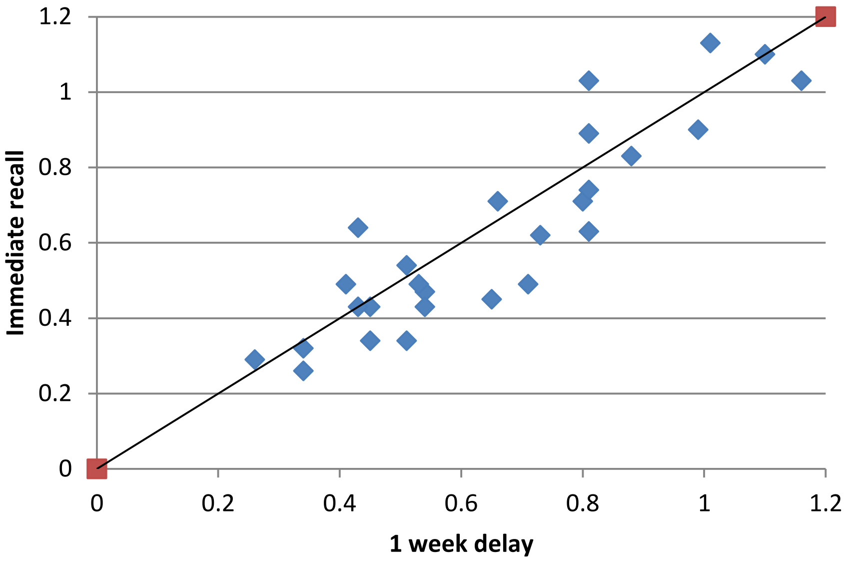
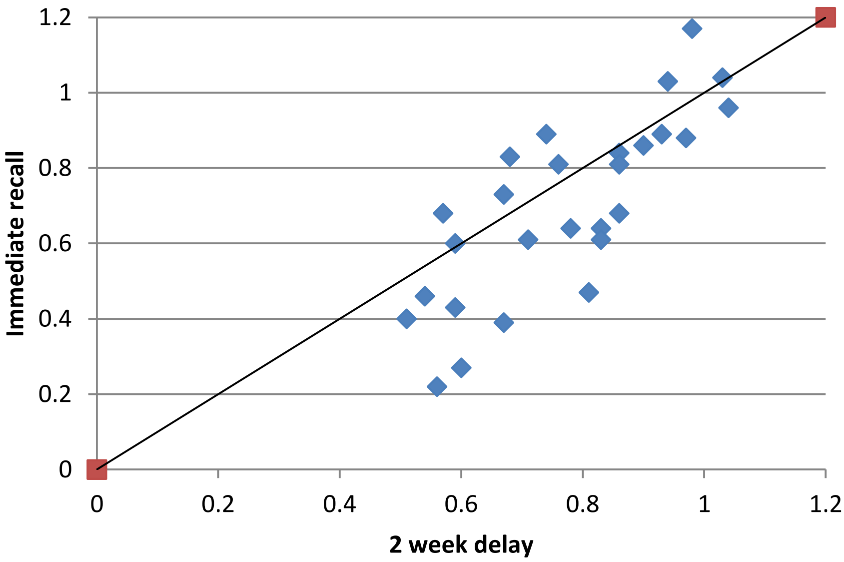


Figure 6.4: Group 2: Comparison of mean RMS_c scores for each of the 27 stimuli in Experiment 7 for immediate and delayed recall.



Assuming a random distribution of values, the binomial distribution indicates that observed frequencies of more than 7 values falling below the line of parity would be unlikely, with a cumulative probability of p = .025 one-tailed)[32]. Figure 6.3 presents the comparison between RMS_c values in group 1 over time. Here we can see that 17 points fall below the line, which indicates that location recall for 17/27 images demonstrate increased RMS_c scores after a one week delay when compared with immediate recall. Figure 6.4 shows the comparison between RMS_c values in group 2. This plot highlights 18 points below the line, suggesting that location recall for 18/27 images are significantly greater in the two week delay condition when compared with immediate recall. Both of these comparisons offer frequencies of increases in RMS_c greater than would be expected by chance, therefore suggesting that significant increases in RMS_c (which equates to a reduction in the accuracy of responses) occur over time.

How is forgetting characterised?

Optimised HELM2 model parameter estimates were generated for the data from each group[33], providing non-significant estimates in all cases: group 1: Immediate recall: x^2 (36, N = 540) = 37.47, *ns*, Group 1: 1 week delay: x^2 (36, N = 540) = 39.76, *ns*, group 2: Immediate recall: x^2 (36, N = 729) = 49.44, *ns*, group 2: 2 week delay: x^2

[32] A one-tailed test was adopted as it was hypothesised that RMS_c scores will increase where forgetting takes place, and not decrease due to reminiscence or hypermnesia (where information is recalled at delay which was previously not recalled at immediate testing) being a highly unlikely outcome for the recall of information from memory over time (see Payne, 1987 for a review).

[33] Confusion matrices are presented within Appendix 12, Tables 6.1 - 6.4.

(36, *N* = 729) = 38.31, *ns*. Parameter estimates for each group are provided within Table 6.5.

Table 6.5: Parameter estimates generated by HELM2 for Experiment 7

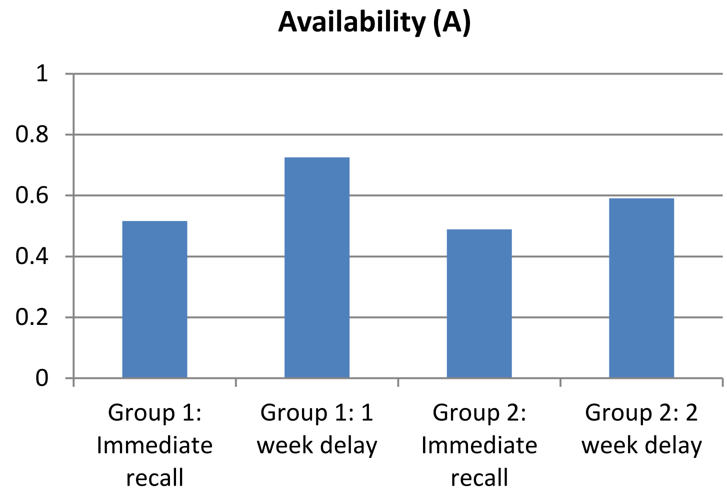
Target location	Group 1				Group 2			
	Immediate recall		1 week delay		Immediate recall		2 week delay	
	A	*SD*	*A*	*SD*	*A*	*SD*	*A*	*SD*
L1	0.43	1.63	0.68	2.20	0.22	0.18	0.64	1.85
L2	0.62	0.89	0.64	1.09	0.48	0.93	0.47	1.35
L3	0.75	0.85	0.48	1.00	0.51	0.65	0.45	0.80
L4	0.66	0.63	1.00	1.05	0.58	0.28	1.00	1.30
L5	1.00	1.86	0.91	2.01	1.00	3.34	0.83	2.06
L6	0.77	1.17	0.89	1.04	0.65	0.72	0.51	0.92
L7	0.06	0.29	0.24	0.15	0.18	0.91	0.70	0.99
L8	0.15	0.27	0.69	1.15	0.46	0.89	0.33	1.49
L9	0.20	0.29	1.00	1.75	0.32	1.23	0.38	2.78
Average	0.52	0.88	0.73	1.27	0.49	1.01	0.59	1.50

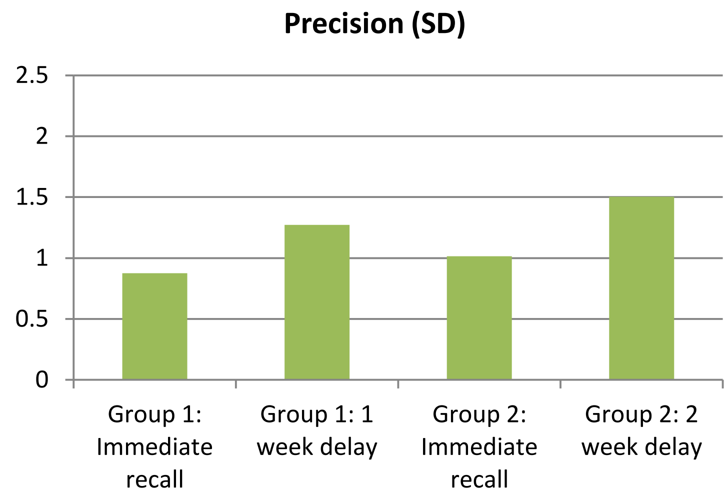
Examinations of the parameter estimations suggest an increase in mean levels of availability (*A*) over time. For group 1, estimated *A* rises from 0.52 to 0.73 following a 1 week recall delay, t (9) = -1.94, p < .05, for group 2, *A* increases from 0.49 to 0.59 following a 2 week recall delay, t (9) = -1.10, *ns*. As it is unlikely that availability of location information will increase between the points of immediate and delayed recall (Payne, 1987), a consideration of the factors which may have resulted in increases in the parameter estimates is presented within the general discussion.

More in line with what we may expect for the recall of spatial memories over time, a decline in precision was noted for both groups, with a rise in estimated *SD* in group 1 from 0.88 to 1.27, t (9) = -2.30, p < .05, and group 2 from 1.00 to 1.50, t (9) = -1.65, *ns*, between immediate and delayed recall.

In summary, these parameter estimates suggest that participants are becoming less accurate in their responses (due to the increased standard deviation of the responses from the correct location), although the comparison for group 2 parameter estimates of *SD* do not quite reach statistical significance, but despite this inaccuracy, overall levels of available information in memory increase (a significant effect for group 1 only). Mean parameter estimations are provided within Figure 6.5.

Figure 6.5: Bar charts indicating mean parameter estimates of Availability (*A*) and precision (*SD*) of location recall for groups 1 and 2 both immediately and following recall delay in Experiment 7.





Analysis 4: What are the effects of delay on confidence in location recall?

Analyses of mean confidence ratings suggest that participant's confidence in the accuracy of their location recalls declines with delay in recall. For group 1, mean confidence of 3.19 across all stimuli at immediate recall falls to 2.85 after 1 week, t (52) = 2.02, $p < .05$. For group 2, mean confidence for immediate recall was 2.22, falling to 1.93 after a 2 week delay, t (52) = 2.57, $p < .01$.

Comparisons of mean confidence and mean performance (RMS_c) across the full stimuli set demonstrate significant negative correlations for each group for both immediate and delayed recall (Table 6.6). However, the correlations for immediate recall represent a significant result, and are larger in each than those for which recall which is delayed. This suggests that over time, the relationship between recall accuracy and confidence in recall is reduced. Plots demonstrating the correlations for both recall instances in each group are presented within Figures 6.6 and 6.7.

Table 6.6: Correlations between mean confidence ratings and mean RMS_c across 27 stimuli for groups 1 and 2 immediate and delayed recall in Experiment 7.

Group and recall condition		*r*
Group 1:	Immediate	-0.41*
Group 1:	1 week delay	-0.22
Group 2:	Immediate	-0.44*
Group 2:	2 week delay	-0.37

* p < .05

Figure 6.6: Correlations between mean confidence ratings and mean RMS$_c$ across 27 stimuli for groups 1 immediate and 1 week delayed recall in Experiment 7.

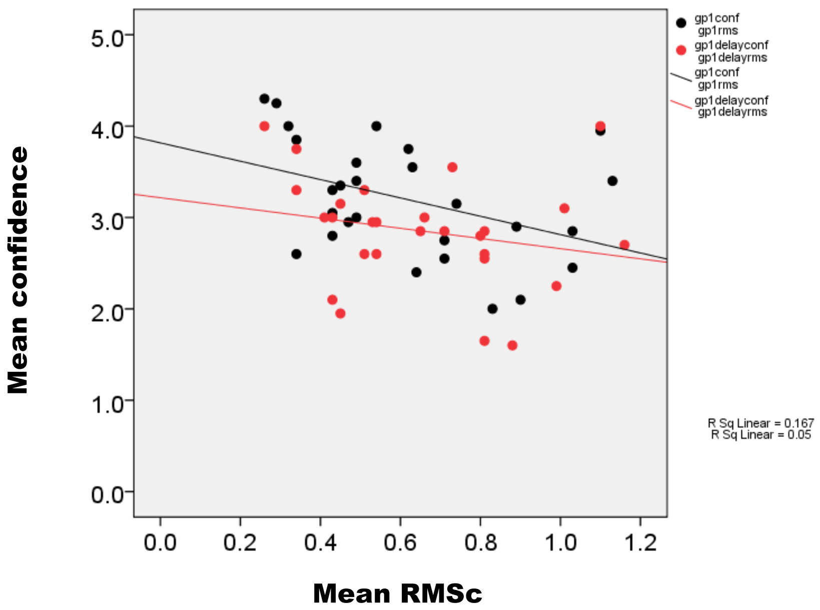
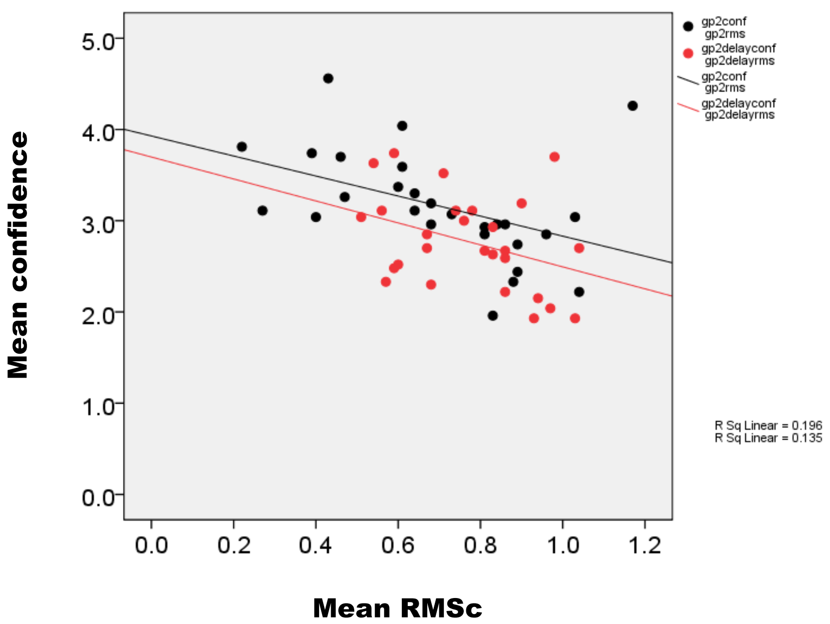


Figure 6.7: Correlations between mean confidence ratings and mean RMS$_c$ across 27 stimuli for groups 2 immediate and 2 week delayed recall in Experiment 7.



Summary

Experiment 7 provides a replication Experiment 1 (Chapter 3), with the addition of a second recall phase either one or two weeks following initial testing. A fundamental issue to bear in mind is that recall for the location of objects within this experiment occurs twice. As such, results should be interpreted with a consideration that location responses in the delayed recall condition may contain responses based upon previous recalls as well as pure memory for the location of cued-target objects (Runquist, 1983).

Initial confirmatory analyses revealed that overall levels of recall performance for the immediate recall of location within both experimental groups were comparable with Experiment 1. This suggests that findings regarding the fundamental nature of memory for location presented within this thesis are replicable.

The effect of time delay on recall was characterised by an increase in RMS_c values (representative of a decrease in overall levels of performance). Although this increase was more pronounced for the recall following a delay of 2 weeks than for 1 week, it should be considered here that this finding may be confounded by the recall of object locations occurring twice.

Analyses using HELM2 suggest an increase in the standard deviation of responses from the correct location value (a reduction in precision), but an increase in mean levels of availability of location information over time. These parameter estimates suggest that participants are becoming less accurate in their responses (due to the increased standard deviation of the responses from the correct location), but that despite this inaccuracy, overall levels of available information in memory increase. It is not unreasonable to propose that these two factors may be inherently linked. Taking into consideration the wider spread of data (as noted by an increase in mean *SD*), any increase in the availability of location information may arise as a result of the increase in the number of locations considered by the model. Furthermore, as the precision of responses are demonstrated to decrease, it is equally likely that increase in the availability of information in memory may be a residual effect of an increase in participant guesses following periods of delay.

Finally, examinations of participant's confidence in the accuracy of recall demonstrated that over time, correlations between confidence and accuracy reduce. This is a significant development, suggestive of an inherent issue in the predictive role of confidence on recall performance, an issue will be considered in detail within the general discussion.

Experiment 8

Experiment 8 offers a replication of the experimental methodology of Experiment 2 (location memory or complex real-world images), which examined the effects of additional verbal information at stimulus viewing on subsequent memory or location. As a development from this initial study, Experiment 8 offers an additional recall element designed to investigate how this memory for location can be quantified following either a 1 or a 2 week delay.

Method

Stimuli, materials and procedure

The experimental design is exactly like that for Experiment 7 (above), yet with the addition of a verbal commentary at stimuli encoding (full details of the verbal commentaries are provided in Chapter 2, commentaries are presented in Appendix 6). For the purposes of brevity, information which is common between Experiments 7 and 8 will not be repeated within this section.

Participants

47 undergraduate students (6 male, 41 female) from Nottingham Trent University volunteered in return for course research credits, or a payment (£3). All participants were screened for normal/corrected to normal vision, and none had taken part in previous experiments concerned with visual memory. Participants were randomly assigned to either the 1 week or 2 week delay condition, resulting in two sets of within-participants data, with

group 1 = 26 participants (3 male, 23 female), age range 18-41 years, mean = 21 years 2 months, completing the recall phase of the experiment both immediately and after a 1 week delay period, and group 2 = 21 participants (3 male, 18 female), age range 18-27 years, mean = 19 years 11 months, completing the recall phase both immediately and after a 2 week delay period.

Analysis 1: Experimental reliability

Overall levels of performance in both experiments (as indicated by RMS_c scores), together with mean confidence in recall for each of the stimuli are presented within Appendices 12 and 13. As for the previous experiment, a first stage of analysis was to examine the reliability of the experimental findings for the immediate recall data relative to the methodologically equivocal Experiment 2. This initial confirmatory analysis is presented within Appendix 15.

Findings reveal that, as expected, that the immediate recall responses in Experiment 8 were very similar in terms of location recall accuracy to the responses witnessed in Experiment 2 (group 1: $r\ (26) = .927$, $p < .001$; group 2: $r\ (26) = .895$, $p < .001$), and as such, the participants are responding in a highly similar manner across the two experiments.

Analysis 2: Recall performance as a function of verbal commentary

Immediate recall

The presence of a verbal commentary resulted in decreased mean RMS_c scores for immediate location recall when compared with the data from Experiment 7. Mean RMS_c in Experiment 7: group 1: immediate recall = 0.62, Experiment 8: group 1: immediate recall = 0.40, t (52) = 3.48, p < .001; Experiment 7: group 2: immediate recall = 0.62, Experiment 8: group 2: immediate recall = 0.40, t (52) = 3.85, p < .001.

Delayed recall

Mean RMS_c scores for Experiment 8 for delayed recall were also smaller than those witnessed within Experiment 7, suggesting that the initial benefit of verbal commentary on performance is maintained over periods of delay. Mean RMS_c in Experiment 7: group 1: 1 week delay = 0.65, Experiment 8: group 1: 1 week delay = 0.52, t (52) = 2.25, p < .05; Mean RMS_c in Experiment 7: group 2: 2 week delay = 0.77, Experiment 8: group 2: 2 week delay = 0.61, t (52) = 3.35, p < .001.

Analysis 3: Recall performance over time

An increase in RMS_c scores was noted following recall delay, with 0.40 for group 1: immediate recall, rising to 0.52 following a one week recall delay, t (26) = -5.691, p < .001, and 0.47 for group 2: immediate recall, rising to 0.61 following a two week recall delay, t (26) = -5.061, p < .001.

Figures 6.10 and 6.11 present a comparision of mean RMSc scores per stimulus for immediate and delayed recall of the same images in groups 1 and 2. Assuming a random distribution of values, the binomial distribution indicates that observed frequencies of more than 7 values falling below the line of parity would be unlikely, with a cumulative probability of p = .025.

Figures 6.8 and 6.9 demonstrate 24/27 points fall below the line for data elicited from both groups, which indicates that location recall for 24/27 images demonstrate increased RMS_c scores after a one week and a two week delay when compared with the respective immediate recall data. As both of these comparisons offer frequencies of increased RMS_c values which are greater than would be expected by chance, these results indicate that delay in recall results in a reliable decrease in levels of overall recall accuracy.

Figure 6.10: Group 1: Comparison of mean RMS_c scores for each of the 27 stimuli in Experiment 8 for immediate and delayed recall.

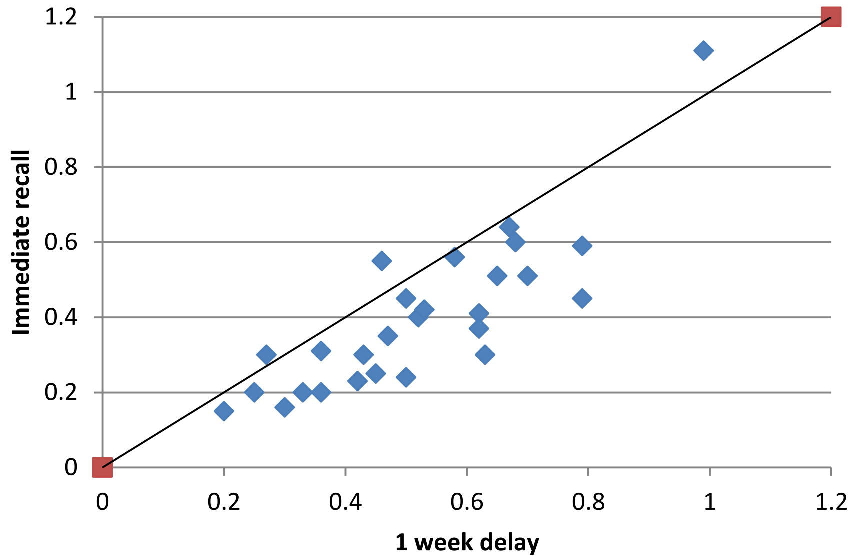
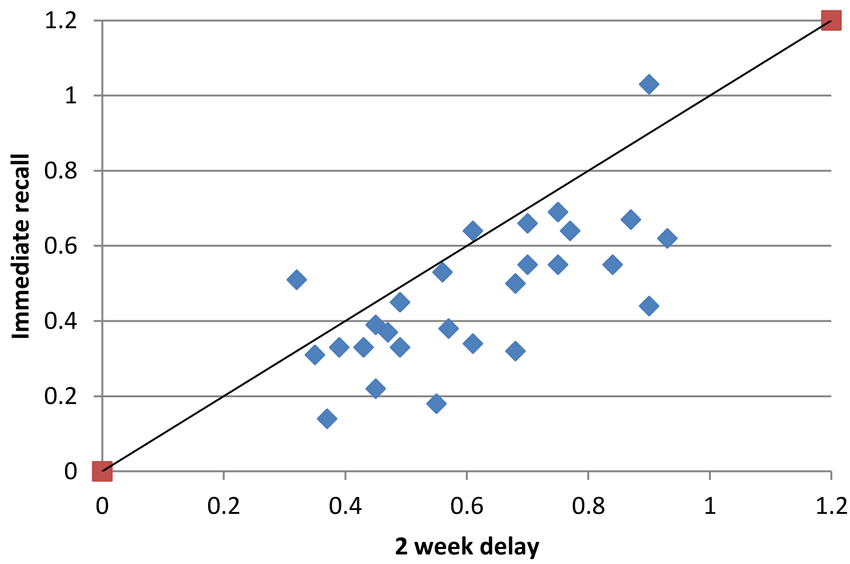


Figure 6.11: Group 2: Comparison of mean RMS_c scores for each of the 27 stimuli in Experiment 8 for immediate and delayed recall.



How is forgetting characterised?

Optimised HELM2 models were calculated for each group[34]. The model was able to provide non-significant model predictions for all observed data matrices with the exception of the observed immediate recall data in group 1: Immediate recall: x^2 (36, N = 702) = 63.75, p < .01, group 1: 1 week delay: x^2 (36, N = 702) = 43.09, *ns*, group 2: Immediate recall: x^2 (36, N = 567) = 39.37, *ns*, group 2: 2 week delay: x^2 (36, N = 567) = 26.00, *ns*. Parameter estimates are provided within Table 6.11.

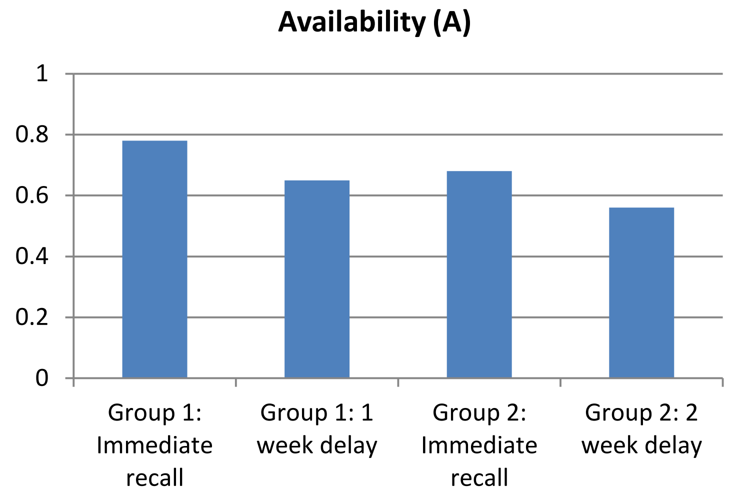
Table 6.11: Parameter estimates generated by HELM2 for Experiment 8.

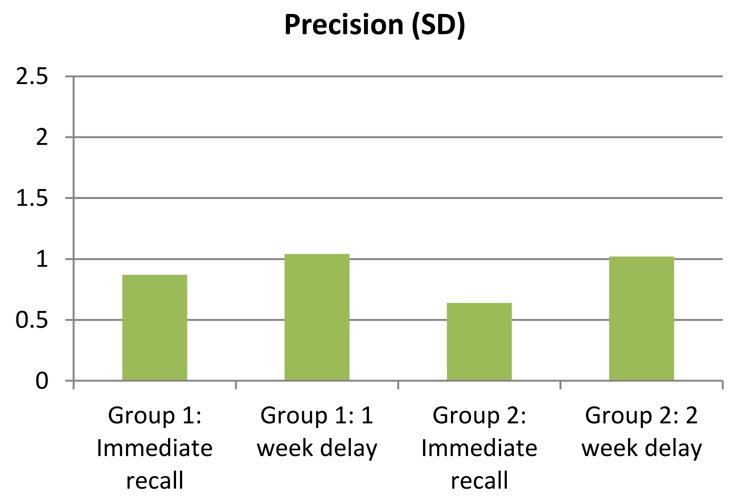
Target location	Group 1				Group 2			
	Immediate recall		1 week delay		Immediate recall		2 week delay	
	A	*SD*	*A*	*SD*	*A*	*SD*	*A*	*SD*
L1	0.82	1.21	0.78	1.02	0.58	0.84	0.59	1.01
L2	0.90	0.83	0.70	0.87	0.74	0.84	0.65	1.04
L3	0.94	0.72	0.80	0.84	0.75	0.25	0.71	0.89
L4	0.97	0.54	0.95	0.76	0.79	0.45	0.67	0.73
L5	1.00	1.74	0.76	1.54	0.32	0.16	0.65	1.39
L6	0.83	0.66	0.37	0.10	0.87	0.69	0.70	0.89
L7	0.42	0.54	0.19	0.25	0.58	0.68	0.37	1.63
L8	0.66	0.74	0.58	1.52	0.81	0.64	0.24	0.10
L9	0.48	0.87	0.67	2.47	0.70	1.23	0.47	1.47
Average	0.78	0.87	0.65	1.04	0.68	0.64	0.56	1.02

[34] Confusion matrices are presented within Appendix 13, Tables 6.7 - 6.10.

Examination of parameter estimates suggest a decrease in the availability (*A*) and precision (as highlighted by an increase in *SD*) of memory for location across all images over time. For group 1, estimated levels of availability of location information (*A*) decline, with a fall from 0.78 for immediate recall to 0.65 following a 1 week delay, t (8) = 2.25, p < .05, and the *SD* of the distribution of responses increase from of 0.87 for immediate recall, to 1.04, t (8) = -0.77, *ns*. For group 2, estimated *A* falls from 0.68 immediately to 0.56 following a 2 week recall delay, t (8) = 1.53, *ns*, with a rise in *SD* of 0.64 to 1.02 over time, t (8) = -2.19, p < .05. These analyses suggest that overall levels of available information in memory decline over time, and responses become less precise. Despite two of these comparisons failing to reach statistical significance, results were marginal. Mean parameter estimates of *A* and *SD* are presented in Figure 6.12.

Figure 6.12: Bar charts indicating mean parameter estimates of Availability (*A*) and precision (*SD*) for groups 1 and 2 immediately and following recall delay in Experiment 8.





Analysis 4: Overall effects of commentary on parameter estimates

Immediate recall

A comparison of parameter estimates of *A* for group 1: immediate recall between Experiments 7 and 8 confirm the findings of Chapter 3 in that an accompanying verbal commentary at stimulus encoding results in higher levels of available information in memory. For group 2, however, the effect is reversed, with greater estimated mean *A* for Experiment 7 (no commentary). Mean *A* across all stimuli and locations in Experiment 7 group 1: immediate recall = 0.52, Experiment 8 group 1: immediate recall = 0.78, t (16) = -2.05, $p < .05$.

Parameter estimates of *SD* suggest that levels of precision are comparable across experiments. Mean *SD* across all stimuli and locations in Experiment 7 group 1: immediate recall = 0.88, Experiment 8 group 1: immediate recall = 0.87, t (16) = 0.01, *ns*. These findings therefore suggest that increased levels of overall performance in the present experiment (as indicated by lower RMS_c values) can be quantified in terms of increased levels of the availability of location information with additional verbal information at encoding.

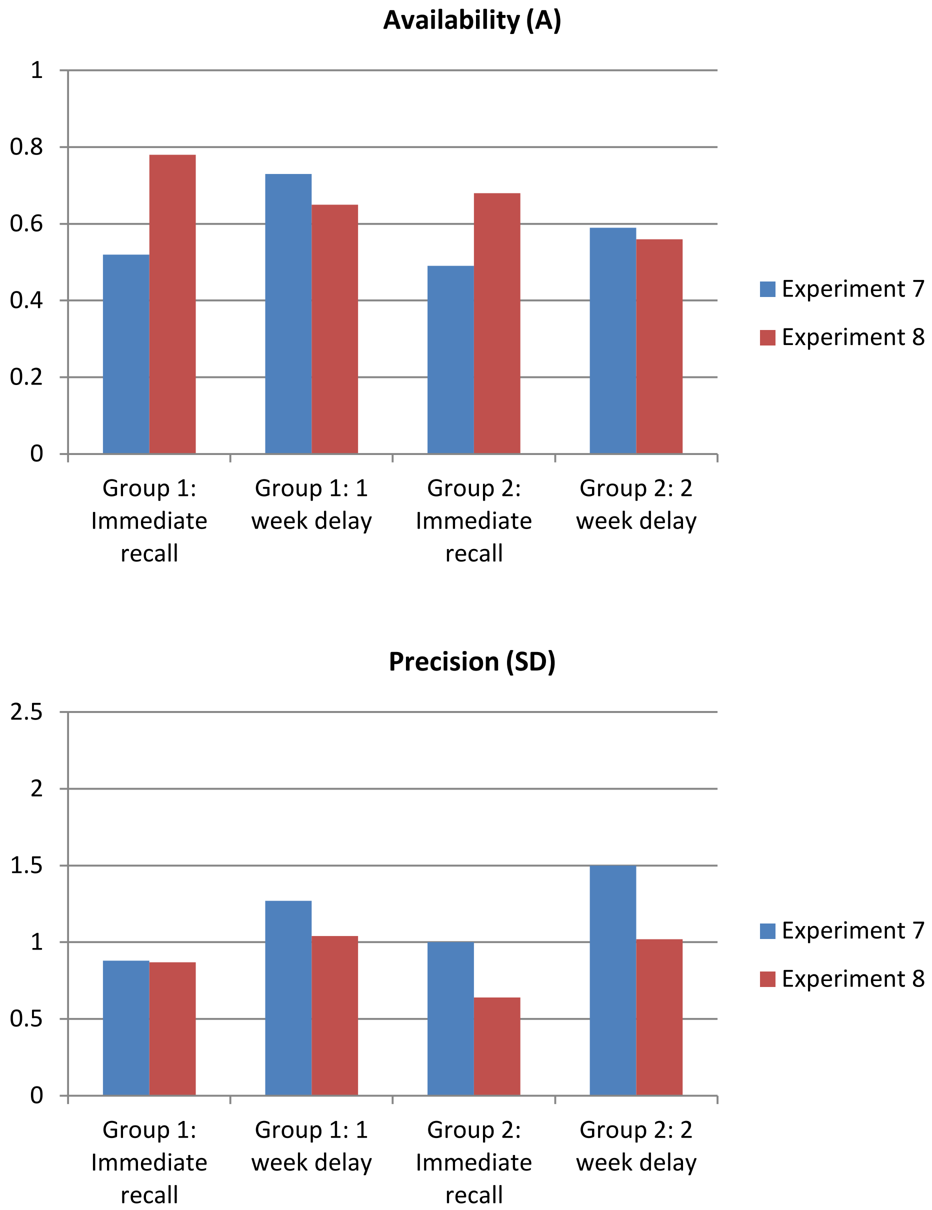
Delayed recall

Over time, the benefit of verbal commentary has been shown to remain, with a persistence of lower mean RMS_c scores for delayed recall in Experiment 8 (see above). An examination of the parameter estimates in these two experiments reveal that despite levels of *A* in Experiment 8 being higher for immediate recall, following a recall delay, levels of availability become comparable across the two experiments: Experiment 7 group 1: 1 week delay = 0.73, Experiment 8 group 1: 1 week delay = 0.64, t (16) = 0.70, *ns*; Experiment 7 group 2: 2 week delay = 0.59, Experiment 8 group 2: 2 week delay = 0.56, t (16) = 0.31, *ns.*

However, parameter estimates of *SD* are shown to be lower in Experiment 8 over time. Experiment 7 group 1: 1 week delay = 1.27, Experiment 8 group 1: 1 week delay = 1.04, t (16) = 0.72, *ns*; Experiment 7 group 2: immediate recall = 1.01, Experiment 8 group 2: immediate recall = 0.64, t (16) = 1.13, *ns*; Experiment 7 group 2: 2 week delay = 1.50, Experiment 8 group 2: 2 week delay = 1.02, t (16) = 1.87, $p < .05$.

These findings suggest that for delayed recall, the overall performance benefit from additional verbal information at encoding within Experiment 8 (as indicated by lower RMS_c values) can be quantified in terms of greater precision in recall (lower *SD* parameter estimates) than demonstrated for the data in Experiment 7. Mean parameter estimates of *A* and *SD* are provided in Figure 6.13.

Figure 6.13: Bar charts indicating mean parameter estimates of Availability (*A*) and precision (*SD*) for groups 1 and 2 both immediately and following recall delay in Experiments 7 & 8.



Analysis 5: What are the effects of delay on confidence in location recall?

Analyses of mean confidence ratings suggest that participant's confidence in the accuracy of their location recalls declines with delay. Nevertheless, mean confidence ratings for the present experiment (group 1: Immediate recall = 3.71, 1 week delay = 3.07; group 2: immediate recall = 3.71, 2 week delay = 2.98) are higher than was witnessed in Experiment 7 (group 1: Immediate recall = 3.19, 1 week delay = 2.85; group 2: immediate recall = 3.16, 2 week delay = 2.77), at all time points. This confirms the earlier findings in Chapter 3 which suggest that a verbal commentary at encoding results in higher mean levels of confidence in participant's location recalls.

For the present experiment, mean confidence for immediate recall within group 1, across all stimuli, falls from 3.61 to 3.07 after 1 week, t (52) = 4.44, *ns*. For group 2, mean confidence for immediate recall was 3.71, falling to 2.98 after a 2 week delay, t (52) = 5.87, *ns*. It should be noted, however, that the failure to detect a significant result here is in contrast to the decline in precision in Experiment 7, which demonstrated significant differences in participant's confidence in recall over time. As such, it appears that although mean confidence does decline with time in Experiment 8, this decline is not as pronounced as was witnessed in the previous experiment.

Comparisons of mean confidence and mean performance (RMS_c) across the full stimuli set demonstrate significant negative correlations in each group for immediate and delayed recall (Table 6.12). For group 2, the correlations for immediate recall are larger than those for recall which is delayed. However, in group 1, data suggest the reverse effect. Findings from Experiment 7 suggest that over time, the relationship between recall accuracy and confidence in recall is reduced. Although this is witnessed for the present data in group 2, the results for group 1 show a slight increase in the size of correlation between confidence in recall and overall performance following a period of delay. Plots demonstrating the correlations for both recall instances in each group are presented within Figures 6.14 and 6.15.

Table 6.12: Correlations between mean confidence ratings and mean RMS_c across 27 stimuli for groups 1 and 2 immediate and delayed recall in Experiment 8.

Group and recall condition		*r*
Group 1:	Immediate	-0.39
Group 1:	1 week delay	-0.49*
Group 2:	Immediate	-0.59***
Group 2:	2 week delay	-0.29

* p < .05
*** p < .001

Figure 6.14: Correlations between mean confidence ratings and mean RMS$_c$ across 27 stimuli for groups 1 immediate and 1 week delayed recall in Experiment 8.

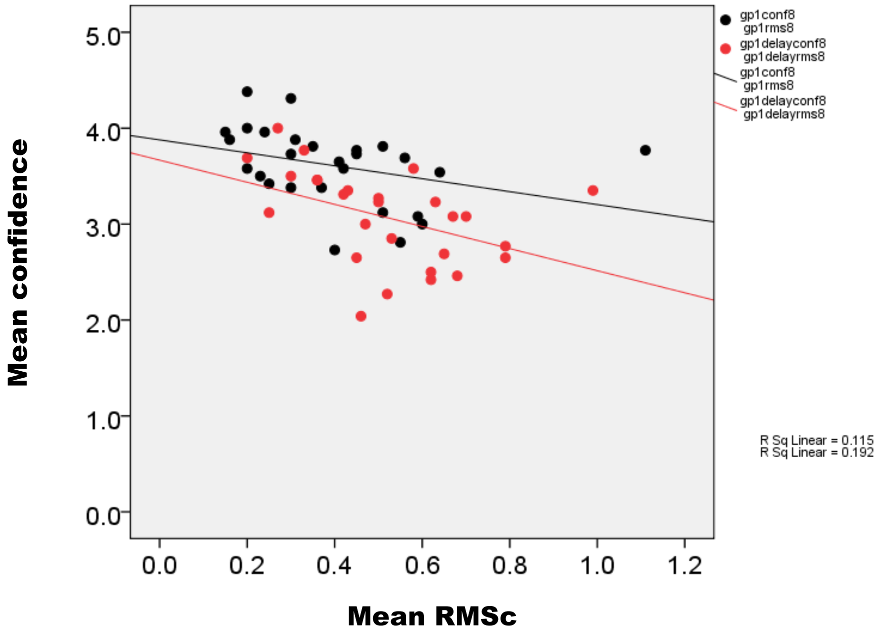
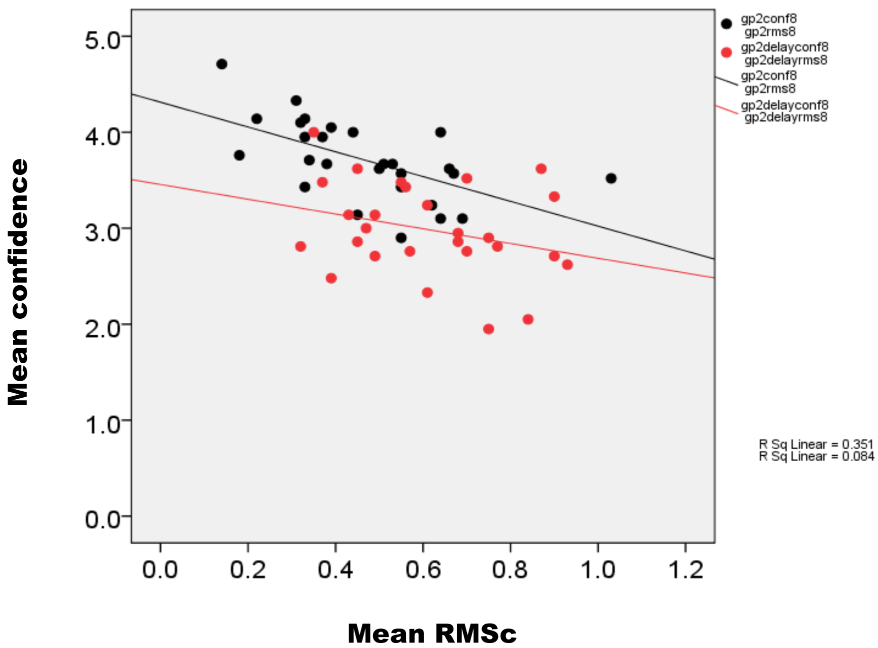


Figure 6.15: Correlations between mean confidence ratings and mean RMS$_c$ across 27 stimuli for groups 2 immediate and 2 week delayed recall in Experiment 8.



Summary

Experiment 8 offered an examination of the effects of additional verbal information at stimulus viewing on subsequent memory or location immediately and following either a 1 or a 2 week delay. Initial confirmatory analyses revealed that overall levels of immediate recall performance were comparable to the methodologically identical Experiment 2. These results suggest that findings presented within this thesis regarding the fundamental nature of memory for location with additional verbal information are replicable.

The effect of additional verbal information at encoding resulted in lower RMS_c scores than were witnessed for data within Experiment 7, both immediately and following periods of recall delay. Over periods of delay, a significant increase in RMS_c values was observed, highlighting the fact that over time, levels of overall recall accuracy decline for the majority of stimuli tested.

HELM2 was able to provide non-significant models of the data for all matrices except for the immediate data for group 1. This may however be due to a large source of far-miss error in recall for image 5C within this particular data set, the sources of which have been previously examined within Chapters 3 and 4. An examination of parameter estimates suggest that over time, the reduction in recall accuracy, as indicated by RMS_c, can be quantified in terms of a decrease in both the availability of location information, and in the precision of recall. Furthermore, a comparison to the parameter estimates generated in Experiment 7 suggest that despite levels of availability being initially higher for Experiment 8 in which participants receive extra verbal image information at encoding, following periods of delay, availability becomes comparable between the two experiments. Precision on the other hand is higher in Experiment 8, suggesting that the overall performance benefit over time manifests itself as greater levels of the precision of recall over periods of delay.

6.3 Experiments 5 and 6: Effects of recall delay on memory for simple images

Experiment 5: Introduction

The purpose of Experiment 5 was to examine the effects of delay on memory for simple real-world stimuli (stimuli set B)[35].

The immediate recall data from Experiment 5 has been presented within the previous chapter (effects of object density), and is presented alongside the delayed recall data within this chapter purely for comparative purposes.

Method

Please refer to Chapter 5 for full details of the methods of Experiment 5.

Results

Analysis 1: Is memory for location comparable across different stimuli?

In each of the test weeks, participants viewed 9 images (representing all target locations L1-L9) totalling 27 images over the three week period. In the final week of presentation (week 3), participants were asked for a location judgement for all 27 images (9 of which were viewed on the same day, 9 one week prior, and 9 two weeks prior). Each of these images tested were different. For this reason, when comparing performance as a function of time delay it is important to understand that although this is a

[35] Ratings regarding participant's confidence in the accuracy of their location recalls were not elicited in Experiment 5.

comparison of location judgements representing L1-L9 for each time condition, recall is being tested at each occasion for *different* images. This is a particular consideration in light of the knowledge that individual picture composition can have an effect upon the nature of the responses it elicits. For this reason, a test for homogeneity of responses for the overall totals per location across each of the three weeks was conducted. This revealed a non-significant result, x^2 (16, N = 999) = 25.52, *ns*, which suggests that participants were responding in a similar manner across the three image sets. It is therefore viable to compare performance as a function of delay across these different images testing memory for the same absolute locations.

Analysis 2: The effects of delay on memory for location in simple stimuli

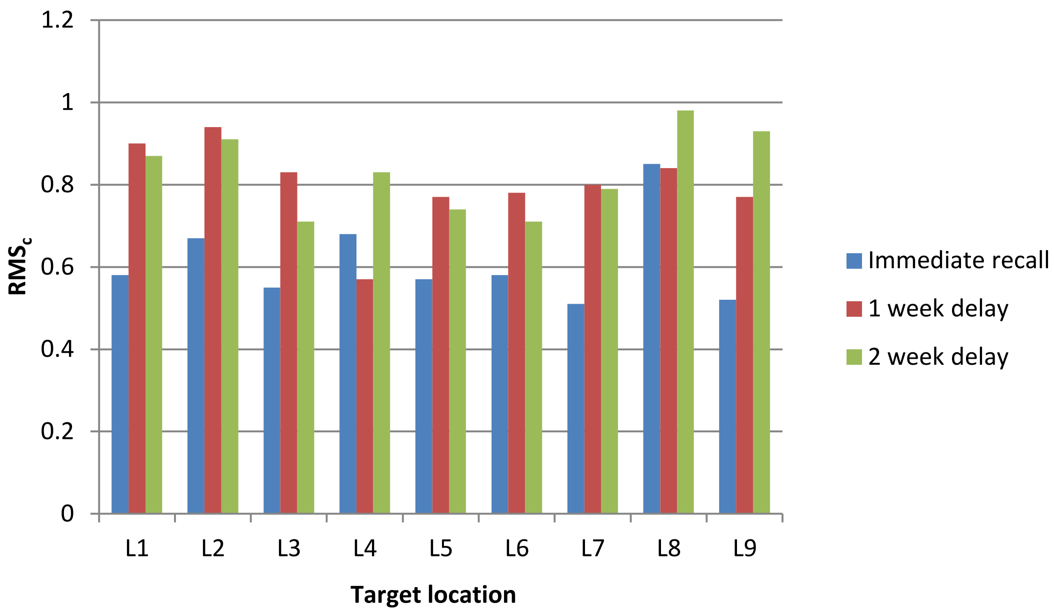
Mean RMS_c scores for all participants responses across individual stimuli are presented in Table 6.13. Comparisons of mean RMS_c scores across locations L1-L9 reveal an increase from 0.61 for immediate recall to 0.80 for a 1 week delay, and 0.83 for a 2 week delay. RMS_c values from both delay conditions demonstrate a significant difference to those from immediate recall, t (16) = -3.77, $p < .001$(1 week delay) and, t (16) = -4.48, $p < .001$(2 week delay). However, the comparison between 1 and 2 weeks delay did not demonstrate a significant effect, t (16) = -0.62, *ns*.

Table 6.13: Frequency of locations given as response to each of the 27 stimuli and computed RMS_c scores across the 3 weekly image presentations in Experiment 5.

Presentation Week and Target Location	Location given as response									Total	RMS_c Score
	1	2	3	4	5	6	7	8	9		
	Immediate recall										
3											
1	**22**	19	31	15	4	9	7	4	0	111	0.58
2	2	**22**	31	17	7	16	10	4	2	111	0.67
3	0	9	**38**	25	13	8	12	5	1	111	0.55
4	4	19	32	**17**	12	8	13	4	2	111	0.68
5	1	6	10	11	**37**	17	19	7	3	111	0.57
6	0	7	10	12	28	**25**	20	7	2	111	0.58
7	0	2	5	13	23	19	**33**	15	1	111	0.51
8	0	10	16	20	7	19	23	**15**	1	111	0.85
9	0	4	8	10	9	8	12	19	**41**	111	0.52
Total	29	98	181	140	140	129	149	80	53		
Average											0.61
	1 Week delay										
2											
1	**4**	17	22	22	6	14	10	11	5	111	0.90
2	4	**13**	25	13	6	12	18	15	5	111	0.94
3	2	6	**23**	20	9	19	22	8	2	111	0.83
4	0	5	25	**24**	30	8	12	5	2	111	0.57
5	2	12	13	13	**14**	18	31	6	2	111	0.77
6	2	7	18	27	15	**15**	15	10	2	111	0.78
7	4	14	16	5	7	9	**22**	28	6	111	0.80
8	1	10	15	12	16	19	22	**14**	2	111	0.84
9	1	5	10	13	14	17	23	21	**7**	111	0.77
Total	20	89	167	149	117	131	175	118	33		
Average											0.80
	2 Week delay										
1											
1	**7**	17	19	18	10	14	16	7	3	111	0.87
2	3	**6**	21	14	22	28	9	5	3	111	0.91
3	3	7	**25**	20	23	15	6	11	1	111	0.71
4	6	16	24	**13**	13	8	14	14	3	111	0.83
5	3	8	15	17	**17**	19	18	12	2	111	0.74
6	1	9	17	10	18	**19**	22	13	2	111	0.71
7	1	12	9	20	18	14	**21**	11	5	111	0.79
8	2	7	24	15	19	20	13	**8**	3	111	0.98
9	3	17	15	13	6	14	16	16	**11**	111	0.93
Total	29	98	181	140	140	129	149	80	53		
Average											0.83
Overall total	78	286	517	429	403	411	459	295	119		

These data suggests that overall levels of performance decrease with time (as indicated by an increase in mean RMS_c for individual stimuli), but that this occurs within the first week of recall delay, with no further significant decrease in mean performance between 1 and 2 weeks recall delay. Mean RMS_c scores for images testing recall across target locations for each of the 3 images sets are presented in Figure 6.16.

Figure 6.16: Mean RMS_c scores for all participants by target location for immediate and delayed recall of simple images in Experiment 5.



How is forgetting characterised?

Optimised HELM2 models were able to provide predictions which were not significantly different to the observed data in all three recall matrices; immediate recall: x^2 (36, N = 999) = 49.15, *ns*, 1 week delay: x^2 (36, N =

999) = 47.18, *ns*, 2 week delay: x^2 (36, *N* = 999) = 38.88, *ns*. Parameter estimates are provided within Table 6.14.

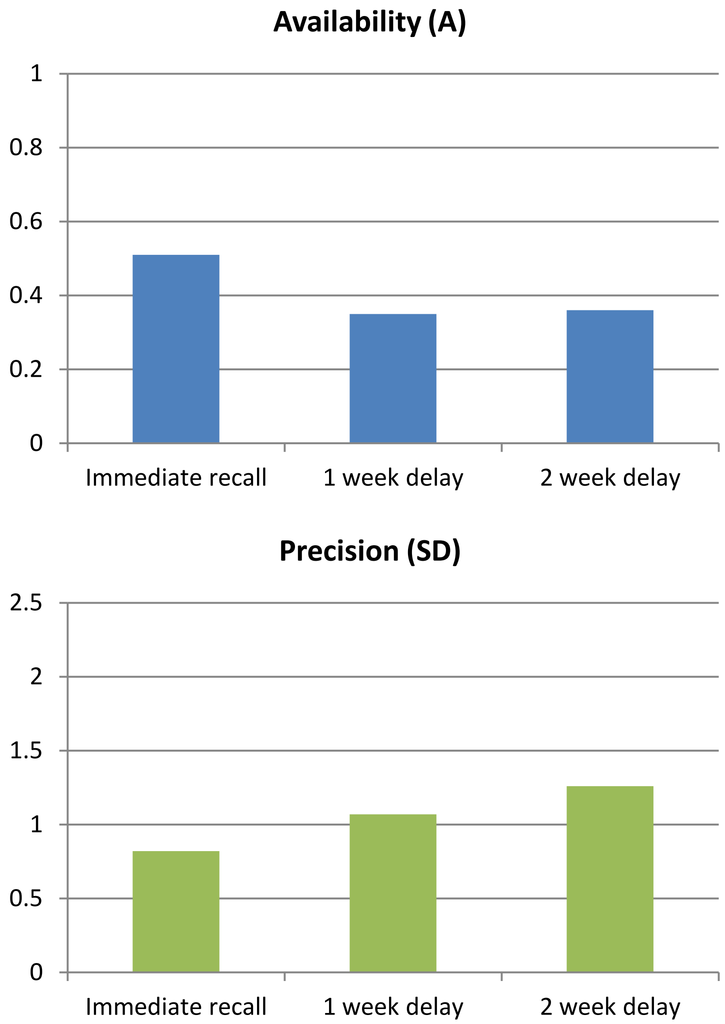
Table 6.14: Parameter estimates generated by HELM2 for Experiment 5.

Target location	Immediate recall		1 week delay		2 week delay	
	A	*SD*	*A*	*SD*	*A*	*SD*
L1	0.68	1.46	0.29	1.28	0.49	2.95
L2	0.43	0.77	0.01	0.10	0.32	0.10
L3	0.51	0.76	0.31	1.44	0.35	0.95
L4	0.50	1.03	0.60	0.96	0.04	0.10
L5	1.00	1.75	0.32	1.06	0.44	1.41
L6	0.26	0.10	0.36	0.94	0.42	1.18
L7	0.70	1.33	0.22	0.56	0.70	2.06
L8	0.02	0.10	0.38	1.31	0.27	0.87
L9	0.48	0.10	0.67	1.94	0.24	1.75
Average	0.51	0.82	0.35	1.07	0.36	1.26

Parameter estimates reveal a decline in mean *A* across each of the 9 images tested for immediate recall (0.51) and 1 week delay (0.35), *t* (16) = 1.40, *ns*, and immediate recall and 2 week delay (0.36), *t* (16) = 1.31, *ns,* each of which do not demonstrate a significant result. The comparison between immediate recall and 1 week delay, however, provides the greatest degree of difference, with a probability of p = .09. A comparison between levels of availability at 1 and 2 weeks delay does not represent a significant difference, *t* (16) = -0.14, *ns.*

A decline in the precision of responses is highlighted over time, with an increase in *SD* at each presentation week: mean *SD for* immediate recall images = 0.82, 1 week delay = 1.07, *t* (16) = -0.89, *ns*, 2 week delay = 1.26, *t* (16) = -1.19, *ns*, however, each of these comparisons failed to demonstrate a significant result. A comparison between mean *SD* at 1 and 2 weeks delay suggest greater levels of precision for the 2 week delay images, which is the reverse of what we may expect, although again this does not present a significant result, *t* (16) = -0.56, *ns*. Mean estimated parameter values of *A* and *SD* across all images are presented in Figure 6.17.

Figure 6.17: Bar charts indicating mean parameter estimates of Availability (*A*) and precision (*SD*) in Experiment 5 both immediately and following recall delay.



Summary

Experiment 5 offers a preliminary examination of the nature of memory for location for simple stimuli across periods of recall delay. An important issue to bear in mind regarding the experimental design of this study is that recall is elicited for different images

An initial test of the homogeneity of responses revealed that despite recall being elicited for the different sets of images across the three recall time periods, participants were responding in a similar manner across the three sets of stimuli. This is in contrast to the lack of homogeneity found within immediate recall for complex stimuli (outlined within Experiment 1), and may be inherently linked to the simplicity of the stimuli used (single-object real-world images).

RMS_c values suggest that levels of performance decrease as a function of time. However, the majority of decline in performance occurs in the first week, with no further significant decrease in mean performance between 1 and 2 weeks delay

An examination of the parameter estimates generated by HELM2 demonstrate a decline in mean *A*, and an increase in mean *SD* (decrease in precision) between immediate recall and the two conditions of delayed recall, however these fail to reach significance in either case. Nor does a comparison between mean levels of *A* between1 and 2 weeks recall delay. Surprisingly, a comparison between mean *SD* at 1 and 2 weeks suggest greater levels of precision for the 2 week delay images. Although this does not represent a significant difference, in light of these findings, it should again be acknowledged that different images are presented at different time points. Although participants recall responses have been shown to be homogeneous, it is possible that there may be some slight variation between data elicited from each of the sets of images.

Due to the nature of this experiment, these analyses unfortunately tell us nothing about the way in which memory for location for the same images is affected by delay in recall. Furthermore, the results of the present experiment are not directly comparable to the findings for complex images over time (Experiment 7), due to substantial differences in the method of stimuli presentation (see Chapter 5 for a discussion). As such, a further experiment is warranted to directly compare memory for location as a function of the complexity of images over periods of recall delay (Experiment 6).

Experiment 6

Experiment 6 provides an opportunity to examine the nature of image complexity as a within-participants design; across three time points (either immediately, or following a 1 week or 2 week recall delay, a between-participant comparison).

Method

Please refer to Chapter 5 for full details of the methods of Experiment 6.

Results

Analysis 1: The effects of delay on memory for location in complex and simple stimuli

Like all previous experiments within this chapter, mean RMS_c scores increased with time for both the 9 complex and the 9 simple images over time, with the largest increase being between immediate and 1 week delayed recall. RMSc scores are presented within Tables 6.15 and 6.16.

Table 6.15: Frequency of locations given as response to each of the 9 stimuli and computed RMS_c scores across 3 time periods for Experiment 6 (complex images).

Presentation week and target location	Location given as response 1	2	3	4	5	6	7	8	9	Total	RMS_c score	Mean confidence
	Immediate recall											
3												
1	**38**	12	2	2	0	0	0	2	1	57	0.19	3.89
2	9	**24**	8	6	5	3	2	0	0	57	0.36	3.37
3	0	4	**28**	14	1	2	0	5	3	57	0.45	3.56
4	1	3	7	**31**	9	4	2	0	0	57	0.29	3.60
5	1	0	4	14	**19**	10	3	5	1	57	0.48	3.05
6	0	0	0	2	16	**31**	7	0	1	57	0.23	3.84
7	0	2	16	4	7	11	**9**	8	0	57	0.78	2.70
8	0	1	3	0	2	28	15	**8**	0	57	0.53	3.61
9	3	5	6	5	3	4	12	11	**8**	57	0.79	2.63
Total	52	51	74	78	62	93	50	39	14			
Average											0.46	3.36
	1 Week delay											
2												
1	**0**	6	14	6	8	7	9	3	0	53	0.92	2.45
2	1	**7**	10	11	3	11	8	2	0	53	0.81	2.30
3	0	2	**12**	16	6	11	3	2	1	53	0.64	2.40
4	2	1	5	**10**	8	10	9	3	5	53	0.85	2.25
5	2	5	6	8	**4**	9	9	9	1	53	0.86	1.77
6	0	1	8	8	20	**11**	4	1	0	53	0.57	2.72
7	0	7	11	12	7	9	**6**	1	0	53	0.98	2.09
8	0	6	6	8	6	16	9	**1**	1	53	0.93	2.32
9	0	2	7	13	6	11	11	2	**1**	53	0.95	2.32
Total	5	37	79	92	68	95	68	24	9			
Average											0.83	2.29
	2 Week delay											
1												
1	**3**	4	10	8	6	10	6	6	0	53	0.94	2.32
2	2	**3**	10	13	6	8	8	3	0	53	0.85	2.21
3	0	3	**14**	12	8	8	7	1	0	53	0.62	2.47
4	0	8	6	**10**	10	6	8	3	2	53	0.73	2.40
5	2	4	6	12	**3**	6	8	10	2	53	0.88	1.77
6	0	0	2	12	23	**11**	5	0	0	53	0.47	2.58
7	0	2	13	13	7	10	**5**	3	0	53	0.91	2.17
8	1	4	7	9	7	14	10	**1**	0	53	0.94	2.57
9	0	1	9	14	4	13	11	1	**0**	53	0.99	2.30
Total	8	29	77	103	74	86	68	28	4			
Average											0.81	2.31
Overall total	65	117	230	273	204	274	186	91	27			

Table 6.16: Frequency of locations given as response to each of the 9 stimuli and computed RMS_c scores across 3 timer periods for Experiment 6 (simple images).

Presentation week and target location	Location given as response									Total	RMS_c score	Mean confidence
	1	2	3	4	5	6	7	8	9			
	Immediate recall											
3												
1	**13**	18	11	4	2	0	4	3	2	57	0.53	3.09
2	0	**23**	24	4	2	3	0	1	0	57	0.30	3.67
3	0	13	**34**	10	0	0	0	0	0	57	0.15	4.26
4	0	0	11	**31**	12	2	0	0	1	57	0.24	3.95
5	0	1	3	2	**38**	7	6	0	0	57	0.24	3.82
6	0	1	1	3	11	**32**	8	0	1	57	0.26	4.02
7	0	0	0	0	3	12	**35**	7	0	57	0.16	4.18
8	0	1	2	2	1	3	24	**21**	3	57	0.33	3.88
9	0	2	3	0	2	2	6	21	**21**	57	0.35	3.68
Total	13	59	89	56	71	61	83	53	28			
Average											0.28	3.84
	1 Week delay											
2												
1	**3**	8	9	1	1	8	12	10	1	53	1.05	2.11
2	0	**2**	14	17	9	9	1	0	1	53	0.72	2.87
3	0	5	**16**	12	7	6	5	2	0	53	0.56	3.30
4	1	3	13	**16**	4	8	7	1	0	53	0.54	2.72
5	0	1	6	11	**11**	14	6	4	0	53	0.54	2.43
6	0	1	10	7	8	**15**	6	5	1	53	0.61	2.58
7	0	5	1	8	12	13	**13**	1	0	53	0.64	2.70
8	0	5	9	3	8	7	11	**9**	1	53	0.80	2.70
9	0	8	4	10	6	4	15	5	**1**	53	0.95	2.28
Total	4	38	82	85	66	84	76	37	5			
Average											0.71	2.63
	2 Week delay											
1												
1	**2**	3	15	5	2	2	16	6	2	53	1.04	2.25
2	0	**7**	10	14	7	9	6	0	0	53	0.73	2.68
3	1	1	**15**	6	9	12	8	1	0	53	0.71	3.32
4	0	3	6	**14**	10	10	8	2	0	53	0.60	2.66
5	0	1	14	15	**3**	10	8	2	0	53	0.66	2.11
6	1	2	9	11	8	**10**	8	3	1	53	0.70	2.62
7	0	0	8	11	12	10	**9**	3	0	53	0.72	2.68
8	0	3	6	5	7	9	13	**8**	2	53	0.71	3.00
9	1	6	9	5	1	10	15	6	**0**	53	0.94	2.19
Total	5	26	92	86	59	82	91	31	5			
Average											0.76	2.61
Overall total	22	123	263	227	196	227	250	121	38			

Effects of image complexity on overall performance over time

Comparisons of the mean RMSc across all images and time periods suggest that overall performance is greater for simple when compared with complex stimuli. Independent t-tests of the mean RMSc scores for individual stimuli revealed that for immediate recall, this comparison represented a significant difference: immediate recall, t (16) = -2.08, p < .05. However, for delayed recall, mean RMSc values per image were not significantly different from one another: 1 week delay, t (16) = 1.57, *ns*, 2 week delay, t (16) = -0.78, *ns*. As such, it can be assumed that although performance for the simple stimuli is significantly improved for immediate location recall, for delayed recall, levels of performance are not significantly greater than that for complex real-world images.

Complex stimuli

Mean RMS_c scores for the complex real-world images increased steeply between immediate and 1 week delayed recall, but were comparable between 1 and 2 weeks delay (immediate = 0.46, 1 week = 0.81, 2 weeks = 0.83). Comparisons of the mean RMSc scores per image revealed a significant difference between immediate recall and 1 week delay, t (16) = -4.37, p < .001, and immediate recall and 2 weeks delay, t (16) = -3.86, p < .001. However, for a comparison of mean RMS_c scores for 1 and 2 weeks delay demonstrated no significant difference, t (16) = 0.27, *ns*.

Simple stimuli

Mean RMS_c scores for the simple real-world images also increased between immediate and 1 week delayed recall, but were shown to be comparable between 1 and 2 weeks delay (immediate = 0.29, 1 week = 0.71, 2 weeks = 0.76). A comparison of the mean RMSc scores per image revealed a significant difference between immediate recall and 1 week delay, t (16) = -5.88, p < .001, as well as between immediate recall and 2 weeks delay, t (16) = -7.82, p < .01. Yet comparisons of mean RMS_c scores per image between 1 and 2 weeks were not demonstrated to be significantly different from one another, t (16) = -0.57, *ns*.

Findings demonstrate that overall levels of performance at both 1 and 2 weeks delay, for simple and complex real-world images, are significantly lower (as indicated by increased RMS_c scores) than for immediate recall. However, this effect is most prominent in the first week of delay, with no significant decrease in performance between 1 and 2 weeks delay.

Analysis 2: How is forgetting characterised?

HELM2 generated non-significant model fits for two of the three complex image matrices: immediate recall: x^2 (36, N = 513) = 64.96, p < .01, 1 week delay: x^2 (36, N = 477) = 47.18, p < .01, and 2 week delay: x^2 (36, N = 477) = 38.88, *ns*. For simple stimuli, all matrix models were sufficient predictions of the data: immediate recall: x^2 (36, N = 513) = 49.15, *ns*, 1 week delay: x^2 (36, N = 477) = 47.18, *ns,* and 2 week delay x^2 (36, N = 477) = 38.88, *ns*. For parameter estimates, see Tables 6.17 & 6.18.

Table 6.17: Parameter estimates generated by HELM2 for each of the 9 complex stimuli in Experiment 6.

Target location	Immediate recall		1 week delay		2 week delay	
	A	*SD*	*A*	*SD*	*A*	*SD*
L1	0.87	0.10	0.03	0.10	0.12	0.88
L2	1.00	2.28	0.16	0.99	0.13	2.34
L3	0.60	0.66	0.27	0.10	0.32	0.99
L4	1.00	1.11	1.00	2.33	1.00	2.19
L5	0.80	0.95	0.63	3.56	0.56	7.17
L6	0.98	0.70	0.94	1.23	1.00	0.98
L7	0.49	0.96	0.31	1.03	0.00	2.17
L8	0.81	0.62	0.02	2.30	0.07	0.10
L9	0.90	5.30	0.22	1.64	0.00	4.46
Average	0.83	1.41	0.40	1.48	0.35	2.36

Table 6.18: Parameter estimates generated by HELM2 for each of the 9 simple stimuli in Experiment 6.

Target location	Immediate recall		1 week delay		2 week delay	
	A	*SD*	*A*	*SD*	*A*	*SD*
L1	0.65	0.96	0.17	2.73	0.03	0.10
L2	0.75	0.10	0.92	1.12	0.75	1.40
L3	1.00	0.64	0.68	1.01	0.31	0.75
L4	0.95	0.71	0.56	0.73	0.72	1.31
L5	0.73	0.10	0.89	1.37	0.34	0.61
L6	0.83	0.61	0.74	1.53	0.73	1.74
L7	1.00	0.71	0.71	1.08	0.59	1.06
L8	0.82	0.65	0.21	0.10	0.61	1.79
L9	0.78	0.78	0.30	0.10	0.00	2.40
Average	0.83	0.58	0.57	1.08	0.45	1.24

Effects of image complexity on parameter estimates

Mean estimates of *A* for all stimuli combined are higher for simple images, as demonstrated in Tables 6.17 and 6.18. However, the mean estimates are not demonstrated to be significantly different from one another (immediate recall, t (16) = -0.92, ns; 1 week delay t (16) = -1.14, ns, 2 week delay, t (16) = -0.59, *ns*). Mean estimates of *SD* represent a similar trend, with higher parameter estimates of *SD* for the complex images, suggestive of lower levels of precision for these stimuli. Again, these comparisons did not represent statistically significant differences between stimuli tested (immediate recall, t (16) = 1.55, ns; 1 week delay t (16) = 0.85, ns, 2 week delay, t (16) = 1.46, *ns*). Comparisons of mean parameter estimates across simple and complex stimuli are presented within Figures 6.18 and 6.19.

Figure 6.18: Bar charts indicating mean parameter estimates of Availability (*A*) for immediate and delayed recall for complex and simple images in Experiment 6.

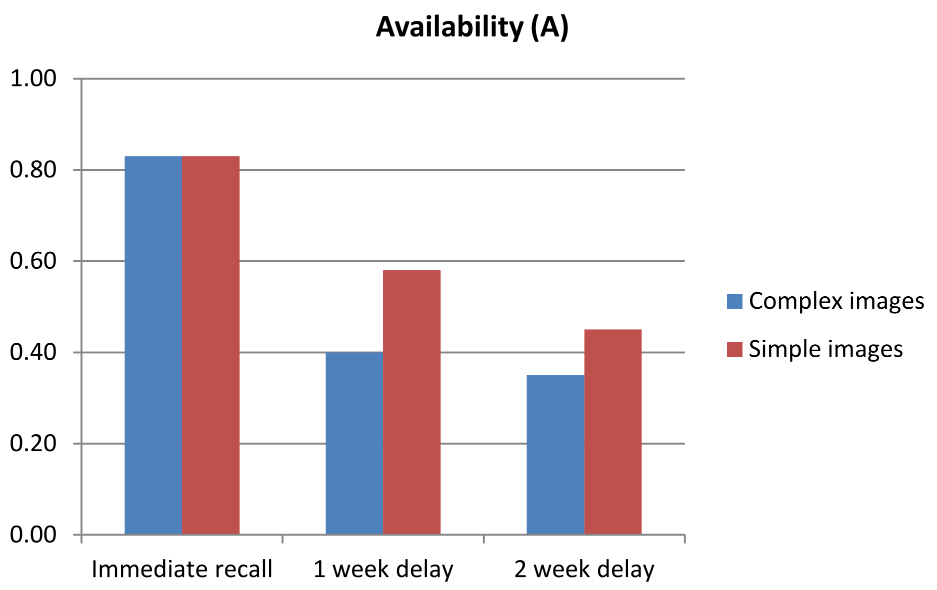
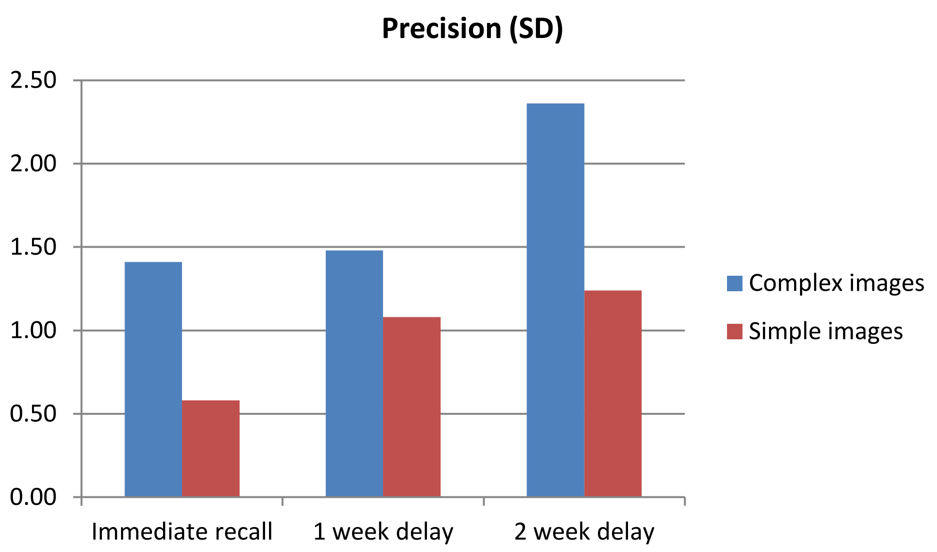


Figure 6.19: Bar charts indicating mean parameter estimates of precision (*SD*) for immediate and delayed recall for complex and simple images in Experiment 6.



Complex stimuli

In line with previous findings, mean levels of predicted *A* decline over time, with parameter estimates of 0.83 for immediate recall, falling to 0.40 after 1 week and 0.35 after two weeks of recall delay. Comparisons of the mean *A* parameter estimates for all images demonstrate significant differences between immediate and delayed recall of both 1, t (16) = 3.13, p < .01, and 2 weeks, t (16) = 3.20, p < .01, yet no significant difference between 1 and 2 weeks recall delay, t (16) = 0.23, *ns*.

Similar findings were demonstrated for mean levels of precision over time, in that the precision of responses declined, with an increase in the mean *SD* across all image from 1.41 at immediate recall, to 1.48 after 1 week and 2.36 following 2 weeks recall delay. However, comparisons of mean *SD* estimates for each image between immediate and delayed recall demonstrate that these differences are not statistically significant ;1 week delay: t (16) = -0.10, *ns*; 2 week delay: t (16) = -1.06, *ns*, as is the case for the comparison between 1 and 2 weeks recall delay, t (16) = -1.08, *ns*

Simple stimuli

Once again, mean levels of predicted *A* declined as a function of time, with parameter estimates of 0.83 for immediate recall falling to 0.57 for 1 week and 0.45 for 2 weeks recall delay. As with the complex stimuli, independent t-tests reveal a significant decline in *A* between immediate recall and 1 week delay, t (16) = 2.50, p < .05, and between immediate recall and 2 week delay, t (16) = 3.57, $p < .01$, but not between 1 and 2 weeks delay, t (16) = 0.89, *ns*.

Like the results for complex images, precision of responses declines over time, with a rise in mean parameter estimates of *SD* from 0.58 at immediate recall, to 1.08 for 1 week and 1.24 for 2 weeks recall delay. As with the previous analyses, comparisons of the mean estimates of *SD* for individual images revealed a significant result between immediate and delayed recall (1 week, t (16) = -1.77, $p < .05$; 2 week, t (16) = -2.60, $p < .01$) but not between the two delay conditions (t (16) = -0.44, *ns*).

Findings indicate that the decrease in overall levels of performance for recall over time can be quantified as a loss of both the availability of location information and the precision of recall for both simple and complex real-world images, but that the majority of this information is lost between immediate recall and recall after 1 week.

Analysis 2: What are the effects of delay on confidence in location recall?

Mean confidence ratings for all stimuli, and averaged across time can be found in Tables 6.15 and 6.16. Analyses of mean confidence ratings suggest that participant's confidence in the accuracy of their location recalls is slightly higher for simple over complex images, and declines between immediate recall and 1 week delay for both types of stimuli, with no further decline between 1 and 2 week recall, (complex images, mean confidence for immediate recall = 3.36, 1 week delay = 2.29, 2 week delay = 2.31; simple images, immediate = 3.84, 1 week delay = 2.63, 2 week delay = 2.61), A comparison of the confidence in recall between simple and complex images averaged across time reveal that the relative declines in confidence do not demonstrate statistically significant results (complex images, immediate versus 1 week recall delay, t (16) = 6.02, *ns*; immediate versus 2 week recall delay, t (16) = 5.97, *ns*; simple images, immediate versus 1 week recall delay, t (16) = 7.40, *ns*; immediate versus 2 week recall delay, t (16) = 7.05, *ns*).

Correlations between overall recall performance (RMS_c) and confidence in recall for each of the simple and complex stimuli over time are presented within Table 6.19. As was the case in Experiment 7 (complex images), these correlations reveal that the relationship between confidence and recall performance declines with recall delay in both stimuli sets. Significant correlations between mean confidence and mean RMSc were only demonstrated for immediate recall in both sets of stimuli. Plots demonstrating the relationships can be found in Figures 6.20 and 6.21.

Table 6.19: Correlations between mean confidence ratings and mean RMS_c across 27 stimuli for groups 1 and 2 immediate and delayed recall in Experiment 8.

Time	*r*	
	Complex stimuli	*Simple stimuli*
Immediate recall	-0.91**	-0.96**
1 week delay	-0.54	-0.65
2 week delay	-0.44	-0.44

** p < .01

Figure 6.20: Correlations between mean confidence ratings and mean RMS$_c$ across the 9 complex stimuli for immediate and delayed recall in Experiment 6.

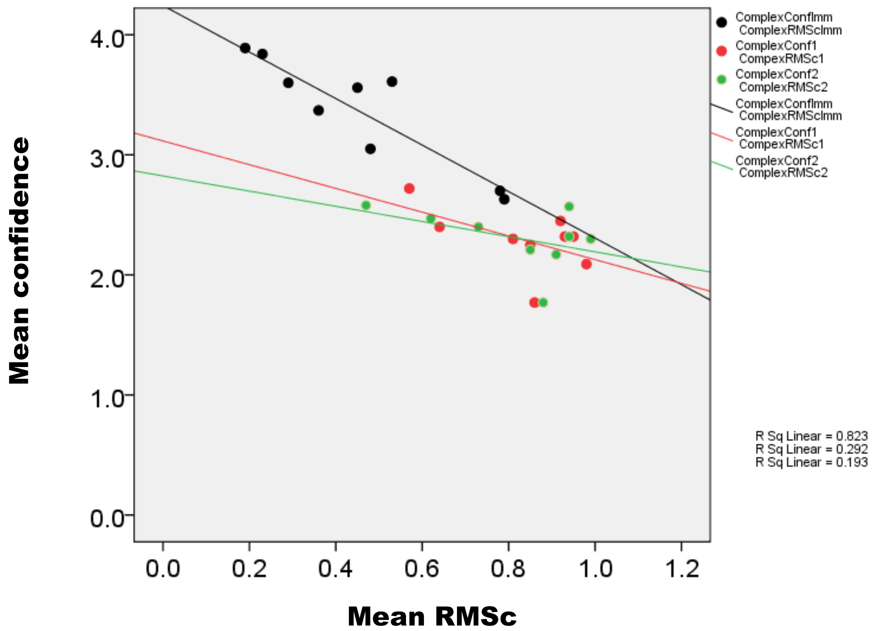
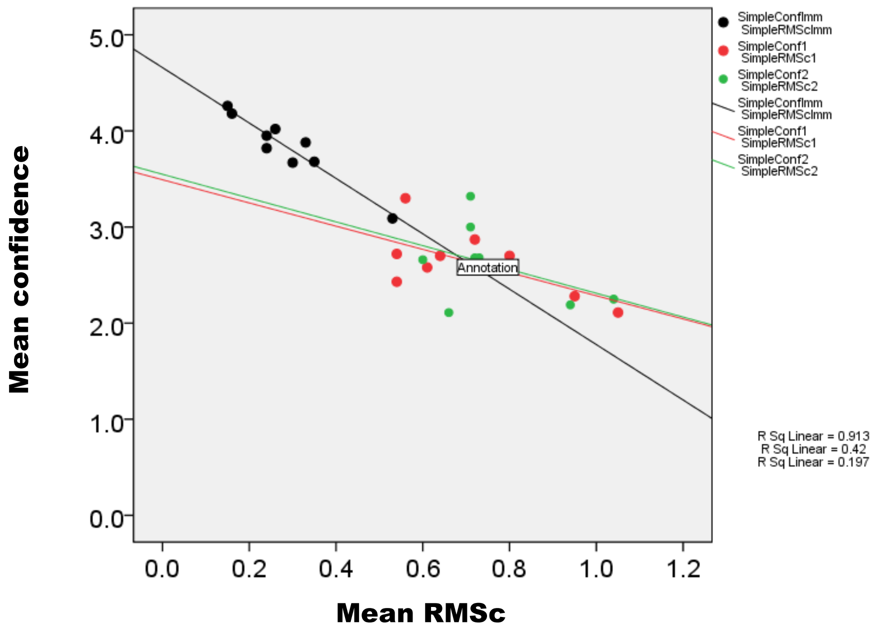


Figure 6.21: Correlations between mean confidence ratings and mean RMS$_c$ across the 9 simple stimuli for immediate and delayed recall in Experiment 6.



Summary

Experiment 6 offers a within-participant comparison of memory for simple and complex real-world images as a function of delay. This allows direct comparisons to be sought in the nature of memory for location as a function of image complexity over time.

Findings revealed, in line with the majority of experiments presented herein, that memory for location declines as a function of delay, with the largest decline occurring within the first week of delay. Comparisons of mean RMS_c values for stimuli between 1 and 2 weeks delay failed to provide any significant differences in performance. Recall performance for the simple stimuli was greater in the immediate recall condition, however, following periods of delay, RMSc values were comparable between stimuli types, suggesting that although memory for location is initially better for simple images, the rate of forgetting is more pronounced, resulting in equivocal performance with complex images one week.

Though parameter estimates generated by HELM2 suggest greater availability and precision of recall in simple images when compared with complex images, these differences do not prove to be statistically significant. For each stimuli type, availability and precision of recall decline with time, with the majority of forgetting occurring between immediate recall and 1 week delay. As with RMS_c values, no differences are observed between parameter estimates for 1 and 2 weeks delay.

Finally confidence in recall for all images declines as a function of delay, yet not significantly. However, correlations reveal once more that the relationship between confidence and recall performance weakens over time.

6.4 Effects of forgetting across four experiments

In summary, data from four experiments assessing the nature of recall over time have demonstrated five key findings:

1. Memory for location becomes less accurate over time (as demonstrated by an increase in RMS_c), see Figure 6.18.
2. The majority of decline in performance is witnessed between immediate recall and 1 week delay.
3. Decreases in performance can be quantified (in the majority of cases) as a loss of both the availability of location information, and a decrease in the precision of recall.
4. Confidence in the accuracy of recall declines over time, with the majority of loss occurring within the first week of delay.
5. The relationship between confidence and recall performance decreases over time.

Figure 6.22: Overall recall performance, as indicated by RMS_c scores across all four experiments for immediate, 1, and 2 weeks delay.

Figure 6.22 plots the mean RMS_c scores for all experimental groups within each of the four studies presented in this chapter. Despite the mixture of experimental conditions and methodologies employed, it is demonstrated that a clear pattern has emerged regarding the accuracy of recall over time. Yet it should be noted that a clear benefit in recall of verbal commentary can be witnessed following 2 weeks recall delay.

6.5 General Discussion

The role of forgetting of spatial memories has warranted little attention within the field of visual memory, despite numerous investigations into the potential benefits it may offer to applied issues in document retrieval (Lansdale & Coates, 1999; Lansdale, et al., 2005; Lansdale, Scrivener, & Woodcock, 1996). Experiments presented within this chapter examined the effects of delay on memory for location, in the knowledge that application of spatial cognition to any form of image retrieval system would require *a priori* understanding of the likelihood of recall over time.

What can we learn from these experiments about the nature of forgetting?

1. Forgetting occurs

The first point to note from the findings of four experiments is that memory for location *is* subject to forgetting. In each of the four experiments, memory for location was poorer for the delayed conditions when compared to immediate recall. Although this may not appear to be a surprising result, these studies represent the first examination of forgetting for location of cued-target objects in real-world scenes

2. Forgetting can be quantified as a loss of availability and precision

HELM2 was able to provide models which were not significantly different to the majority of observed data matrices within these experiments. For those unable to be sufficiently modelled, large variations within data distribution were observed. For example, the immediate recall matrix for

Experiment 8 provided a substantial number of far-miss errors in recall for image 5C, whilst recall for all other stimuli was relatively accurate.

Parameter estimates generated by the model account for the decline in memory performance as a decrease in the availability of location information, and a spread in the distribution of responses over time in each of the experiments, with the exception of parameter estimates of availability within Experiment 7. However, as memory for location was elicited twice within this experiment, the failure of this data to adhere to the observed trend witnessed in all other examinations may be confounded by experimental design. Nevertheless, recall was also elicited twice within Experiment 8 which provided statistically significant decreases in mean availability and precision between immediate and delayed recall. As such, there appears to be something other than experimental method impacting upon the observed parameter estimates for this particular set of data. Given more time, further investigations into the source of this inconsistency would have been undertaken.

3. Benefits of additional information at encoding are long-lasting

The results of Experiment 8 serve to confirm the previous theoretical findings of Experiment 2 in that the accuracy of recall can be elevated with the provision of additional verbal information at encoding. This was evident in lower mean RMS_c values for the recall of location across the same stimuli in Experiment 7, both immediately, and following periods of 1 and 2 weeks delay. Findings from this experiment suggest that whilst the provision of verbal commentaries alongside images does not eliminate forgetting, overall levels of performance still outweigh those for the recall of images presented alone. Parameter estimates of mean availability and precision suggest that this performance benefit is a result of increased precision in recall within Experiment 8, whereas levels of available information are comparable across the two experiments.

4. The immediate benefit for simple stimuli is eliminated over time

Memory for the immediate recall of location has been previously demonstrated to be superior to that for complex real-world stimuli (Chapter 5). Experiment 6 provides evidence to support this theoretical finding for the immediate recall of location. However, the delayed recall data for both simple and complex real-world images failed to demonstrate significant differences in either mean RMSc, or mean parameter estimates. These findings demonstrate that although the relative density of objects within a scene impact upon the immediate recall of object location, following a time delay of 1 week, forgetting effects appear more pronounced for simple stimuli, resulting in equivocal performance levels for complex images. This is an interesting finding theoretically as it suggests that the encoding of location for simple stimuli is not dissimilar than for complex images, despite an initial benefit for single-object stimuli.

5. Confidence is a poor predictor of availability for delayed recall

Previous experiments have consistently demonstrated large correlations between overall levels of performance and participant’s confidence in the accuracy of their location responses (see Chapters 3 and 5). An examination of the correlations between confidence and recall accuracy in the present experiments suggests that although these two factors are highly related for the immediate recall of location, the relationship diminishes at each of the two delayed recall tests. This has significant implications for document retrieval strategies based upon user confidence as it renders the ability to predict the relative success of retrieval from their confidence in the accuracy of their location memory less effective with time.

6. Similar patterns are observed despite methodological variations

Finally, despite the disparity of experimental designs and manipulations presented within this chapter, findings are relatively consistent regarding each of the 5 points above. Figure 6.18 provides a visual representation of the patterns of results generated for overall performance within each of the conditions of the four experiments presented here. This is encouraging as it suggests that memory for location in real-world images is subject to basic principles of decline.

The ability to observe replicable patterns of results identifies a unique opportunity to quantify memory for location over time. The applied impact of this is that should memory for location prove to be of benefit to image retrieval, then predictions regarding levels of information available in memory may be adequately modelled, and predictions made regarding both the required constraints for image search and the likelihood of retrieval.

As this is a novel area of investigation, there are few comparisons which can be made within the literature regarding the theoretical implications of the present results. However, within the general discussion section, the applied implications of the results demonstrated thus far are considered relative to the feasibility of exploiting human spatial cognition for practical retrieval solutions.

Chapter seven: general discussion

The aims of this thesis were to quantify the effects of image content, image complexity and time delay on memory for location. The series of work presented here represents research funded by the Engineering and Physical Sciences Research Council (EPSRC) as part of a large-scale examination of the human cognitive factors which may be exploited for applications of image retrieval. The three main objectives of this research were; (1) to examine the nature of location recall across a range of naturalistic stimuli which vary in terms of semantic and visual complexity, (2) to assess the HELM analytical framework (Lansdale, 1998) as a means of quantifying location recall for real-world images, and (3) to explore the effects of forgetting within location memory with reference to both of the above.

7.1 Principal findings

1. Links with previous research

First, it is important to establish what we already knew about memory for location prior to the research presented herein. An examination of the literature concludes that location memory for real-world images is sparse (Lansdale, et al., 2005). Studies examining memory for location have concentrated their efforts on the recall of highly simplistic, artificially constructed stimuli (Baguley, et al., 2006; Irwin & Zelinsky, 2002; Lansdale, 1998; Mandler & Parker, 1976; Mandler, Seegmiller & Day, 1977; Naveh-Benjamin, 1987). Unfortunately, these studies tell us little about the nature of memory for location in dynamic real-world scenes, in which objects co-occur in semantic, information -rich contexts. Should the aim of this thesis have been to examine purely theoretical issues in recall, then stimuli constructed to suit experimental design would offer a highly appealing route for investigation, as these stimuli exclude the multiple complexities associated with the study of dynamic real-world pictures. However, taking into consideration the aims of the present research, it is of practical importance to examine highly variable naturalistic stimuli. In true Darwinian style, until true complexity is revealed, theory cannot progress.

A set of experiments conducted by Lansdale, et al., (2005) demonstrated the impact of individual image composition on the accuracy of location recall, with significant levels of variability displayed for the recall of objects testing the same absolute location across different images. These studies highlight an effect of semantic salience, whereby items central to the understanding of the scene (foreground items) elicit more accurate recall responses than background items. The authors discovered that the effects of semantic saliency could be suppressed, and overall levels of recall accuracy increased, through the presence of additional verbal information at encoding. This hypothesised that this verbal commentary, describing the scene content, served to equalise attention across foreground and background items during encoding. Data also revealed that participants' confidence in the accuracy of their location judgements was a good predictor of the availability of location information in memory. The research described here forms the basis from which current investigations evolved. Experiments 1 and 2 sought to establish strong links with this previous research. Following the methodological and analytical techniques of Lansdale and colleagues (2005), initial experiments examined the nature of location memory for objects within novel real-world images, whilst examining the applicability of the HELM analytical model to quantify location memory recall. The remainder of this chapter will be concerned with the theoretical findings of these, and subsequent experiments, in terms of what they add to the knowledge surrounding spatial memory for visual information, together with a consideration of the potential application of location memory to image database design.

2. Initial investigations into memory for complex real-world images

Experiment 1 provided an investigation of the fundamental patterns of recall witnessed for memory on a continuum. Experiment 2 contributed the additional variable verbal descriptors during image encoding. The findings from these initial experiments were multifaceted, in that in some respects, they strengthened what we already knew about memory for location, yet in others, they questioned some of the fundamental assumptions previously held for location recall.

Data from Experiments 1 & 2 revealed some key similarities with the data of Lansdale, et al., (2005), in that a central bias, known to exist for stimuli presented on a continuum (Jones, 1976; Lansdale, 1998; B. Tversky &

Schiano, 1989), manifests itself in the reduced likelihood for participants to respond with locations at the periphery of the stimulus array. High levels of correct location recall and near-miss error were demonstrated, yet as with the previous investigations, this could be accounted for using a model of inexact recall only (the parameter of exact recall was not required). And finally, the provision of a verbal commentary at encoding resulted in increased availability of location information in memory. However, confidence in recall was not predictive of availability of location recall, but instead was highly correlated with overall performance, as measured using RMS_c. Furthermore, the distribution of error witnessed for a novel set of real-world images provided greater levels of inter-stimulus variation than had been previously observed for natural images. The upshot of this was that the HELM model was unable to accurately model the location memory data observed for a number of matrices generated within these experiments.

Resulting implications of these findings were that a reconsideration of the HELM model was required in order to provide a means of quantifying memory for location which is subject to substantially more variable error distributions than had been previously noted. Furthermore, theoretical investigations regarding the effects of image content were required to parse out the factors involved in the generation of substantial variations in error. Without an understanding of the key influencing factors on recall for complex stimuli, the application of memory for location to applied issues in image retrieval would undoubtedly lead to inefficient query strategies.

Nevertheless, observations of high degrees of recall accuracy for a number of stimuli suggest, at the broadest level, that a location-based search strategy for image recall is feasible. Yet a deeper understanding of the relevant influences on large error distributions would only serve to strengthen the approach.

3. Effects of image content on memory for location

Previous research by Einhauser, Spain and Perona (2008) argue that ‘interesting’ objects (i.e. those frequently recalled) serve to guide human attention. Given that the indexing of objects in space is argued to occur as a by-product of perceptual processing (Mou, et al., 2004), location memory should follow attention. In an investigation of the potential sources of far-miss error in recall, Experiment 3 provided an examination of the objects participants defined as interesting within complex real-world images. This aim of this research was to assess whether far-miss errors could be attributable to confusions in memory with other key objects in a scene. Findings highlighted a role for object confusions in the distribution of location recall errors, yet these findings are taken with some trepidation due to the interplay of multiple components of memory for location, including memory for correct target locations, inexact memory for correct target locations, and guessing (including response bias). It is proposed that participants represent complex images in memory as a feature-map of salient object locations. Where sufficient levels of encoded information regarding the identities of these objects are not available within memory, participants may select an incorrect object (i.e. an object other than the target) from this spatial map, in error, at recall. The implications of these findings for picture database design are twofold. First, having *a priori* knowledge of the locations of key objects with an image may be used to set parameters of errors likely to be generated by users for the recall of a given image. Second, should a user's confidence in recall be low, as we know from previous experiments that confidence is highly correlated with performance, the weight given to these error parameters can be increased, therefore maximising the potential of far-miss errors to help, and not hinder, retrieval.

4. Effects of image complexity on memory for location

Lansdale and colleagues (2005) first noted an effect of semantic saliency whereby objects central to the meaning of the scene elicited more accurate location recall than background objects. In an examination of the effects of semantic complexity on memory for location, Experiment 4 observed participants location recall responses to images depicting threatening relationships result in an underestimation of the distance between two objects, an effect not witnessed in neutral counterpart scenes. These findings suggest that viewers pay attention to more than the mere spatial arrangements of objects in a location recall test, and that the inherent messages arising from real-world inter-object relationships have a biasing effect on the recall of absolute target-object locations. The relative density of objects within an image was the focus of Experiments 5 and 6. Results identified that memory for the location of objects in simple real-world images was superior to location recall for cued targets in complex images. This is in contrary to research which suggests that object locations should be strengthened by multiple frames of reference (Wang, et al., 2005).

It is proposed that for simple images, the object confusions witnessed for complex images simply cannot occur. The representations of simple stimuli in memory are likely to comprise of significantly less features than representation of complex images, thereby reducing the likelihood of far-miss errors in recall. Taken together, these experimental findings offer evidence to suggest that memory for the spatial properties are governed by both bottom-up visual image features and top-down semantic contextual factors regarding scene meaning and understanding. As a result, picture databases wishing to employ spatial memory would require a consideration of the relative semantic complexities, as well as the visual properties of images, to enable effective retrieval for emotional stimuli. As Experiment 4 represents a novel area of investigation, further examinations are required to determine whether other types of emotional or arousing stimuli impact upon spatial memory in light of a wealth of evidence to suggest emotional memory effects (Hamann, 2001; Kensinger & Corkin, 2003; Lang, et al., 1990; Öhman, et al., 2001; Phelps, 2004).

5. Effects of delay on memory for location

Findings from four experiments investigating the effects of delay on memory for location suggest that over periods of recall delay, forgetting of spatial memories can be explained in terms of reduced levels of the availability of location information in memory and lower levels precision in recall. As suggested by classical forgetting functions (e.g. Ebbinghaus, 1885), the greatest reduction in availability and precision occurs early on (within the first week of recall delay), with a slower reduction over the second week of delay, but less of a reduction for commentary conditions. Examinations of forgetting in simple and complex real-world images identify that the initial recall benefit for simple images is lost over time, resulting in equivocal recall performance than is the case for complex images following a 1 week delay in recall. Additionally, findings suggest that correlations between confidence in recall and recall performance diminish with time. However, with the addition of verbal information at encoding, both immediate *and* delayed location memory can be improved, offering an important area for further investigation.

Yet, despite the disparity of experimental designs and manipulations across the four experiments, patterns of forgetting are relatively consistent in each case. This suggests that memory for location in real-world images is subject to basic principles of decline. The ability to observe replicable patterns of results identifies a unique opportunity to quantify memory for location over time. The applied impact of this is that should memory for location prove to be of benefit to image retrieval, then predictions regarding levels of information available in memory may be adequately modelled, and predictions made regarding both the required constraints for image search and the likelihood of retrieval.

Other findings are, however, less conducive to picture database design. For example, a decline in the relationship between confidence and recall performance has significant implications should a system rely on confidence as a predictor for the likelihood of recall. Any decline in the relationship between these two attributes would reduce the ability to predict the relative success of retrieval based upon user assurance.

7.2 Quantifying memory for location using the HELM framework

The HELM analytical framework (Lansdale, 1998) allows for the quantification of memory for stimuli presented on a continuous dimension. HELM is novel in its consideration of the inherent levels of information which can be assimilated from near-miss errors in recall. Despite such errors being frequently noted in the recall of stimulus presented on a continuous dimension, (Detterman, 1977; Jones, 1976; Lansdale, 1998; Lee & Estes, 1977b; Nairne, 1991; Toglia & Kimble, 1976), and the knowledge of how informative these recall can be (Lansdale, 1998; Naveh-Benjamin, 1987), the consideration of imprecise information for location is substantially under evaluated (Lansdale, 1998). Nevertheless, the fundamental assumption of this model is that errors in recall will be centred on the continuum target value, although perfectly valid for simple stimuli, (and also made by Huttenlocher, et al., 1991), it was demonstrated in the early experiments of this thesis (Chapter 3) that this assumption does not hold true for the recall of location in complex real-world images.

HELM was designed to provide predictions as to the most likely state of memory to have produced observed recalls for the location of objects in simple photographs. Model parameters are defined by distinct psychological processes of inexact recall (Lansdale, 1998), which are governed by an information theoretic assumption of bits of information regarding the location of objects in picture being accrued over the time course of image presentation. For the purposes of memory for location, should acquired information not be sufficiently detailed as to provide an accurate location representation, then the model assumption will dictate that errors in recall will fall at cells neighbouring the correct location value. However, theoretical findings arising from Experiments 1, 2, and 3 of the present research demonstrate that for the recall of object location from complex natural stimuli, errors in recall can be subject to, amongst other factors, confusions with other key object in an image, which have the effect of clustering of error at locations distant from the correct target value. The HELM model provides a finer grain of analyses that has been previously proposed for location memory, yet this poses an inherent problem in that it widens the gap between raw data and psychological interpretation (Lansdale, et al., 2005). When memory is elicited from dynamic real-world images, the parameters defined by HELM are insufficient to reflect the complexities of the psychological processes involved.

Following the identification of far-miss errors in recall, for which HELM could not provide satisfactory predications (Experiments 1 and 2), reconsideration was made regarding the fundamental assumption that errors in the recall of location will be centred on the correct location value. Despite many of the parameter assumptions of performance for in Experiments 1 and 2 being corroborated by analyses of RMS_c scores, the fact remains that the HELM model was unable to provide non-significant predictions of the data distributions for the majority of complex stimuli matrices. Therefore, a modified version of HELM was proposed (HELM2), which was better able to account for errors in recall which were not centred on the correct location value. This model allows for the centre of the error distribution to vary away from the target location where required based upon an optimisation of the mean value of the error distribution, whilst accounting for the precision of recall using the standard deviation of responses from this mean value. Although the parameter estimates of availability and precision within HELM2 present less psychological meaning than the estimates within HELM, this modified version provides a means by which to provide non-significant estimates of the most likely state of memory to have resulted in the location recall data for objects in real-world images. This is a prime example of how theory can be constrained by complexity.

Results discussed herein are conducive of a thesis comprising three main elements. First, it offers links to previous research and a development of existing analytical techniques. Second, a theoretical expansion of the literature on memory for location in natural stimuli. And third, a consideration of findings pertinent to the applied opportunities for information retrieval.

7.3 Location memory as the applied solution? Conclusions and implications for future research

From the analyses presented, we can only provide details regarding overall levels of recall accuracy, and estimates as to the most likely state of memory which produced the location recall data for these stimuli. Deciding upon whether levels of available location information will be potentially informative to the storage and retrieval of images from picture databases would be a judgement for those considering the implementation of such strategies to assess. However, should we reflect back to the initial applied issue posed within the introduction, that is the retrieval of a specific image from a collection of pictures highly similar in content, then the ability to exploit memory for the location of specific objects within previously viewed images offers a distinct opportunity to limit the numbers of unwanted returns. The potential for the exploitation of location information to picture database design may therefore lie within specific contexts in which traditional query methods are likely to result in an inefficient search. Furthermore, the ability to improve location memory both immediately and following periods of recall delay using additional verbal information at encoding offers an exciting area for future research.

A number of subsequent analyses have been considered, which, given unlimited time and resources, would have complimented the work undertaken in this PhD. These investigations include a substantial exploration of the nature of emotional image content on memory for location.

Although it has been demonstrated within Experiment 4 that memory for location can be biased by threat-victim relationships, however, there is a large body of evidence to suggest that emotive and arousing stimuli of all kinds can either enhance or interfere with recall (see above). Should this be the case, then this may provide a substantial limitation to image databases of emotive pictures wishing to utilise location memory as a query language for recall. As such, an examination of emotive image content other than threat on memory for location is a key area for investigation.

Additionally, recent analyses by Damien Litchfield and colleagues suggest that directing gaze may offer increased performance in the detection of chest nodules on x-rays for novice radiographers. Findings demonstrated that by superimposing an expert's scanpath onto the x-ray, identification of nodules was increased. However, superimposing other novice-radiographers scanpaths onto an x-ray failed to increase nodule detection. This suggests that novices following experts viewing patterns are likely to look at locations relative to diagnosis (Litchfield, Ball, Donovan, Manning,

& Crawford, 2010). It has been demonstrated across each of the experiments presented within this thesis that memory for location in complex real-world images can be improved, an effect which is dependent upon where participants allocate their attention, and on the amount of information they receive at encoding (for example, the presence of additional verbal information at recall, and an observed benefit for semantically salient foreground items). As such this methodology provides an exciting opportunity to examine whether memory for location can be 'trained' in effect, whereby a fixed scanpath is superimposed onto images which are to be catalogued. As a result, users could be directed in a particular gaze pattern designed to maximise levels of location information encoded within memory, and subsequently increasing the likelihood of greater levels of accuracy in recall.

List of Appendices

Appendix 1

Stimuli set A: 27 complex real-world images

Image 1A: *Charity Run*.
Target = old lady

Image removed due to copyright restrictions

Image 1B: *Selfridges*.
Target = illuminated no entry sign

Image removed due to copyright restrictions

Image 1C: *Spamalot*.
Target = knight in green and white

Image removed due to copyright restrictions

Image 2A: *Football Manager*.
Target = stewards face

Image removed due to copyright restrictions

Image 2B: *Lipstick*.
Target = face of the woman holding lipstick

Image removed due to copyright restrictions

Image 2C: *Medieval Jousting*.
Target = face of the red knight

Image removed due to copyright restrictions

Image 3A: *Boozy Commentators*.
Target = cigarette

Image removed due to copyright restrictions

Image 3B: *Dinosaurs at Buckingham Palace*.
Target = foreground chandelier

Image removed due to copyright restrictions

Image 3C: *Injured Footballer*.
Target = injured footballer's face

Image removed due to copyright restrictions

Image 4A: *Army Cadets*.
Target = washing up liquid bottle

Image removed due to copyright restrictions

Image 4B: *Marie Antoinette*.
Target = Marie Antoinette's face

Image removed due to copyright restrictions

Image 4C: *Taiwan Toilet Restaurant*.
Target = blue flask

Image removed due to copyright restrictions

Image 5A: *Golf Disappointment*.
Target = golf clubs

Image removed due to copyright restrictions

Image 5B: *Heron*.
Target = blackbird

Image removed due to copyright restrictions

Image 5C: *Speed Campaigners*.
Target = face of the boy in the foreground

Image removed due to copyright restrictions

Image 6A: *Baghdad Shooting*.
Target = handgun held by man in purple shirt

Image removed due to copyright restrictions

Image 6B: *Kneeling Protestor*.
Target = kneeling protestor's head

Image removed due to copyright restrictions

Image 6C: *Palestine*.
Target = man dressed in white

Image removed due to copyright restrictions

Image 7A: *Climbing Frame*.
Target = blonde hair

Image removed due to copyright restrictions

Image 7B: *Earthquake Refugees*.
Target = toddler's face

Image removed due to copyright restrictions

Image 7C: *Richard Hammond Crash*.
Target = policeman dressed in black

Image removed due to copyright restrictions

Image 8A: *Classroom*.
Target = drawing of an apple

Image removed due to copyright restrictions

Image 8B: *Statue on Crosby Beach*.
Target = dog

Image removed due to copyright restrictions

Image 8C: *Training*.
Target = oldest of the two boys dressed in a blue t-shirt

Image removed due to copyright restrictions

Image 9A: *Seaside Pier*.
Target = the pier's pavilion

Image removed due to copyright restrictions

Image 9B: *Camel Train*.
Target = man on horseback

Image removed due to copyright restrictions

Image 9C: *Horse Racing*.
Target = jockey in blue and white silks

Image removed due to copyright restrictions

Appendix 2

Stimuli set B: 27 simple real-world images

Location 1, week 1: *Sheep*.

Image removed due to copyright restrictions

Location 1, week 2: *Pylon*.

Image removed due to copyright restrictions

Location 1, week 3: *Man carrying surfboard*.

Image removed due to copyright restrictions

Location 2, week 1: *Boy in sea*.

Image removed due to copyright restrictions

Location 2, week 2: *Palm tree*.

Image removed due to copyright restrictions

Location 2, week 3: *Windsurfer*.

Image removed due to copyright restrictions

Location 3, week 1: *Lightning*.

Image removed due to copyright restrictions

Location 3, week 2: *Giraffe*.

Image removed due to copyright restrictions

Location 3, week 3: *Cactus*.

Image removed due to copyright restrictions

Location 4, week 1: *Rock*.

Image removed due to copyright restrictions

Location 4, week 2: *Snowman*.

Image removed due to copyright restrictions

Location 4, week 3: *Hiker*.

Image removed due to copyright restrictions

Location 5, week 1: *Buffalo*.

Image removed due to copyright restrictions

Location 5, week 2: *Heron*.

Image removed due to copyright restrictions

Location 5, week 3: *Wind turbine*.

Image removed due to copyright restrictions

Location 6, week 1: *Church spire*.

Image removed due to copyright restrictions

Location 6, week 2: *Horse*.

Image removed due to copyright restrictions

Location 6, week 3: *Dog*.

Image removed due to copyright restrictions

Location 7, week 1: *Monkey*.

Image removed due to copyright restrictions

Location 7, week 2: *Lighthouse*.

Image removed due to copyright restrictions

Location 7, week 3: *Cross*.

Image removed due to copyright restrictions

Location 8, week 1: *Daffodil*.

Image removed due to copyright restrictions

Location 8, week 2: *House*.

Image removed due to copyright restrictions

Location 8, week 3: *Boat*.

Image removed due to copyright restrictions

Location 9, week 1: *Man in shade*.

Image removed due to copyright restrictions

Location 9, week 2: *Statue*.

Image removed due to copyright restrictions

Location 9, week 3: *Motorbike*.

Image removed due to copyright restrictions

Appendix 3

Stimuli set C: 9 spatially matched real-world images pairs depicting neutral and threat relationships

Image pair: *Arrested*.

Threat relationship
Target Exp. 5a = policeman
Target Exp. 5b = suspect

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = lady standing
Target Exp. 5b = lady sitting

Image removed due to copyright restrictions

Image pair title: *Bird Shoot*.

Threat relationship
Target Exp. 5a = bird
Target Exp. 5b = woman

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = bird
Target Exp. 5b = girl

Image removed due to copyright restrictions

Image pair: *Dog and Hare*.

Threat relationship
Target Exp. 5a = hare
Target Exp. 5b = dog

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = rock
Target Exp. 5b = dog's head

Image removed due to copyright restrictions

Image pair: *Fighting Silhouette*.

Threat relationship
Target Exp. 5a = man on left
Target Exp. 5b = man on right

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = man walking
Target Exp. 5b = woman cycling

Image removed due to copyright restrictions

Image pair: *Knife Chase*.

Threat relationship

Target Exp. 5a = man with knife

Target Exp. 5b = man in suit

Image removed due to copyright restrictions

Neutral relationship

Target Exp. 5a = man with glove

Target Exp. 5b = men talking

Image removed due to copyright restrictions

Image pair: *Lion and Gazelle*.

Threat relationship
Target Exp. 5a = lion
Target Exp. 5b = gazelle

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = lion
Target Exp. 5b = girl

Image removed due to copyright restrictions

Image pair: *Matador*.

Threat relationship
Target Exp. 5a = matador
Target Exp. 5b = bull

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = matador in blue
Target Exp. 5b = matador in red

Image removed due to copyright restrictions

Image pair: *Rabbit and Fox*

Threat relationship
Target Exp. 5a = fox
Target Exp. 5b = rabbit

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = rabbit on right
Target Exp. 5b = rabbit on left

Image removed due to copyright restrictions

Image pair: *Surfing*.

Threat relationship
Target Exp. 5a = shark fin
Target Exp. 5b = surfer

Image removed due to copyright restrictions

Neutral relationship
Target Exp. 5a = crouching surfer (left)
Target Exp. 5b = standing surfer (centre)

Image removed due to copyright restrictions

Appendix 4

Stimuli set C: Recall images for Experiment 4a

Image pair: *Arrested*.

Threat relationship
Target = missing policeman

Image removed due to copyright restrictions

Neutral relationship
Target = missing lady

Image removed due to copyright restrictions

Image pair title: *Bird Shoot***.**

Threat relationship
Target = missing bird

Image removed due to copyright restrictions

Neutral relationship
Target = missing bird

Image removed due to copyright restrictions

Image pair: *Dog and Hare*.

Threat relationship
Target = missing hare

Image removed due to copyright restrictions

Neutral relationship
Target = missing rock

Image removed due to copyright restrictions

Image pair: *Fighting Silhouette*.

Threat relationship
Target = missing man

Image removed due to copyright restrictions

Neutral relationship
Target = missing man walking

Image removed due to copyright restrictions

Image pair: *Knife Chase*.

Threat relationship
Target = missing man with knife

Image removed due to copyright restrictions

Neutral relationship
Target = missing man with glove

Image removed due to copyright restrictions

Image pair: *Lion and Gazelle*.

Threat relationship
Target = missing lion

Image removed due to copyright restrictions

Neutral relationship
Target = missing lion

Image removed due to copyright restrictions

Image pair: *Matador*.

Threat relationship
Target = missing matador

Image removed due to copyright restrictions

Neutral relationship
Target = missing matador

Image removed due to copyright restrictions

Image pair: *Rabbit and Fox*

Threat relationship
Target = missing fox

Image removed due to copyright restrictions

Neutral relationship
Target = missing rabbit

Image removed due to copyright restrictions

Image pair: *Surfing*.

Threat relationship
Target = missing shark fin

Image removed due to copyright restrictions

Neutral relationship
Target = missing surfer

Image removed due to copyright restrictions

Appendix 5

Stimuli set C: Recall images for Experiment 4b

Image pair: *Arrested*.

Threat relationship
Target = missing suspect

Image removed due to copyright restrictions

Neutral relationship
Target = missing lady

Image removed due to copyright restrictions

Image pair title: *Bird Shoot*.

Threat relationship
Target = missing woman

Image removed due to copyright restrictions

Neutral relationship
Target = missing girl

Image removed due to copyright restrictions

Image pair: *Dog and Hare*.

Threat relationship
Target = missing dog's head

Image removed due to copyright restrictions

Neutral relationship
Target = missing dog's head

Image removed due to copyright restrictions

Image pair: *Fighting Silhouette*.

Threat relationship
Target = missing man

Image removed due to copyright restrictions

Neutral relationship
Target = missing woman cycling

Image removed due to copyright restrictions

Image pair: *Knife Chase*.

Threat relationship
Target = missing man in suit

Image removed due to copyright restrictions

Neutral relationship
Target = missing men talking

Image removed due to copyright restrictions

Image pair: *Lion and Gazelle*.

Threat relationship
Target = missing gazelle

Image removed due to copyright restrictions

Neutral relationship
Target = missing girl

Image removed due to copyright restrictions

Image pair: *Matador*.

Threat relationship
Target = missing bull

Image removed due to copyright restrictions

Neutral relationship
Target = missing matador

Image removed due to copyright restrictions

Image pair: *Rabbit and Fox*

Threat relationship
Target = missing rabbit

Image removed due to copyright restrictions

Neutral relationship
Target = missing rabbit

Image removed due to copyright restrictions

Image pair: *Surfing*.

Threat relationship
Target = missing surfer

Image removed due to copyright restrictions

Neutral relationship
Target = missing surfer

Image removed due to copyright restrictions

Appendix 6

Verbal commentaries for stimuli set A

The target item for object location recall is highlighted in **bold**. The full duration of each verbal commentary in seconds is highlighted after the image title and followed by a breakdown of duration by title and description.

1A: Charity Run - 20s (2+18)

Over 1000 women took part in the annual Medical Solutions charity run yesterday, raising funds for breast cancer research. This picture shows a group of runners taking part, with **Ethel, 69,** on the far left. Ethel is an ex-patient whose cancer is now in remission.

1B: Selfridges - 19s (2+17)

The Selfridges building in Birmingham was completed in 2003 at a cost of £60 million. The construction provides a modern backdrop to the busy street in front, allowing cars, traffic lights and a **no entry sign** to stand out clearly in this picture.

1C: Spamalot - 20s (2+18)

Spamalot, a new musical adaptation of the most popular Monty Python movie, 'Monty Python and the Holy Grail' returns to Broadway this month. The cast are happy, none more so than the **knight shown here in green and white**, looking stunned at the audience's reaction!

2A: Football Manager - 17s (3+14)

Steve Thompson, manager of Nottinghamshire County FC was overwhelmed by adoring fans after yesterdays defeat over Torquay United. Here we can see Thompson being led away from the confusion to safety by a smiling **steward**.

2B: Lipstick - 15s (2+13)

In a waiting room, four women prepare for an interview. As three women sit together on the couch, one **woman who is about to apply red lipstick** sits alone.

2C: Medieval Jousting - 15s (2+13)

A regular event at Belvoir Castle is medieval jousting. Spectators can get a good view of the action from the nearby bank. Here we can see the **red knight** take a blow to his shield from his burly opponent.

3A: Boozy Commentators - 17s (3+14)

In a live comedy sketch show, comeans imitate snooker commentators while drinking several pints of lager. One comean lights up a **cigarette** on stage, and proceeds to smoke it while the other continues with the commentary.

3B: Dinosaurs at Buckingham Palace - 19s (3+16)

Models of Pterosaur, the flying reptiles of pre-historic skies, were hung from the roof of Buckingham Palace's main ballroom in the name of science today. The extensive models came terrifyingly close to a glass and crystal **chandelier** during installation.

3C: Injured Footballer - 18s (2+16)

Aston Villa produced a brilliant display to prevent the Premiership leaders gaining another win at Stamford Bridge. The game finished in a 1-1 draw. However, things were not looking good for Villa when striker Luke Moore was injured, his **face** contorted with pain.

4A: Army Cadets - 17s (2+15)

Each February, a cadet camp is organised involving a number of adventure tasks. In this picture, some young cadets all muck in to clean the lunchtime dishes. However, the girl holding the **washing up liquid bottle** looks reluctant to give it up.

4B: Marie Antoinette - 20s (2+18)

Sofia Coppola's new film Marie Antoinette tells the career of the queen from her arrival in France in 1769 at the age of 14. **Marie Antoinette** is shown here crossing the royal gardens as her lady in waiting follows closely behind.

4C: Taiwan Toilet Restaurant - 15s (2+13)

A restaurant in Southern Taiwan has caused a stir with its dazzling bathroom decor. In this picture, two young women look at the menu. One of the women has brought her own drink with her, which she keeps in a **blue flask**.

5A: Golf Disappointment - 17s (2+15)

Following a bug which undoubtedly put him off his game, the loss in the golfing European Order of Merit title did not come as a surprise to Paul Casey or his caddy yesterday. Both men appear disheartened as they gather around Casey's **clubs**.

5B: Heron - 16s (2+14)

A rare scene shows a heron in a domestic setting as it sits in a tree of a residents' back garden. A **blackbird** watching from a nearby fence appears puzzled at the presence of the unexpected guest.

5C: Speed Campaigners - 17s (2+15)

A group of children and their parents gather at the roadside in Lambley to campaign against speeding motorists. **The first boy in the picture** is holding a sign, which reads, "please drive slowly", and **his face** looks very upset.

6A: Baghdad Shooting - 20s (2+18)

Yet another bomb hit Baghdad Wednesday, killing at least eight people and wounding another 32. Here, friends and family of a victim show their resentment of the attack. One man wearing a purple shirt holds a **handgun** in the air in anger.

6B: Kneeling Protestor - 17s (2+15)

A wall of armed police prove to be more than enough to stop a lone protestor in his path. The protester drops his green flag and sinks to his knees. The **protestors head** faces directly towards the barricade.

6C: Palestine - 15s (2+13)

Here, Palestinian gunmen, dressed from head to toe in black, guard the streets from Israeli forces. **One man wearing white** bravely walks through the agitated scene.

7A: Climbing Frame - 17s (2+15)

Children hand by their feet and legs from a climbing frame in a school playground for this picture. Although most of the children appear to be enjoying themselves, the girl with **blonde hair** looks less than impressed, and would probably rather be back on solid ground.

7B: Earthquake Refugees - 18s (2+16)

Following the 2005 earthquake in Pakistan, this picture shows one family of refugees as they move from emergency shelters into new temporary housing facilities. A **young boy** looks directly into the camera as his family continue to pack up their belongings.

7C: Richard Hammond Crash - 16s (2+14)

Police investigate the wreckage of the jet-powered dragster, in which Top Gear presenter Richard Hammond was involved in a near-fatal crash yesterday. As one officer gathers evidence, another **officer, dressed in black** takes a long look at the damage.

8A: Classroom - 15s (2+13)

Two girls fight for attention in a school classroom as they attempt to answer a question set by their teacher. Behind them on the blackboard are a number of drawings including a smiley face, a ball and an **apple**.

8B: Statue on Crosby Beach - 20s (4+16)

An installation by Anthony Gormley named ‘Another Place’ can be seen on Crosby beach from July 2nd onwards, and consists of 100 cast-iron, life-size figures spread out over 3 kilometers. In this picture a **dog** inspects one of the statues from a distance.

8C: Training - 20s (2+18)

Femi Fehintola is 24, and soon to fight for the British super-featherweight title. This picture shows him training in his home town of Sheffield, while two young boys look on. **The elder of the two boys**, wearing blue, ignores Femi and directs his full attention to the cameraman.

9A: Seaside Pier - 15s (2+13)

Here, holidaymakers take a moment to relax in front of the impressive pier at Bournemouth. Some tourists wander along the pier in search of the sea, while others take shelter from the wind in the pier's **pavilion**.

9B: Camel Train - 19s (2+17)

For several months every year, traders from the Ethiopian Highlands make the arduous journey north in search of salt. The men load goods onto the camels, with the head camel carrying tents, grain and water. In this picture, one **man** leads the camel train on horseback.

9C: Horse Racing - 18s (2+16)

Jockey John Egan briefly put his current troubles behind him yesterday when guiding home his first winner since sustaining a crashing fall at Wolverhampton. Here, **Egan, wearing blue and white silks**, came from behind to steal the lead at Haydock.

Appendix 7

Interesting item selection response booklet: Experiment 3

Exploiting Spatial Cognition in Picture Database Design: Experiment 3. Extraction of Location Memory in Later Inspection Processes.

Instructions

This study is designed to identify which features or qualities of newspaper images make them effective pictures. You will be given a set of 27 pictures taken from newspapers in the form of picture cards. Please view each picture in turn; there will be no time limit for the viewings.

Following the viewing of each picture, please use the answer booklet attached to write down the 5 most important items in that picture. Each picture has its own response grid, with a thumbnail of the corresponding picture to ensure the responses each match the correct image.

Please ensure you have 5 items for each picture, and that no spaces are left blank. If you are unable to find 5 important items, please use the remaining spaces to write down anything else you can see in the picture.

Please enter your age and sex below before beginning the experiment:

AGE: _________

SEX: M / F **(please circle)**

Please feel free to ask the researcher any questions you may have regarding this study at any point.

Questions or problems regarding this research should be addressed to Helen Henshaw, School of Social Sciences, Nottingham Trent University, Burton Street, Nottingham, NG1 4BU. Email helen.henshaw@ntu.ac.uk, Tel. 0115 848 (5644).

Example response page

5 interesting item responses are elicited for each of the 27 complex real-world images of stimuli set A in the same format as shown below.

Image removed due to copyright restrictions

Image removed due to copyright restrictions

Image removed due to copyright restrictions

Image removed due to copyright restrictions

Image removed due to copyright restrictions

Appendix 8

Sudoku distracter task

Sudoku Rules:

Some cells already contain numbers, known as "givens". The goal is to fill in the empty cells, one number in each, so that each column, row, and region contains the numbers 1 to 9 exactly once. Each number in the solution therefore occurs only once in each of three directions".

You have **5 minutes** for this task:

6								3
		5	9		8		4	
	1			6		9		
	8				5		3	
9				3		2		7
		1	4					
				2		8		
5		4						
					3		1	

When the 5 minutes is up, you will be asked to resume the experiment via instructions on the computer screen. Please resume the experiment at this point, even if you have not completed the puzzle.

Appendix 9

Frequency graphs of interesting items in Experiment 3: Stimuli set A

Image 1A

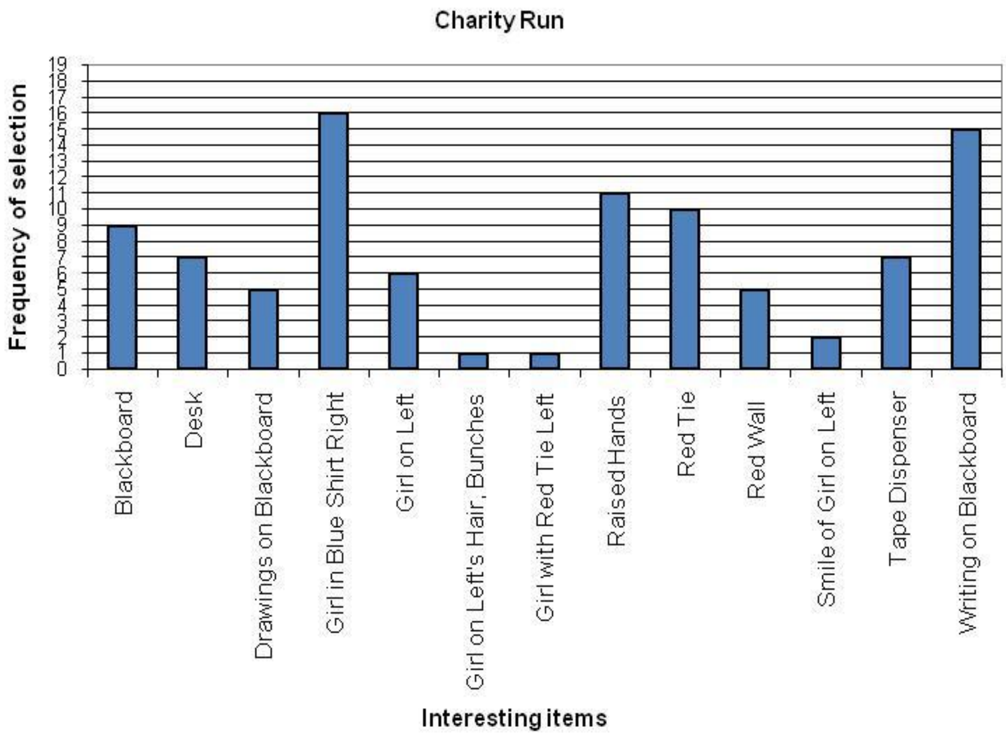


Image 1B

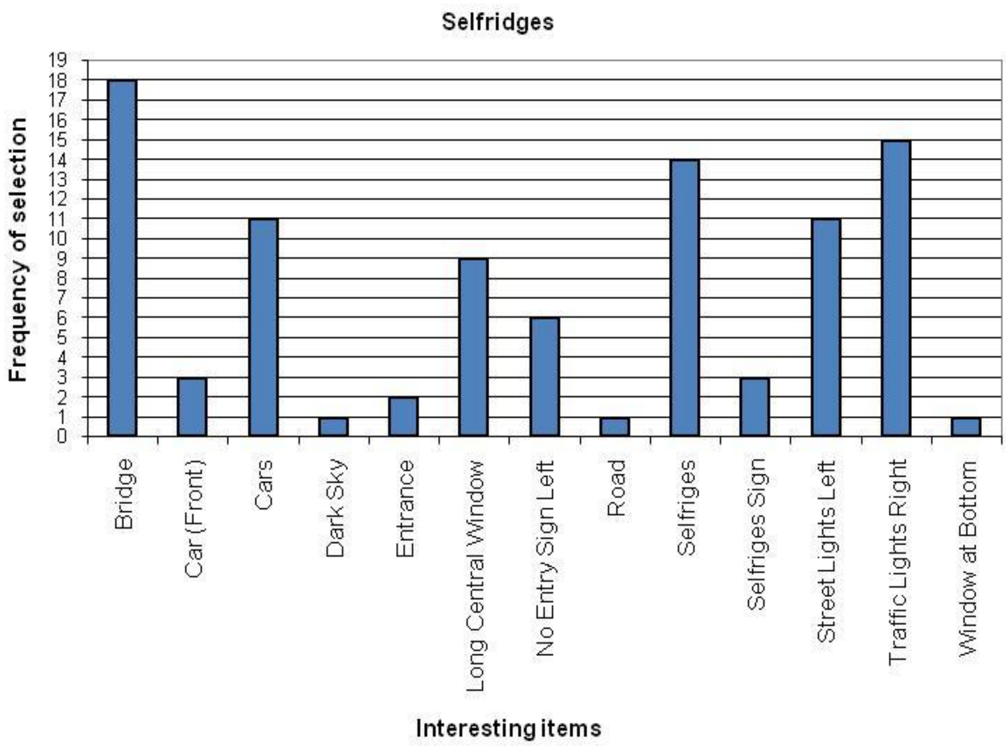


Image 1C

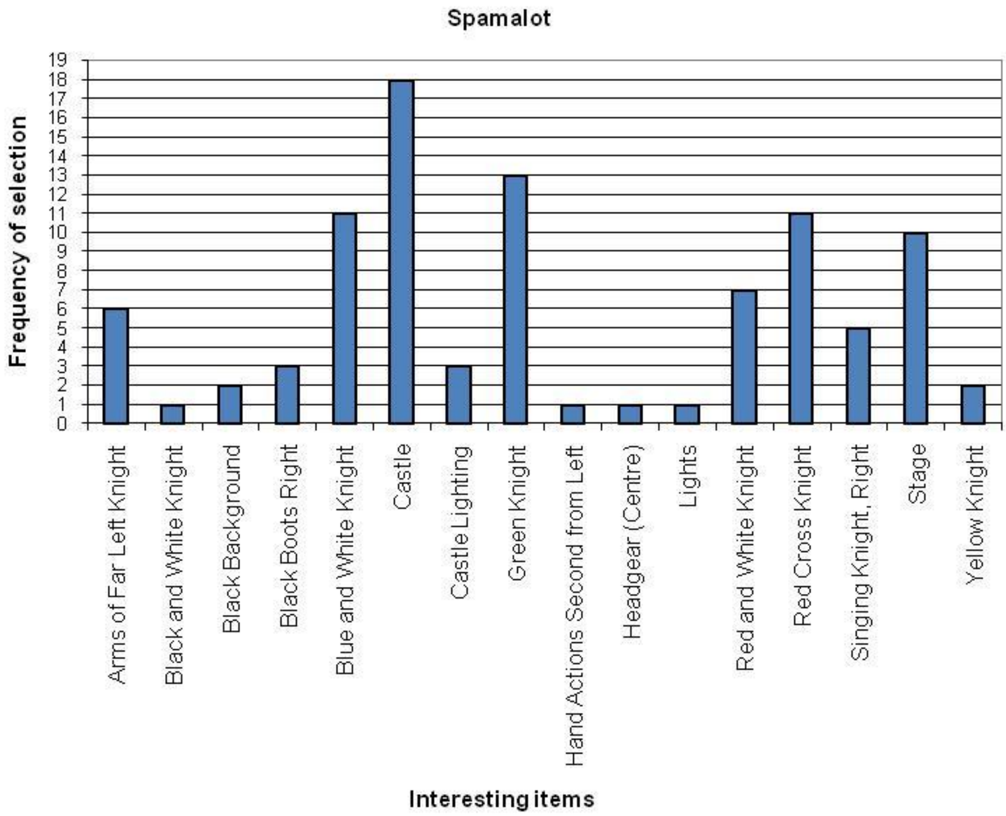


Image 2A

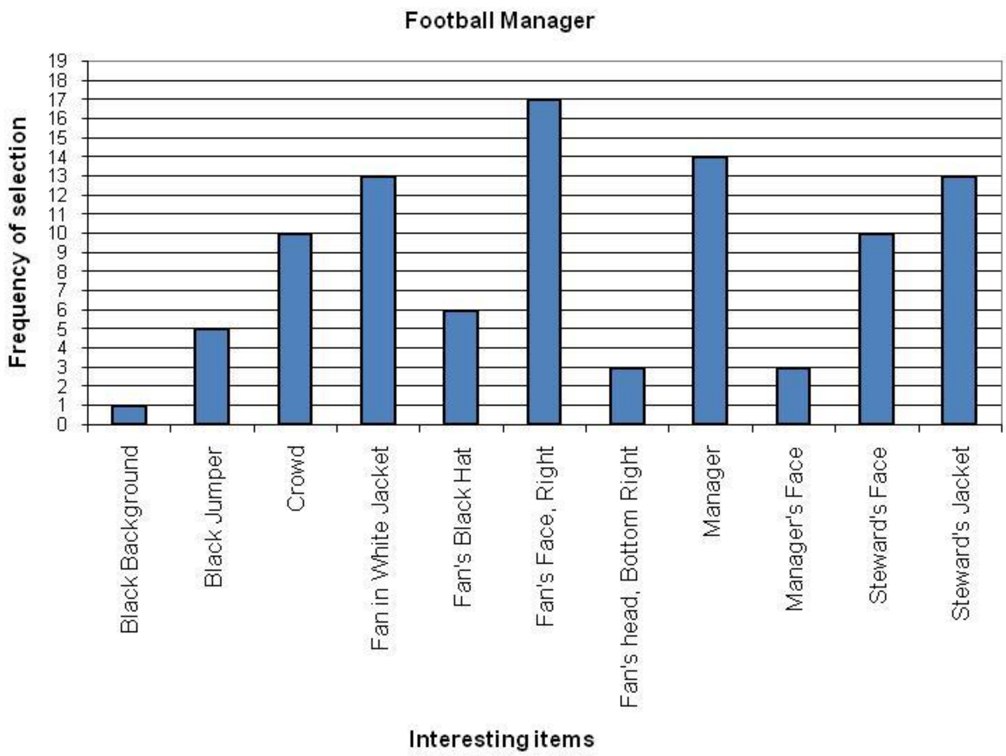


Image 2B

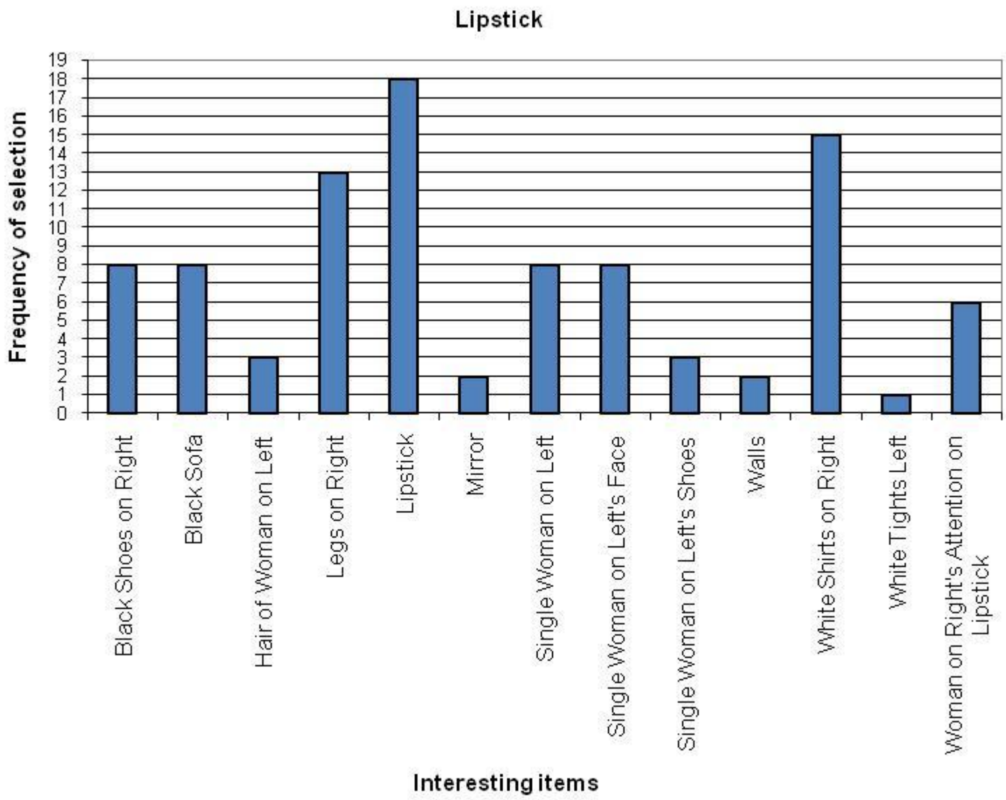


Image 2C

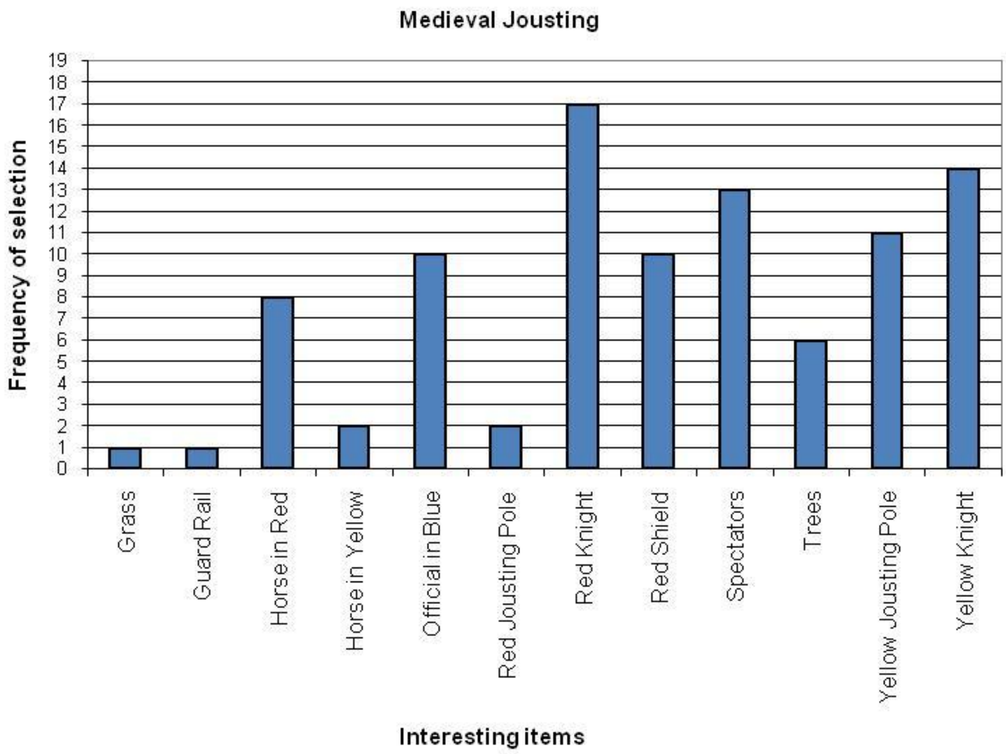
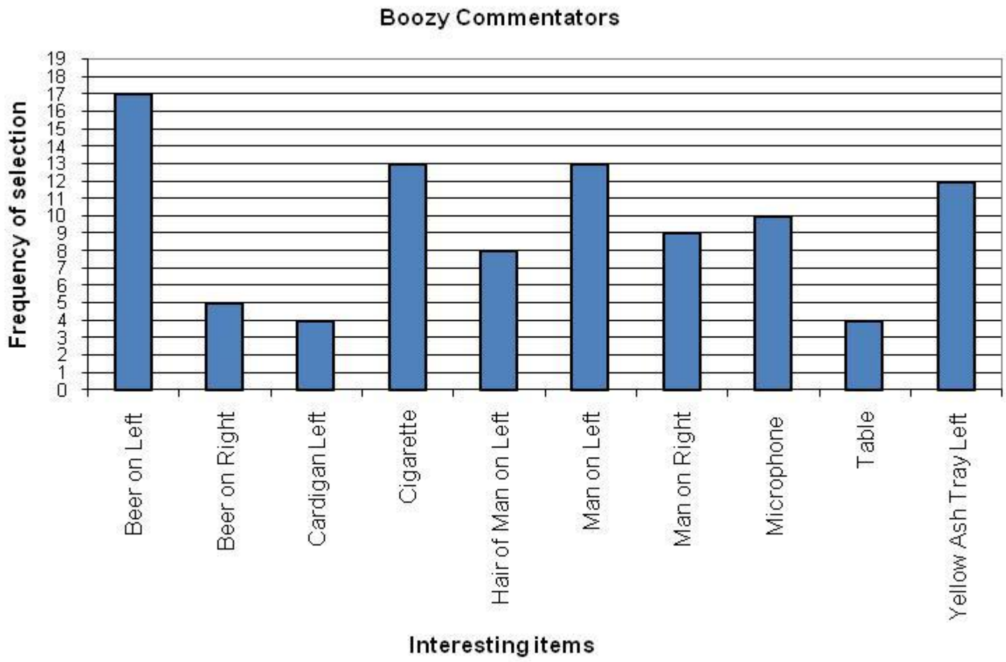


Image 3A



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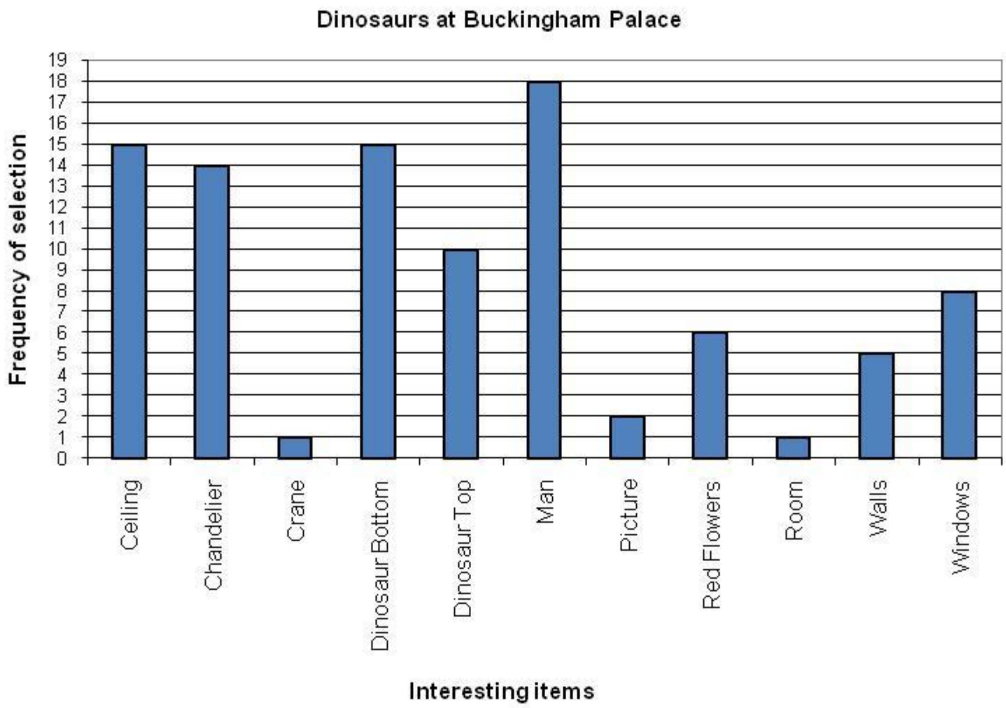


Image 3C

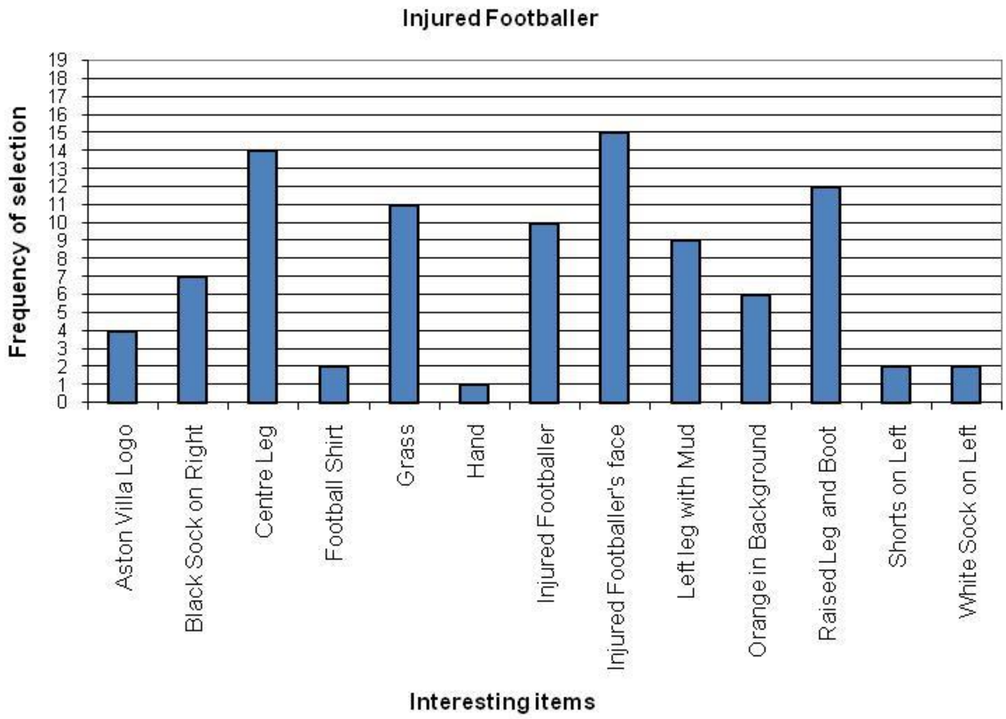
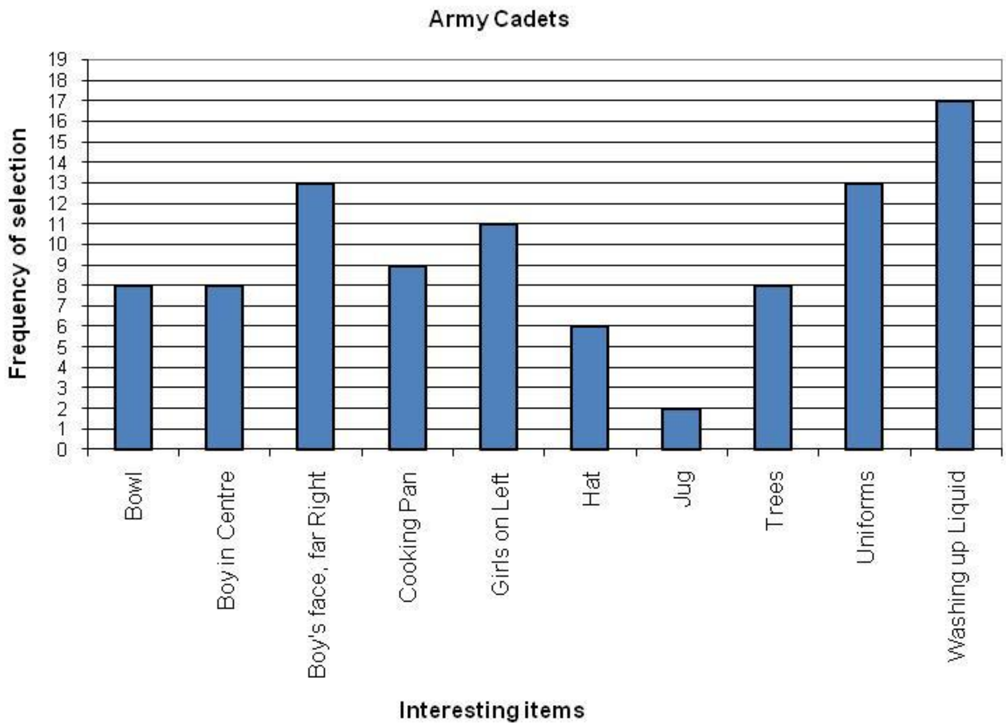


Image 4A



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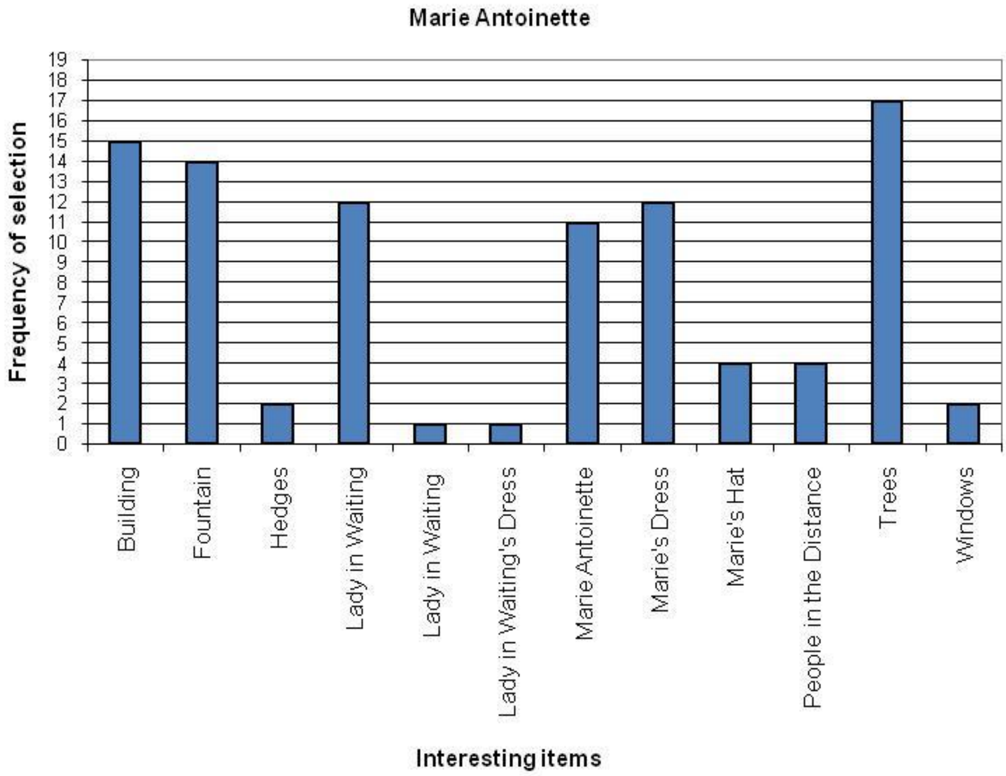

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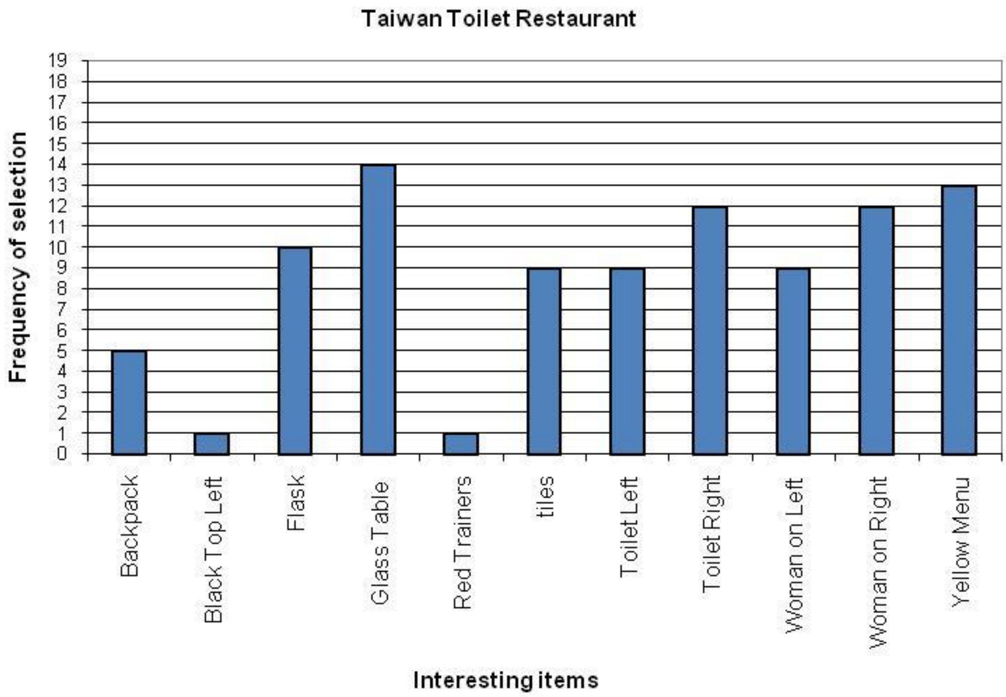

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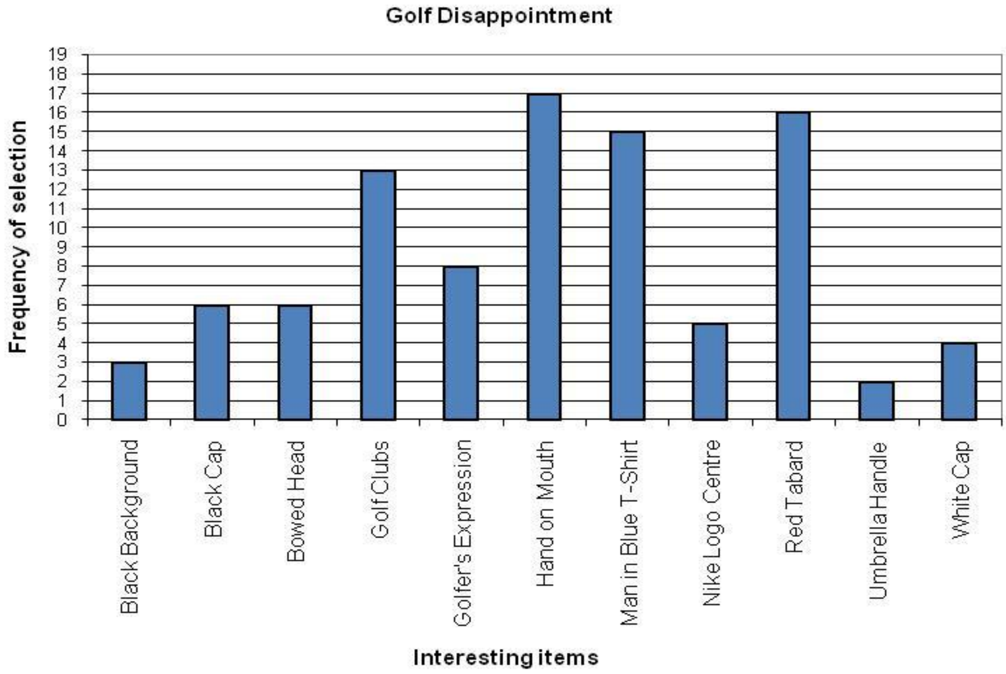


Image 5B

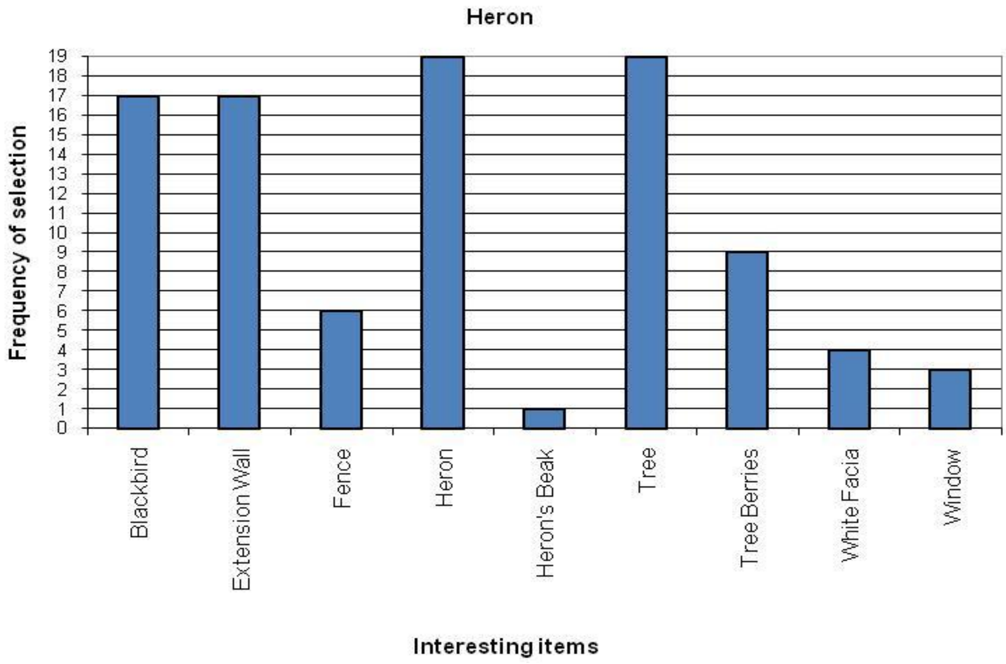
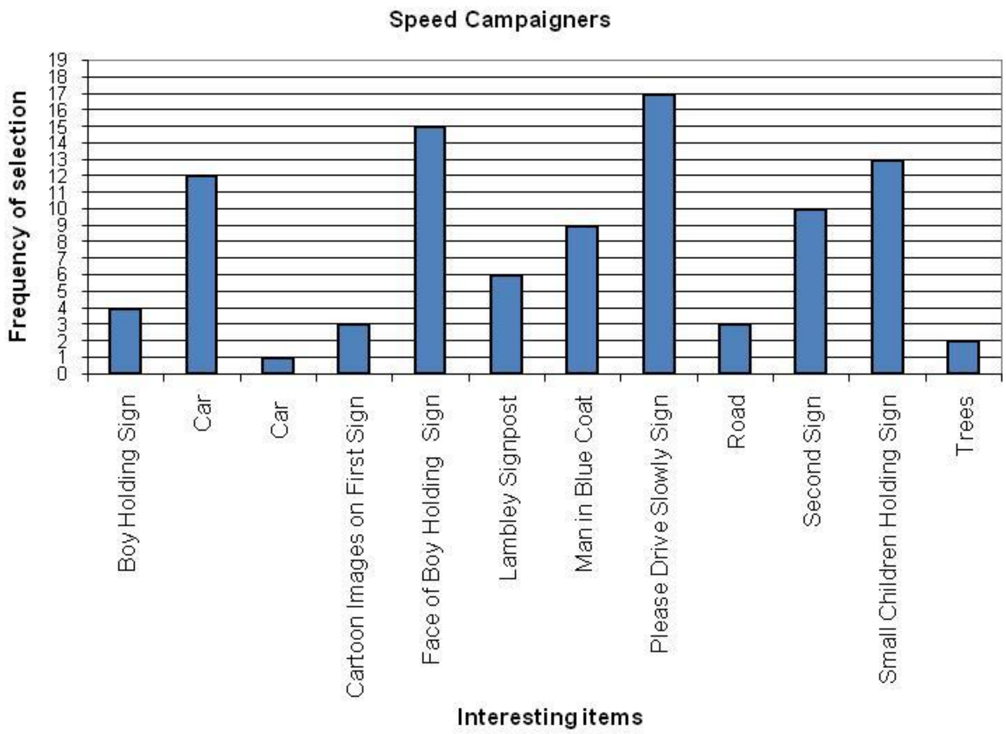


Image 5C



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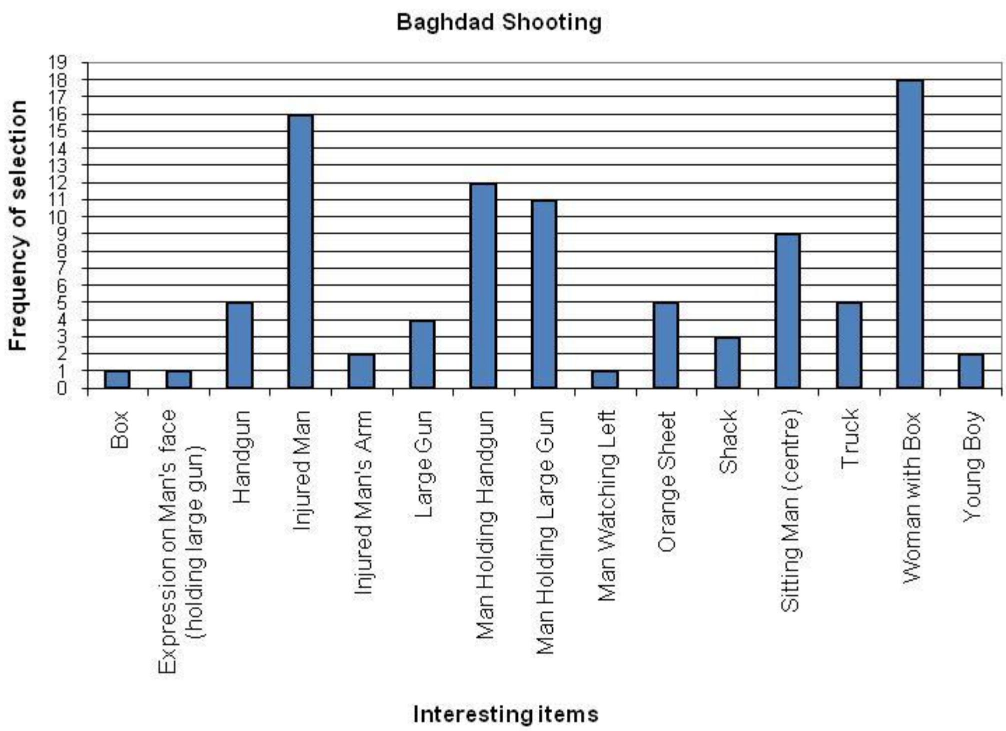


Image 6B

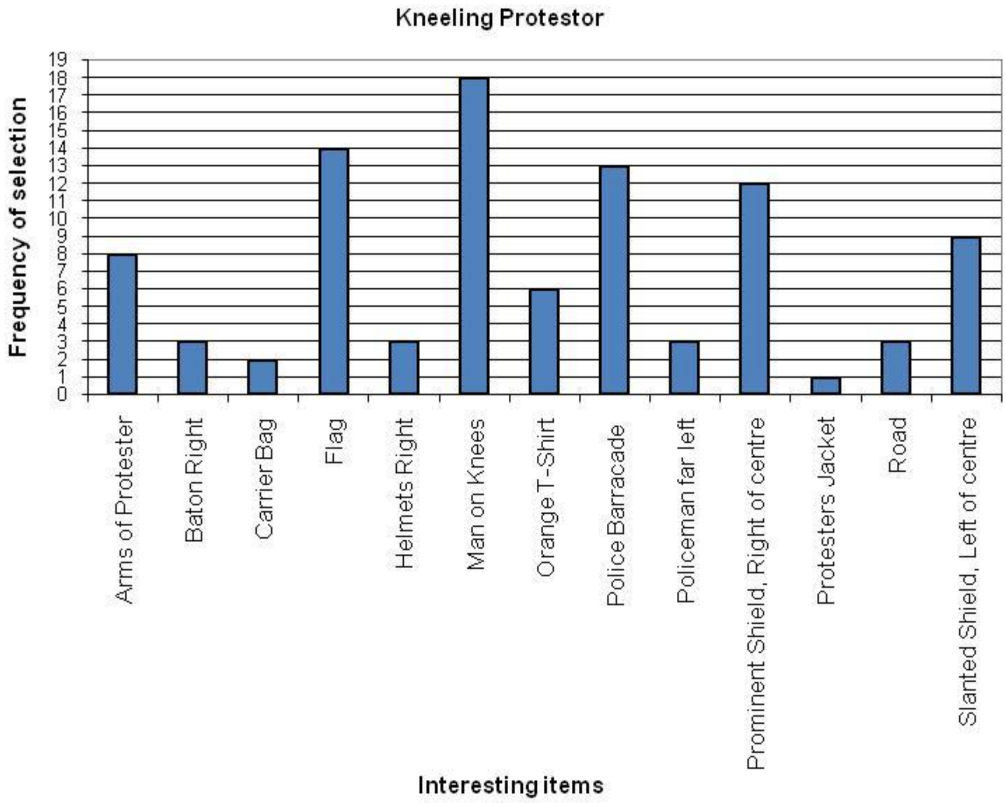
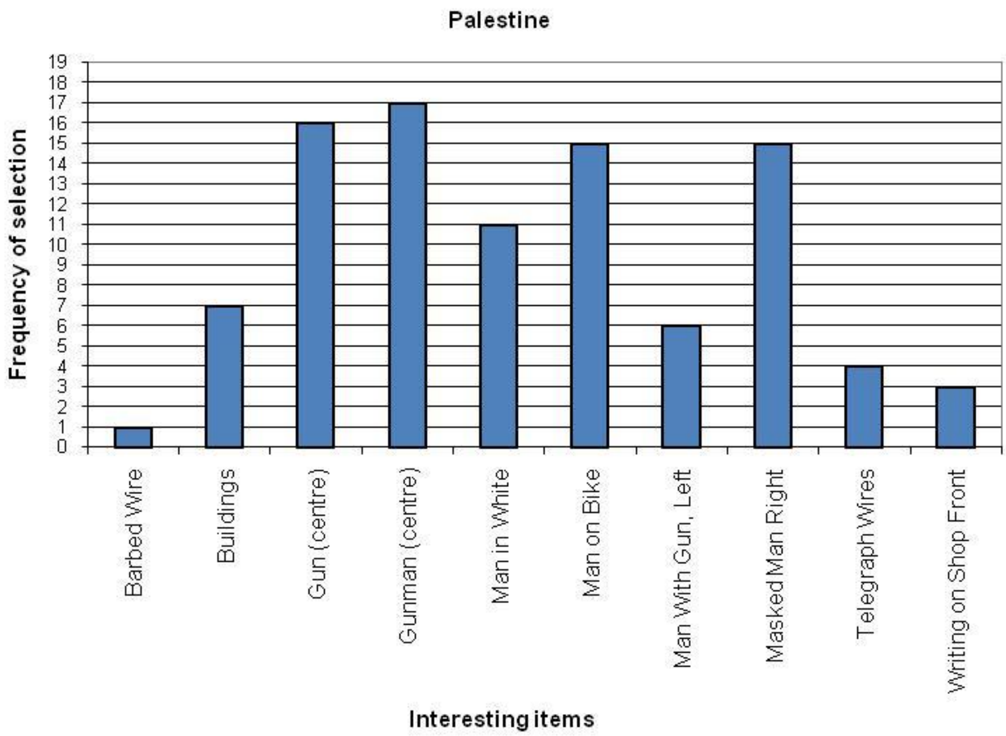


Image 6C



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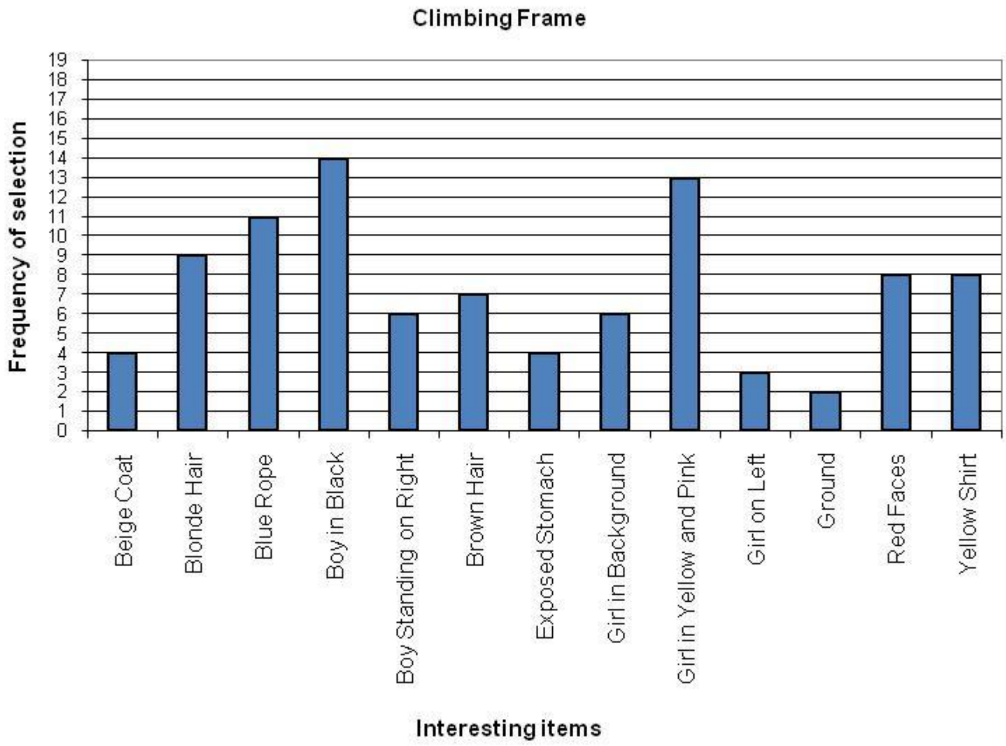


Image 7B

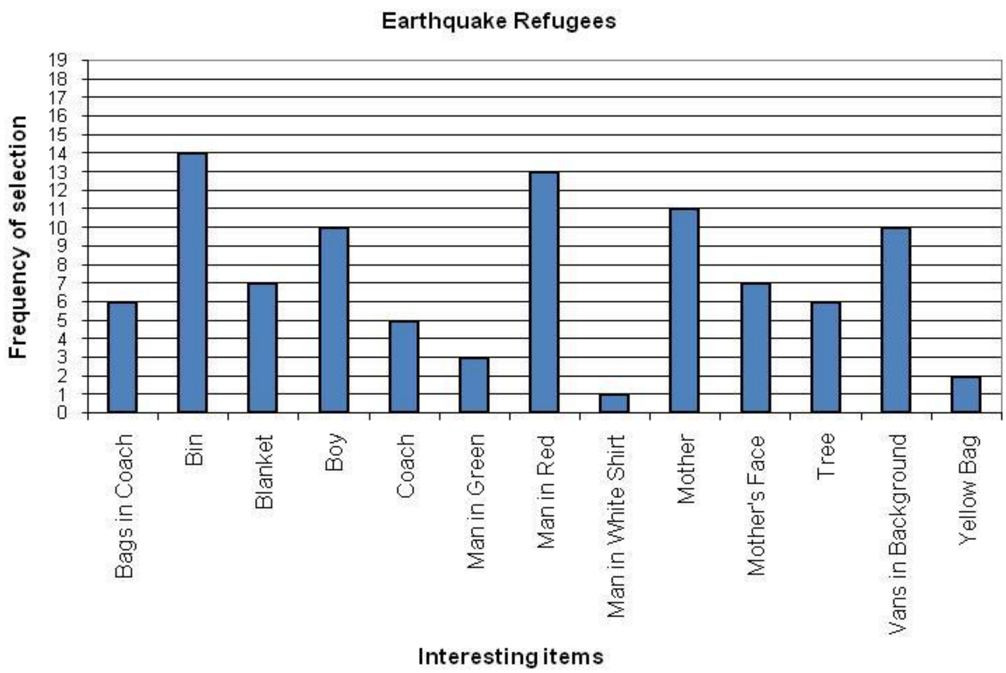


Image 7C

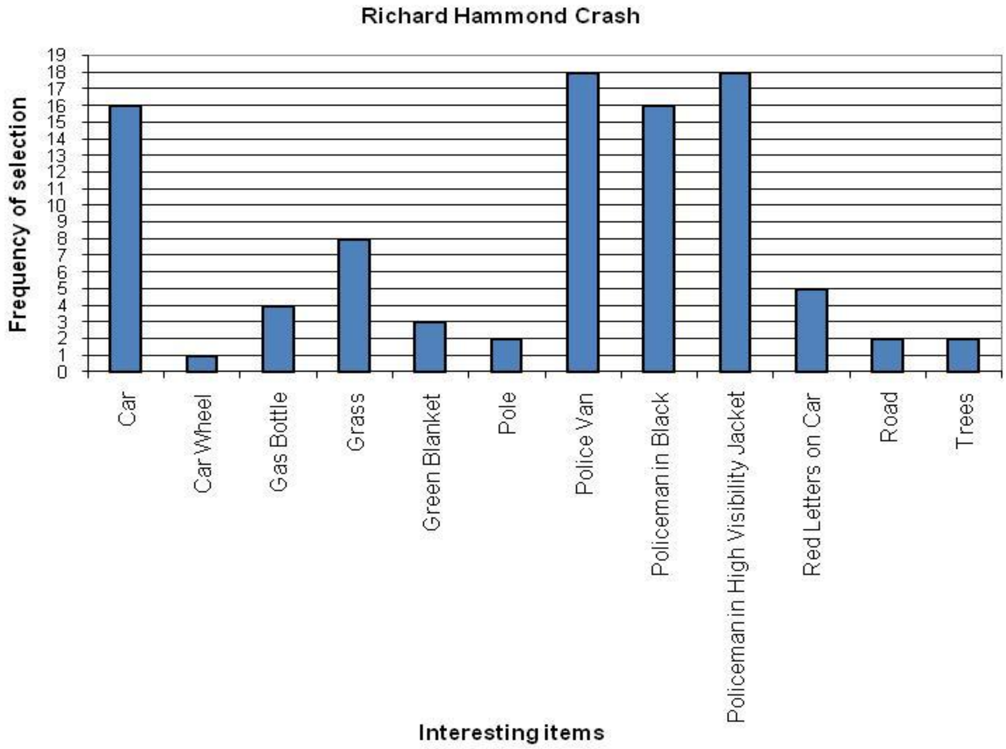
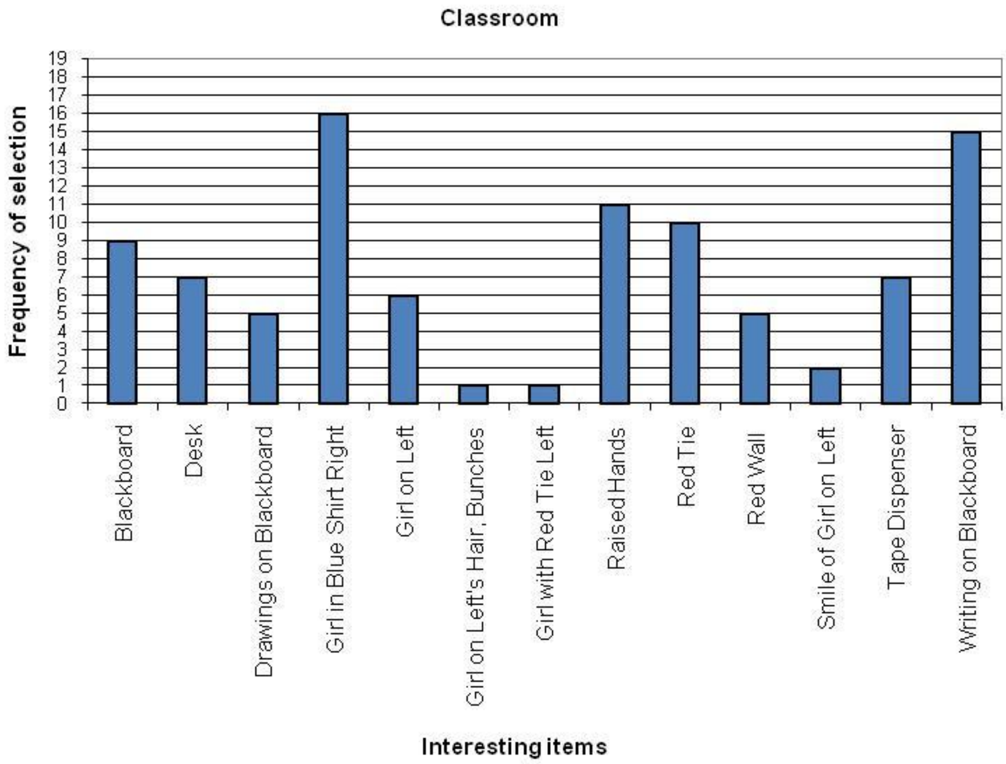


Image 8A



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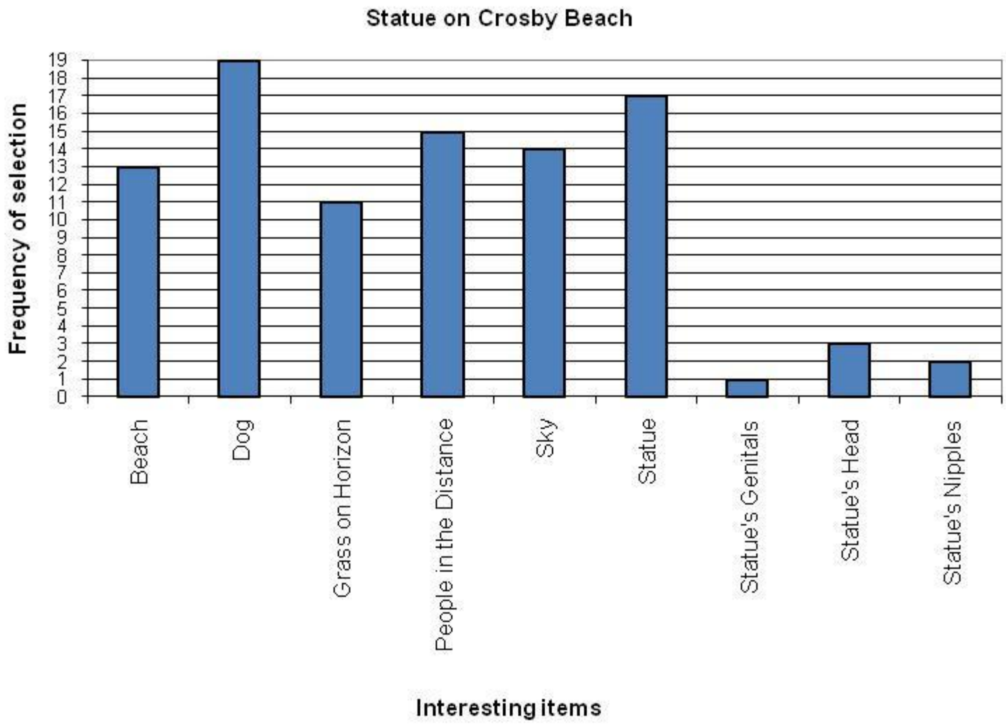

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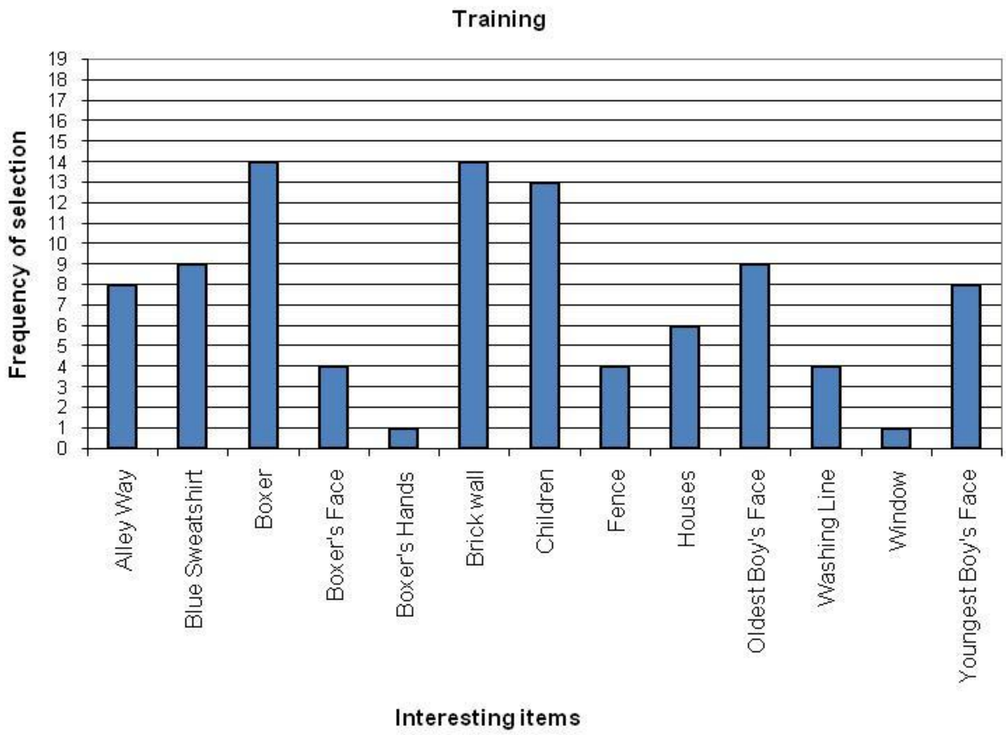


Image 9A

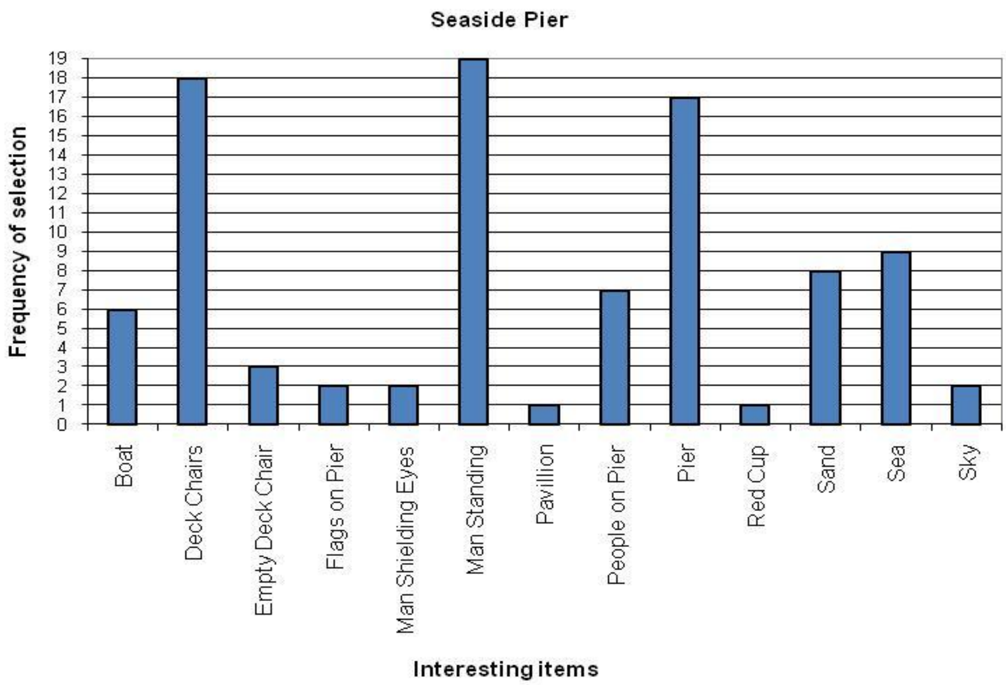


Image 9B

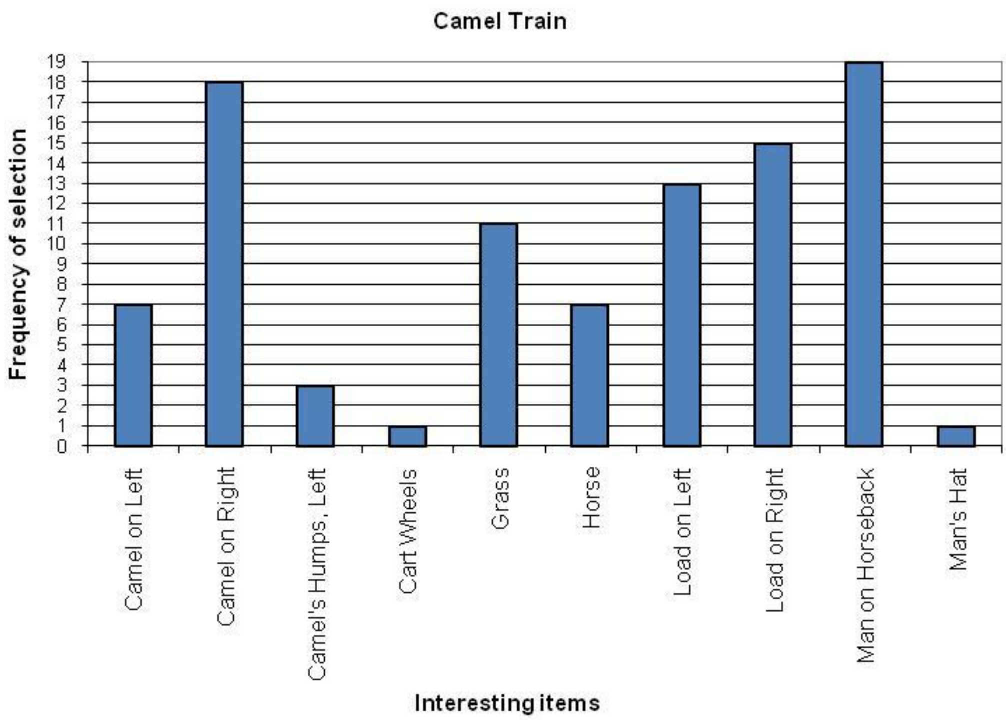
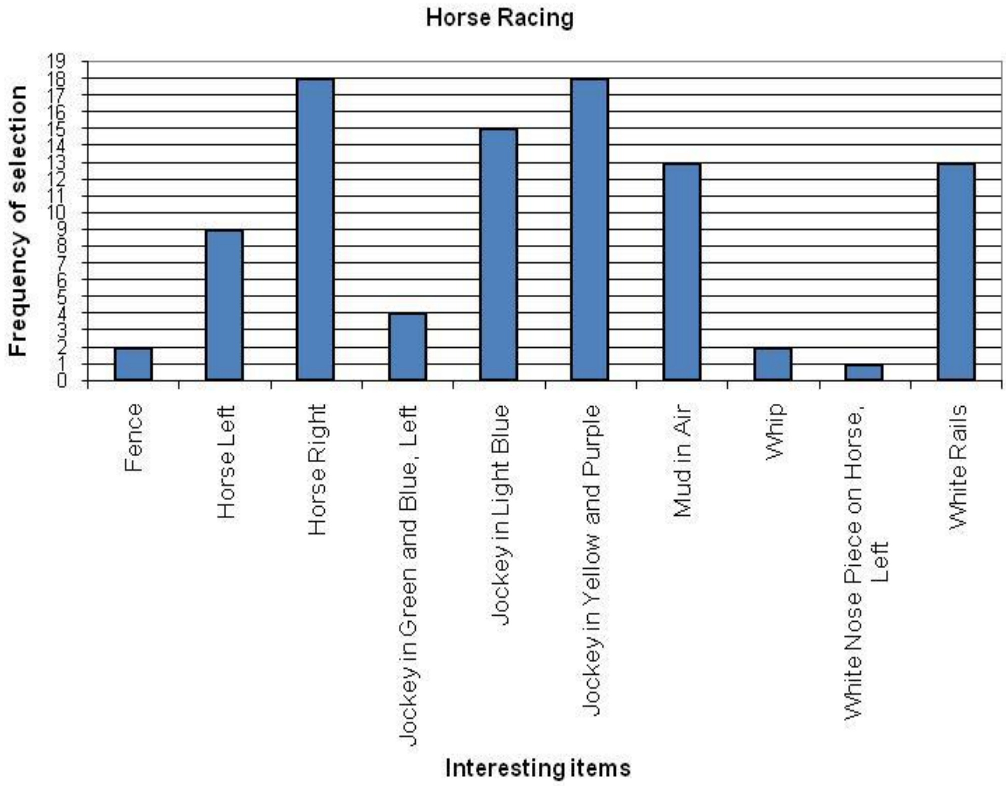


Image 9C



Horse Racing
Frequency of selection
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Fence
Horse Left
Horse Right
Jockey in Green and Blue, Left
Jockey in Light Blue
Jockey in Yellow and Purple
Mud in Air
Whip
White Nose Piece on Horse, Left
White Rails
Interesting items

Appendix 10

Frequency matrices of interesting item selections and saliency predictions

for Expeirment 3: Stimuli set A

Central location point of each target object is highlighted in red. 5 most salient features are indicated by shaded cells.

1A: Charity Run

	1	2	3	4	5	6	7	8	9
A	4	2	4		3		3		2
B			1				1		
C	3		5		6				2
D	7								
E	2	1	6	2	6	3	5	2	3
F	3								
G	3		5			3	1		
H							1		1
I		1		1					

1B: Selfridges

	1	2	3	4	5	6	7	8	9
A					1				
B									1
C	7		16	3					
D								4	
E					11				
F				5				13	
G									
H	6		1	6			4	3	
I	2	3	3		5		1		

1C: Spamalot

	1	2	3	4	5	6	7	8	9
A	3								
B		6							
C					18			6	
D	3		2				1		
E			10			12	2	8	
F	6		1	5					
G									
H									
I				1	10				1

2A: Football Manager

	1	2	3	4	5	6	7	8	9
A					1			3	
B		12			1			16	7
C				13			1		
D						15			
E	10				1				
F				6					
G		3							
H				1			5		
I									

2B: Lipstick

	1	2	3	4	5	6	7	8	9
A		1							
B		11				5		4	1
C	3	17							
D		7				1	4	7	
E	1			7	2		2		2
F	1								3
G	1	1		1	2		3		
H	5			1					
I				2					

2C: Medieval Jousting

	1	2	3	4	5	6	7	8	9
A	1								
B	1		3						
C		3			4				
D				10					1
E	1	17	9					13	
F					2	3			
G		8			7	4	4		
H						1			2
I					1				

3A: Boozy Commentators

	1	2	3	4	5	6	7	8	9
A		7							1
B									
C		5	18						6
D						1			11
E	1								1
F		3	2						
G	4	8	5						1
H		7	4					6	
I					4				

3B: Dinosaurs at Buckingham Palace

	1	2	3	4	5	6	7	8	9
A						3	6		
B	5		14				3		
C						14			
D							18		
E				6	2				
F	2								3
G									
H				1		16		1	1
I									

3C: Injured Footballer

	1	2	3	4	5	6	7	8	9
A									
B	4		1				1		
C									
D		7		1					
E			1			3		11	
F			6		13	1			2
G	1	5	2	4					
H			18	3					
I			3	1			6	1	

4A: Army Cadets

	1	2	3	4	5	6	7	8	9
A									
B	2	2		4				6	
C						10	5	5	
D	3			6			2		
E	1	3	1						
F				15		1			5
G	1	4						2	
H					4				
I		1	2		10				

4B: Marie Antoinette

	1	2	3	4	5	6	7	8	9
A									
B		3		4	4				
C				11					9
D		6	2			14	1		
E	6		2	2		3	6		
F		4					1		7
G					9				
H			1						
I									

4C: Taiwan Toilet Restaurant

	1	2	3	4	5	6	7	8	9
A					1				
B			2	10	4	3	3		
C	1			8	2	4	1		
D		7			1			8	5
E					14				
F									
G									
H	10							9	
I			1			1			

5A: Golfing Disappointment

	1	2	3	4	5	6	7	8	9
A		4							1
B		4							
C		15		4					
D			1	3	15				
E							3		
F		9					7		
G					1				
H			3						3
I		7			12				

5B: Heron

	1	2	3	4	5	6	7	8	9
A									
B	1	1			1				
C				1					
D								3	
E		12			4				
F	5		18						3
G				9					
H	8			1	16				
I			5		5				2

5C: Speed Campaigners

	1	2	3	4	5	6	7	8	9
A						7			1
B						3	1	2	
C					18		3		
D			3			4	4		12
E							7		
F			13				10	1	
G			3						3
H									
I									

6A: Baghdad Shooting

	1	2	3	4	5	6	7	8	9
A									
B						11	1	2	1
C								1	
D	6						7	11	
E		2		4					
F				4	7			1	
G		14				1			
H			2		13				3
I				4					

6B: Kneeling protestor

	1	2	3	4	5	6	7	8	9
A		3					3		
B									
C				11			13	3	
D		11		4		19			
E	3								
F									
G						6			
H						1	3		
I			4						11

6C: Palestine

	1	2	3	4	5	6	7	8	9
A			2	2					
B									
C					15		4		
D									
E		2				3			
F			1		16	1	2		
G	4	3				11	7	9	10
H									
I									

7A: Climbing Frame

	1	2	3	4	5	6	7	8	9
A				1					1
B			7						
C						1			6
D			3					4	
E			3		2	13		7	
F	4		4	7			1		
G						4	3		
H		5		4			5		
I				4	2	3		1	

7B: Earthquake Refugees

	1	2	3	4	5	6	7	8	9
A									
B		2			13		10	5	
C		2			1	9			
D		1	8			1			
E	3	7		3					9
F									
G	3				3				
H									
I					7	7			

7C: Richard Hammond Crash

	1	2	3	4	5	6	7	8	9
A									
B							18		
C		3							
D			1						
E		15			5		16		
F		2	3	2	1	1			
G				2	10	2	1	3	
H	1		1						1
I					5		2		

8A: Classroom

	1	2	3	4	5	6	7	8	9
A	1		5	2					
B		3		4	3	4	3	6	
C							3		
D							1		
E		12				13		4	
F									
G		1	7			4		7	
H	2			1	1		2		
I							1		5

8B: Statue on Crosby Beach

	1	2	3	4	5	6	7	8	9
A									1
B									
C									
D			2				11		
E			19						
F									
G		1	1		9				1
H	1		1			13			16
I								19	

8C: Training

	1	2	3	4	5	6	7	8	9
A		2		1					
B	2	5		5					
C		2			3				
D	4								
E		16			8	5		3	
F	1	1					4		1
G				1				14	4
H									12
I	1								

9A: Seaside Pier

	1	2	3	4	5	6	7	8	9
A	2					1			
B		5		1	7		17		2
C	3								6
D	2	15				5			
E								1	
F				5					
G					1	13			
H		1							
I		1				4			3

9B: Camel Train

	1	2	3	4	5	6	7	8	9
A									
B					4				
C		1							
D				3	1	3		1	1
E		9	10		9		16		19
F					5				
G									7
H				1					
I				2	2		1		

9C: Horse Racing

	1	2	3	4	5	6	7	8	9
A							1		
B	4					1	15		
C	2				4		1		
D				3		5			14
E		1		1					
F	9		2				13		5
G									
H			11	1					1
I									1

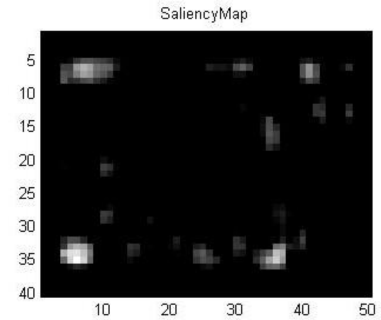
Appendix 11

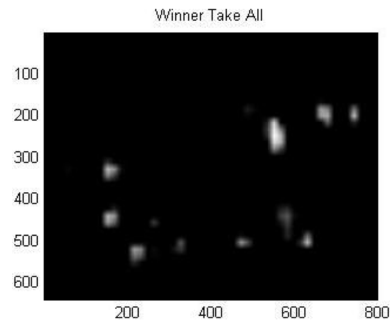
Saliency maps and 5 top saliency predictions for Experiment 3:

Stimuli set A

Image 1A: *Charity Run.*

Image removed due to copyright restrictions

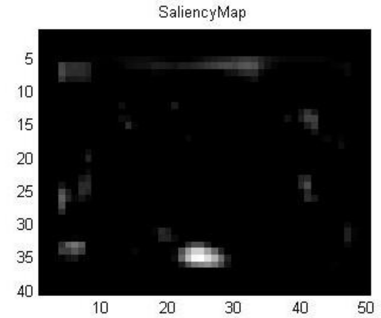


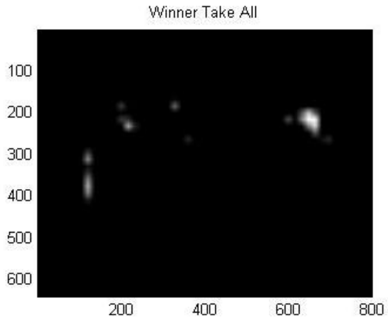


winner: 86,545; t = 102.6 ms - Gabor0.0 (8-4)
winner: 574,559; t = 170.6 ms - Gabor0.0 (8-4)
winner: 102,94; t = 230.5 ms - Intensity (6-3)
winner: 646,86; t = 290.0 ms - Intensity (6-3)
winner: 548,252; t = 368.7 ms - Red/Green (8-5)

Image 1B: *Selfridges*.

Image removed due to copyright restrictions

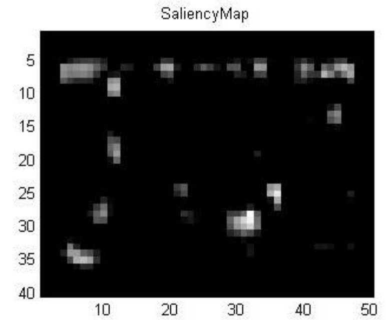


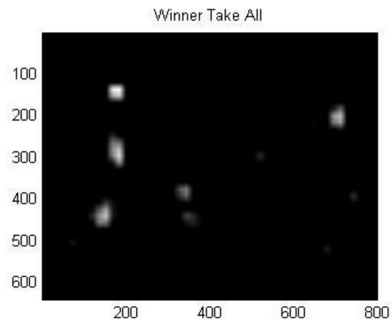


winner: 397,546; t = 97.8 ms - Gabor0.0 (8-4)
winner: 62,411; t = 198.7 ms - Intensity (7-4)
winner: 505,95; t = 281.1 ms - Intensity (6-3)
winner: 643,371; t = 359.5 ms - Blue/Yellow (7-4)
winner: 654,212; t = 437.0 ms - Blue/Yellow (7-4)

Image 1C. *Spamalot*.

Image removed due to copyright restrictions

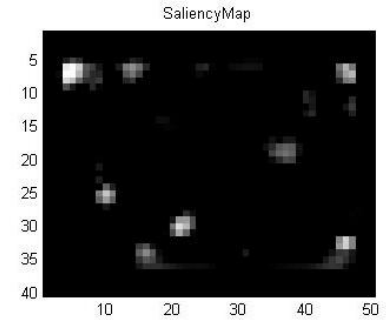


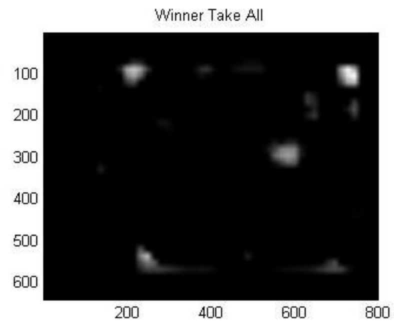


winner: 501,445; t = 103.4 ms - Intensity (6-3)
winner: 569,387; t = 166.9 ms - Red/Green (7-4)
winner: 101,554; t = 225.9 ms - Intensity (6-3)
winner: 735,88; t = 277.5 ms - Gabor0.0 (8-4)
winner: 186,129; t = 324.9 ms - Red/Green (9-5)

Image 2A: *Football Manager*.

Image removed due to copyright restrictions

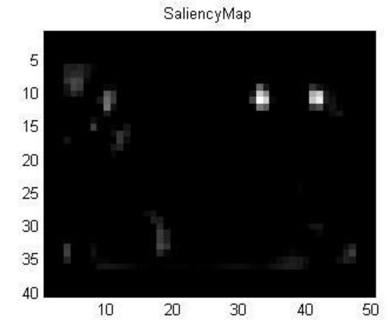


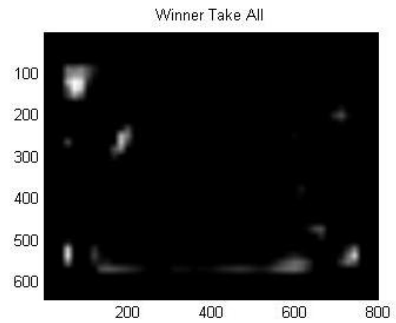


winner: 62,107; t = 103.4 ms - Intensity (7-4)
winner: 327,468; t = 168.9 ms - Red/Green (7-4)
winner: 731,512; t = 223.2 ms - Red/Green (7-4)
winner: 148,391; t = 272.2 ms - Red/Green (8-4)
winner: 753,100; t = 319.2 ms - Intensity (7-4)

Image 2B: *Lipstick*.

Image removed due to copyright restrictions

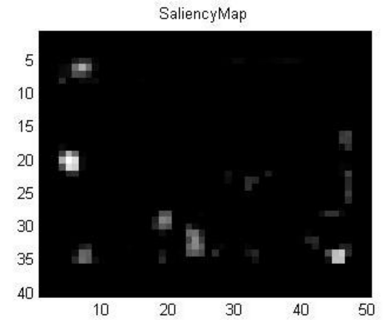


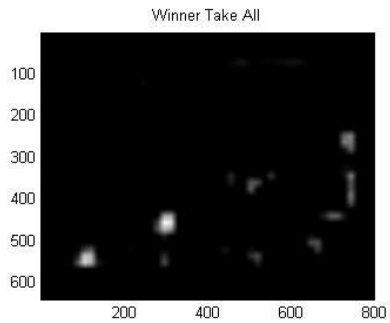


winner: 519,165; t = 100.6 ms - Red/Green (7-4)
winner: 669,170; t = 160.7 ms - Red/Green (7-3)
winner: 156,185; t = 240.0 ms - Red/Green (7-4)
winner: 285,527; t = 330.1 ms - Blue/Yellow (9-5)
winner: 72,123; t = 410.8 ms - Blue/Yellow (9-5)

Image 2C: *Medieval Jousting*.

Image removed due to copyright restrictions

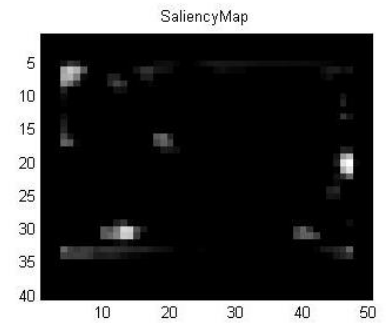


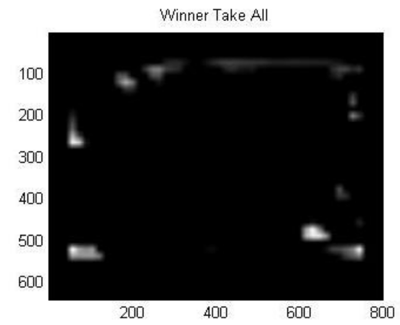


winner: 78,308; t = 98.8 ms - Blue/Yellow (9-5)
winner: 723,541; t = 163.9 ms - Intensity (7-4)
winner: 100,87; t = 222.0 ms - Intensity (6-3)
winner: 374,503; t = 281.1 ms - Blue/Yellow (9-5)
winner: 300,454; t = 335.5 ms - Gabor90.0 (7-4)

Image 3A: *Boozy Commentators*.

Image removed due to copyright restrictions

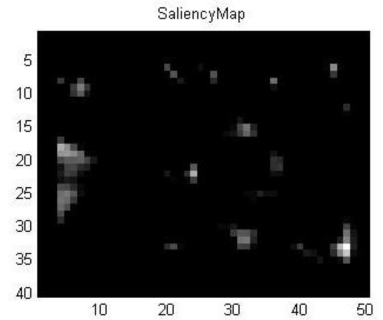


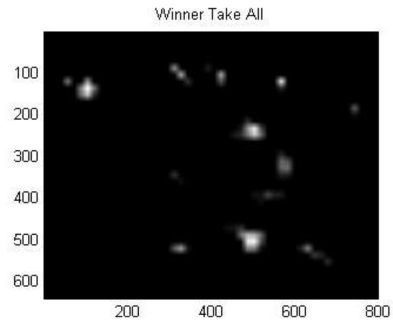


winner: 741,320; t = 101.5 ms - Red/Green (8-5)
winner: 198,473; t = 166.6 ms - Blue/Yellow (7-3)
winner: 76,86; t = 220.9 ms - Gabor45.0 (8-5)
winner: 289,255; t = 295.3 ms - Blue/Yellow (7-4)
winner: 51,517; t = 361.4 ms - Intensity (7-3)

Image 3B: *Dinosaurs at Buckingham Palace*.

Image removed due to copyright restrictions

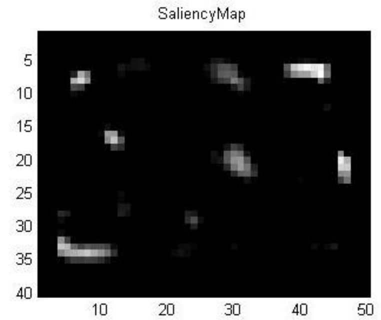


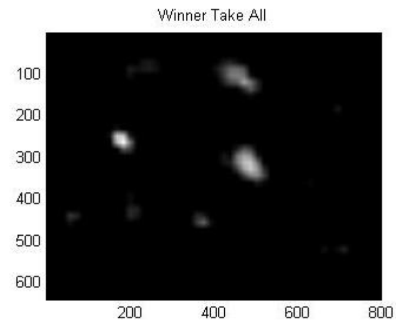


winner: 739,529; t = 103.1 ms - Intensity (7-4)
winner: 370,340; t = 178.9 ms - Blue/Yellow (6-3)
winner: 59,286; t = 239.0 ms - Intensity (7-4)
winner: 712,87; t = 300.4 ms - Intensity (6-3)
winner: 100,144; t = 360.0 ms - Blue/Yellow (9-5)

Image 3C: *Injured Footballer*.

Image removed due to copyright restrictions

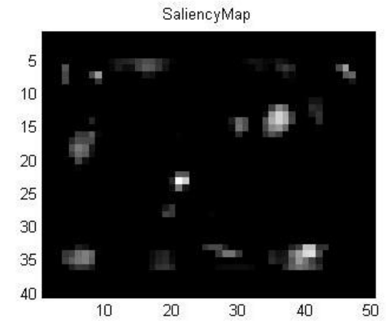


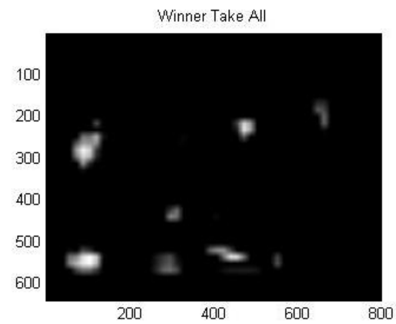


winner: 683,108; t = 104.8 ms - Intensity (8-5)
winner: 731,306; t = 168.4 ms - Red/Green (7-4)
winner: 111,127; t = 223.0 ms - Intensity (7-4)
winner: 124,531; t = 273.0 ms - Intensity (8-5)
winner: 192,266; t = 318.8 ms - Blue/Yellow (9-5)

Image 4A: *Army Cadets*.

Image removed due to copyright restrictions

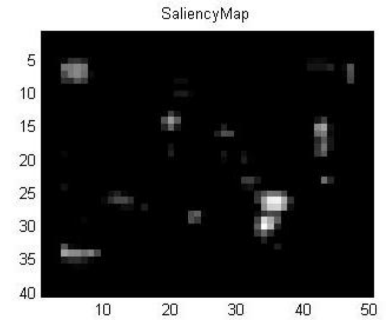


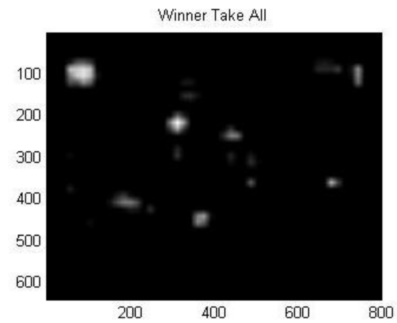


winner: 335,360; t = 106.3 ms - Intensity (7-4)
winner: 653,538; t = 173.2 ms - Blue/Yellow (8-5)
winner: 575,195; t = 228.9 ms - Blue/Yellow (9-5)
winner: 729,85; t = 288.4 ms - Intensity (6-3)
winner: 99,534; t = 351.4 ms - Intensity (8-5)

Image 4B: *Marie Antoinette*.

Image removed due to copyright restrictions

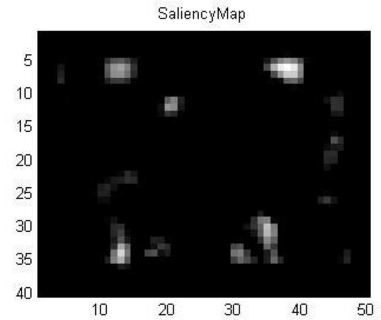


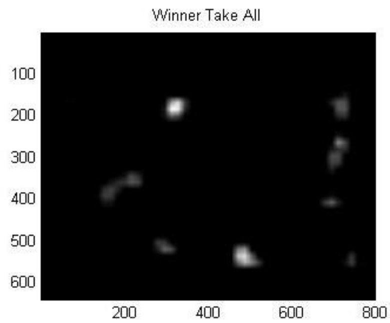


winner: 543,472; t = 103.6 ms - Intensity (6-3)
winner: 565,401; t = 165.4 ms - Blue/Yellow (9-5)
winner: 60,539; t = 230.9 ms - Intensity (7-4)
winner: 685,241; t = 287.0 ms - Red/Green (9-5)
winner: 309,224; t = 338.9 ms - Red/Green (9-5)

Image 4C: *Taiwan Toilet Restaurant*.

Image removed due to copyright restrictions

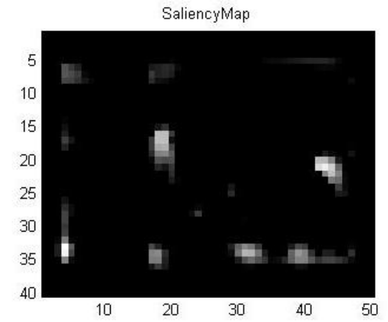


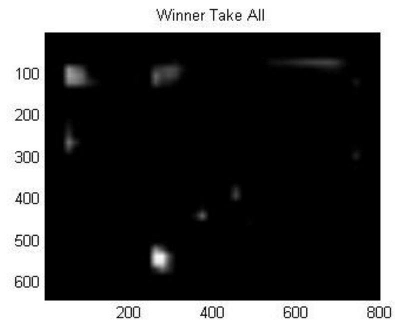


winner: 604,97; t = 98.1 ms - Intensity (8-4)
winner: 206,537; t = 161.0 ms - Intensity (7-4)
winner: 547,479; t = 214.9 ms - Intensity (8-4)
winner: 207,88; t = 267.6 ms - Gabor0.0 (8-5)
winner: 315,179; t = 317.7 ms - Blue/Yellow (8-4)

Image 5A: *Golf Disappointment*.

Image removed due to copyright restrictions

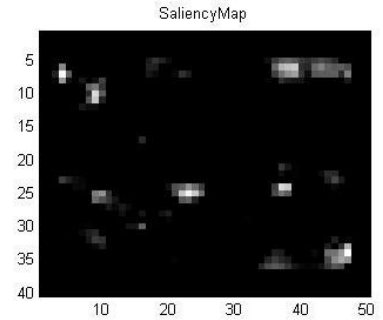


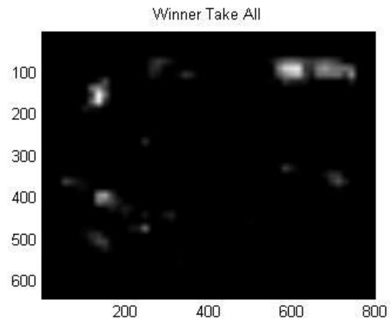


winner: 50,525; t = 105.3 ms - Intensity (7-4)
winner: 685,325; t = 169.0 ms - Blue/Yellow (7-4)
winner: 298,262; t = 228.8 ms - Red/Green (9-5)
winner: 487,533; t = 282.0 ms - Intensity (8-5)
winner: 277,540; t = 341.1 ms - Intensity (8-5)

Image 5B: *Heron*.

Image removed due to copyright restrictions

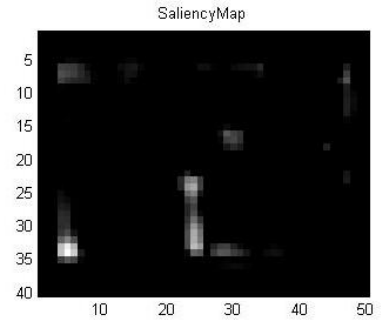


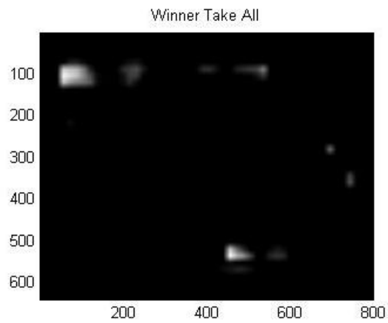


winner: 748,543; t = 107.4 ms - Gabor135.0 (8-4)
winner: 56,104; t = 171.1 ms - Intensity (7-4)
winner: 362,394; t = 222.6 ms - Intensity (8-5)
winner: 583,377; t = 271.8 ms - Intensity (7-4)
winner: 134,156; t = 271.9 ms - Blue/Yellow (9-5)

Image 5C: *Speed Campaigners*.

Image removed due to copyright restrictions

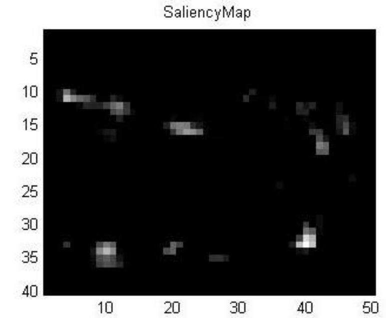


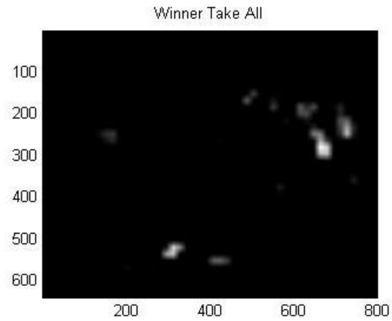


winner: 72,535; t = 101.1 ms - Intensity (8-5)
winner: 379,520; t = 171.7 ms - Blue/Yellow (8-5)
winner: 462,242; t = 264.3 ms - Blue/Yellow (8-5)
winner: 749,113; t = 344.1 ms - Intensity (7-4)
winner: 461,539; t = 416.0 ms - Intensity (8-5)

Image 6A: *Baghdad Shooting*.

Image removed due to copyright restrictions

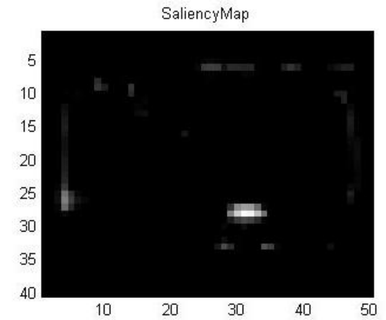


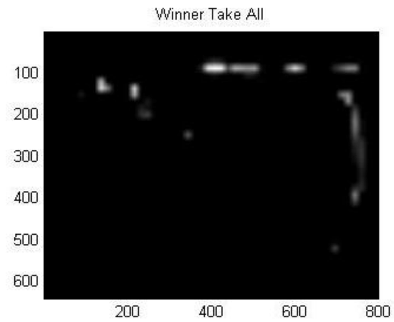


winner: 631,518; t = 101.1 ms - Red/Green (6-3)
winner: 65,165; t = 172.8 ms - Intensity (7-4)
winner: 146,536; t = 172.9 ms - Intensity (8-5)
winner: 352,245; t = 237.0 ms - Intensity (8-4)
winner: 660,286; t = 301.5 ms - Blue/Yellow (8-4)

Image 6B: *Kneeling Protestor*.

Image removed due to copyright restrictions

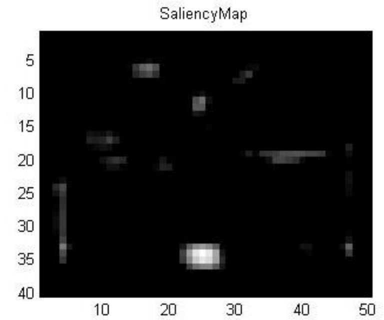


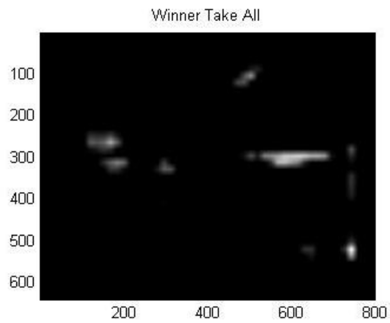


winner: 483,437; t = 98.0 ms - Red/Green (8-5)
winner: 64,406; t = 184.2 ms - Intensity (7-4)
winner: 542,516; t = 273.2 ms - Intensity (7-3)
winner: 439,529; t = 354.3 ms - Intensity (7-3)
winner: 406,87; t = 435.4 ms - Intensity (6-3)

Image 6C: *Palestine*.

Image removed due to copyright restrictions

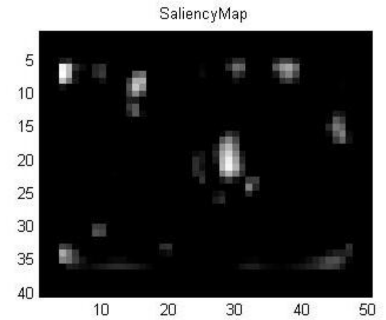


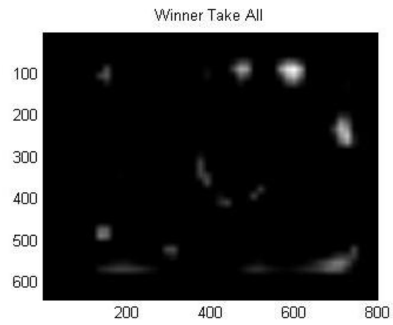


winner: 398,529; t = 96.3 ms - Intensity (8-5)
winner: 59,514; t = 183.1 ms - Intensity (7-4)
winner: 272,97; t = 254.2 ms - Intensity (8-4)
winner: 386,169; t = 315.9 ms - Blue/Yellow (7-4)
winner: 741,521; t = 376.0 ms - Intensity (7-3)

Image 7A: *Climbing Frame*.

Image removed due to copyright restrictions

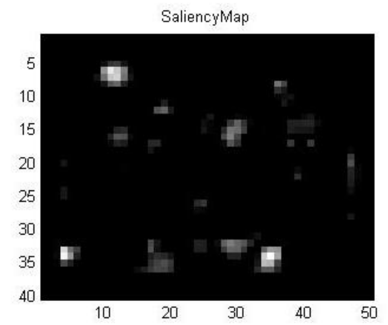


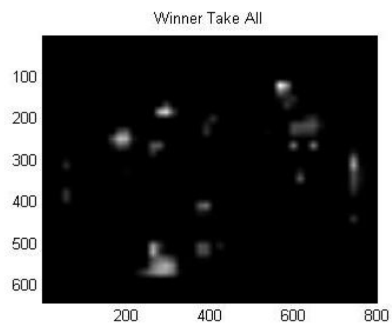


winner: 63,105; t = 104.6 ms - Intensity (7-4)
winner: 449,322; t = 166.5 ms - Blue/Yellow (9-5)
winner: 240,138; t = 224.1 ms - Blue/Yellow (8-5)
winner: 51,541; t = 280.1 ms - Intensity (7-4)
winner: 605,83; t = 330.9 ms - Gabor0.0 (8-4)

Image 7B: *Earthquake Refugees*.

Image removed due to copyright restrictions

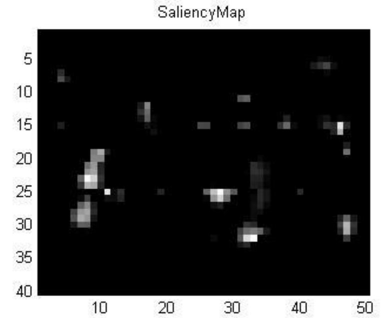


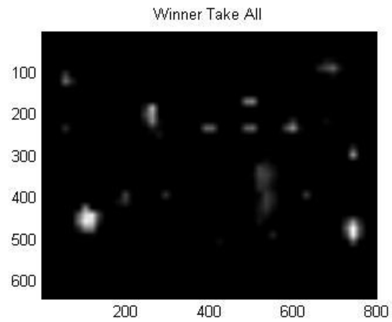


winner: 560,533; t = 102.7 ms - Intensity (8-5)
winner: 63,533; t = 163.7 ms - Intensity (7-4)
winner: 171,82; t = 214.1 ms - Intensity (6-3)
winner: 462,244; t = 281.8 ms - Red/Green (7-4)
winner: 564,113; t = 346.5 ms - Intensity (6-3)

Image 7C: *Richard Hammond Crash*.

Image removed due to copyright restrictions

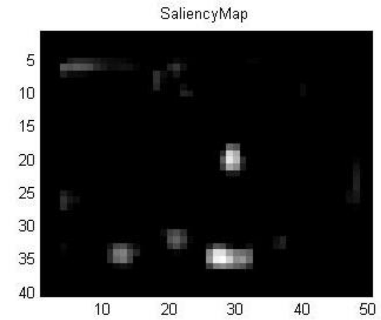


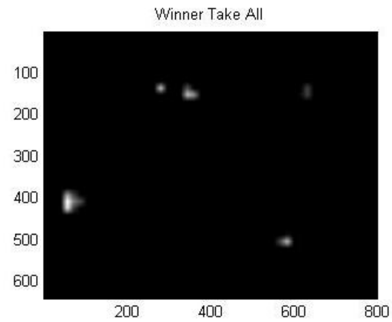


winner: 434,388; t = 107.3 ms - Red/Green (8-4)
winner: 527,500; t = 170.7 ms - Intensity (6-3)
winner: 120,367; t = 170.8 ms - Red/Green (9-5)
winner: 735,241; t = 225.3 ms - Red/Green (7-4)
winner: 744,470; t = 281.5 ms - Gabor90.0 (7-4)

Image 8A: *Classroom*.

Image removed due to copyright restrictions





winner: 444,547; t = 100.3 ms - Gabor0.0 (8-4)
winner: 464,310; t = 161.6 ms - Blue/Yellow (7-4)
winner: 324,511; t = 247.2 ms - Red/Green (9-5)
winner: 89,90; t = 323.9 ms - Intensity (6-3)
winner: 49,414; t = 425.7 ms - Intensity (7-4)

Image 8B: *Statue on Crosby Beach*

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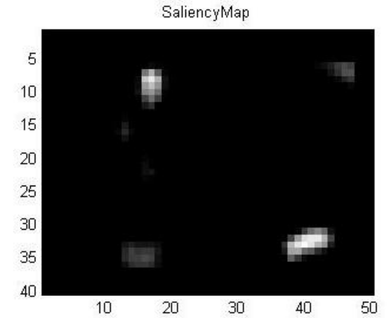
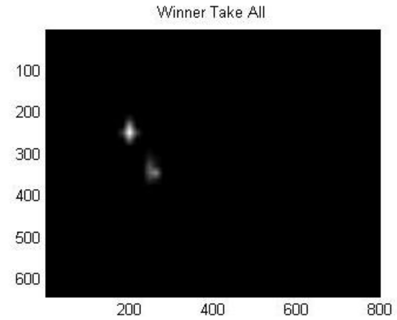
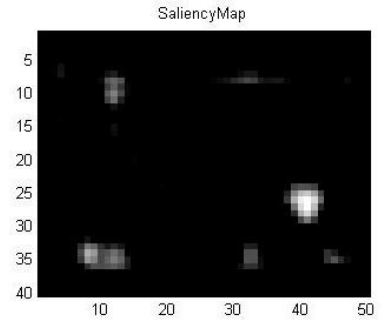


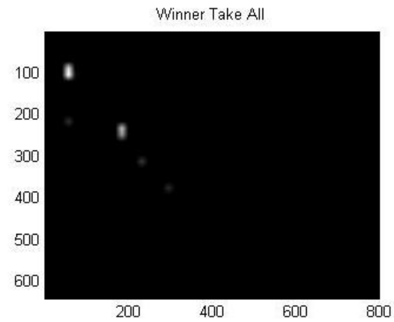


winner: 635,514; t = 97.0 ms - Red/Green (9-5)
winner: 265,113; t = 155.2 ms - Intensity (7-4)
winner: 743,101; t = 250.6 ms - Blue/Yellow (7-4)
winner: 242,559; t = 332.6 ms - Gabor0.0 (8-4)
winner: 203,254; t = 442.0 ms - Intensity (7-4)

Image 8C: *Training*.

Image removed due to copyright restrictions

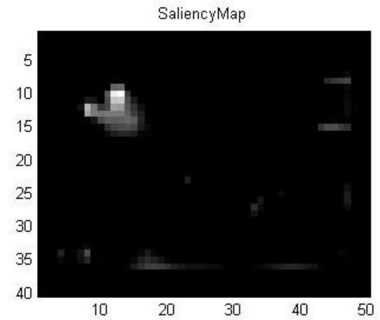


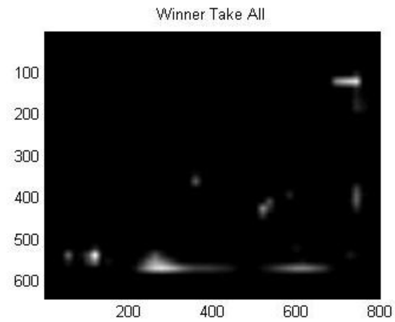


winner: 654,430; t = 96.1 ms - Blue/Yellow (8-5)
winner: 120,544; t = 165.8 ms - Intensity (7-4)
winner: 185,154; t = 233.3 ms - Red/Green (8-5)
winner: 511,118; t = 319.0 ms - Intensity (7-4)
winner: 49,108; t = 475.3 ms - Intensity (7-4)

Image 9A: *Seaside Pier*.

Image removed due to copyright restrictions





winner: 206,149; t = 102.5 ms - Red/Green (9-5)
winner: 119,177; t = 175.6 ms - Intensity (7-4)
winner: 239,212; t = 265.5 ms - Intensity (8-5)
winner: 717,226; t = 351.7 ms - Blue/Yellow (7-4)
winner: 126,544; t = 429.4 ms - Red/Green (8-5)

Image 9B: *Camel Train*.

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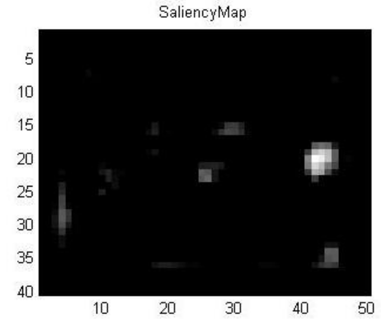
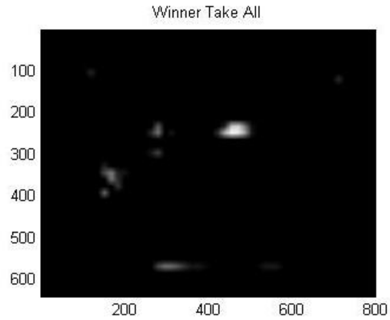
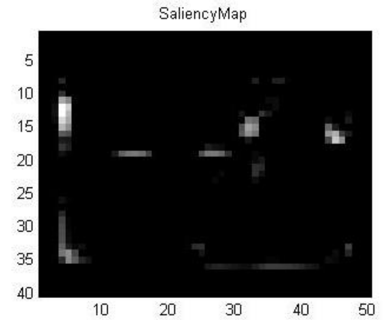


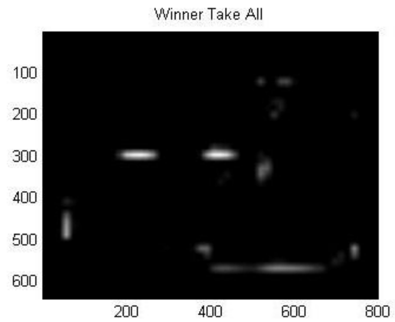


winner: 671,311; t = 98.1 ms - Blue/Yellow (7-4)
winner: 415,367; t = 195.0 ms - Red/Green (6-3)
winner: 690,535; t = 276.0 ms - Intensity (8-5)
winner: 57,462; t = 347.1 ms - Intensity (7-4)
winner: 451,244; t = 421.6 ms - Intensity (8-5)

Image 9C: *Horse Racing.*

Image removed due to copyright restrictions





winner: 53,196; t = 101.6 ms - Intensity (8-4)
winner: 711,270; t = 169.8 ms - Blue/Yellow (8-5)
winner: 509,227; t = 232.4 ms - Intensity (8-4)
winner: 69,533; t = 291.7 ms - Red/Green (8-5)
winner: 228,297; t = 351.2 ms - Blue/Yellow (8-4)

Appendix 12

Confusion matrices of location responses for Experiment 7

Table 6.1: Frequency of location recall for each of the 27 stimuli and computed RMS_c scores for Experiment 7, Group 1 (immediate recall).

Target location and stimulus identifier		Location given as response									Total	RMS_c Score	Mean Confidence
		1	2	3	4	5	6	7	8	9			
						Immediate recall							
1													
	A	**8**	3	3	1	2	0	2	1	0	20	0.49	3.60
	B	**2**	4	6	1	1	3	2	1	0	20	0.71	2.75
	C	**1**	1	6	3	1	4	2	2	0	20	0.90	2.10
2													
	A	2	**7**	4	1	3	3	0	0	0	20	0.45	3.35
	B	3	**10**	5	0	0	0	1	1	0	20	0.29	4.25
	C	0	**1**	7	5	1	2	4	0	0	20	0.74	3.15
3													
	A	0	3	**6**	9	1	0	1	0	0	20	0.34	2.60
	B	0	1	**3**	4	5	5	2	0	0	20	0.71	2.55
	C	0	1	**7**	10	1	0	0	1	0	20	0.34	3.85
4													
	A	1	1	4	**6**	5	1	2	0	0	20	0.47	2.95
	B	0	0	2	**11**	3	3	0	1	0	20	0.32	4.00
	C	1	0	0	**3**	13	2	1	0	0	20	0.49	3.40
5													
	A	0	0	1	6	**6**	4	2	1	0	20	0.43	3.05
	B	0	1	0	4	**9**	1	4	1	0	20	0.43	2.80
	C	1	11	4	2	**0**	2	0	0	0	20	1.10	3.95
6													
	A	0	0	1	2	3	**7**	4	3	0	20	0.43	3.30
	B	0	0	0	0	9	**8**	3	0	0	20	0.26	4.30
	C	0	1	3	5	1	**5**	4	1	0	20	0.64	2.40
7													
	A	0	2	1	0	1	9	**6**	1	0	20	0.49	3.00
	B	1	0	3	5	3	4	**3**	1	0	20	0.83	2.00
	C	0	1	8	3	3	2	**2**	1	0	20	1.03	2.85
8													
	A	0	0	2	0	3	6	8	**0**	1	20	0.62	3.75
	B	0	0	1	1	3	5	7	**3**	0	20	0.54	4.00
	C	0	2	7	5	0	1	3	**1**	1	20	1.13	3.40
9													
	A	2	0	5	0	2	3	2	4	**2**	20	0.89	2.90
	B	0	1	0	1	3	5	2	7	**1**	20	0.63	3.55
	C	2	1	4	1	3	3	4	1	**1**	20	1.03	2.45
Total		24	52	93	89	85	88	71	32	6			
	Average											0.62	3.19

RMS_c = root-mean-square (corrected). Correct location recalls are highlighted in **bold**.

Table 6.2: Frequency of location recall for each of the 27 stimuli and computed RMS_c scores for Experiment 7, Group 1 (1 week delayed recall).

Target location and stimulus identifier		Location given as response									Total	RMS_c Score	Mean Confidence
		1	2	3	4	5	6	7	8	9			
		1 week delayed recall											
1													
	A	**0**	7	4	2	2	3	1	1	0	20	0.71	2.85
	B	**1**	2	7	3	1	2	3	1	0	20	0.80	2.80
	C	**0**	1	4	4	3	3	4	1	0	20	0.99	2.25
2													
	A	1	**2**	4	9	1	1	1	0	1	20	0.65	2.85
	B	0	**11**	5	2	1	0	1	0	0	20	0.26	4.00
	C	0	**1**	7	3	1	5	2	1	0	20	0.81	2.85
3													
	A	0	2	**8**	4	0	5	0	0	1	20	0.51	2.60
	B	0	0	**5**	4	4	5	2	0	0	20	0.66	3.00
	C	0	0	**7**	5	5	3	0	0	0	20	0.45	3.15
4													
	A	0	1	3	**5**	5	3	3	0	0	20	0.54	2.60
	B	0	0	1	**9**	5	5	0	0	0	20	0.34	3.75
	C	0	0	1	**4**	12	3	0	0	0	20	0.41	3.00
5													
	A	0	0	2	2	**6**	6	4	0	0	20	0.45	1.95
	B	0	0	2	3	**5**	6	2	1	1	20	0.54	2.95
	C	1	11	5	2	**1**	0	0	0	0	20	1.10	4.00
6													
	A	0	0	1	2	4	**5**	7	1	0	20	0.43	3.00
	B	0	0	1	0	11	**7**	0	1	0	20	0.34	3.30
	C	0	0	2	4	3	**8**	3	0	0	20	0.43	2.10
7													
	A	0	0	2	1	3	11	**3**	0	0	20	0.53	2.95
	B	0	1	6	1	3	6	**1**	1	1	20	0.88	1.60
	C	0	0	11	3	4	1	**1**	0	0	20	1.16	2.70
8													
	A	0	0	0	4	1	13	2	**0**	0	20	0.73	3.55
	B	0	0	1	0	2	7	8	**2**	0	20	0.51	3.30
	C	0	1	5	4	4	2	2	**2**	0	20	1.01	3.10
9													
	A	1	0	1	3	5	1	4	5	**0**	20	0.81	2.55
	B	0	0	1	3	3	8	3	2	**0**	20	0.81	2.60
	C	0	1	1	3	3	4	6	1	**1**	20	0.81	1.65
Total		4	41	97	89	98	123	63	20	5			
	Average											0.65	2.85

Table 6.3: Frequency of location recall for each of the 27 stimuli and computed RMS_c scores for Experiment 7, Group 2 (immediate recall).

Target location and stimulus identifier		Location given as response									Total	RMS_c Score	Mean Confidence
		1	2	3	4	5	6	7	8	9			
						Immediate recall							
1													
	A	**9**	6	1	1	3	1	1	5	0	27	0.64	3.30
	B	**2**	6	4	3	1	3	5	3	0	27	0.86	2.96
	C	**2**	1	6	6	2	5	4	1	0	27	0.88	2.33
2													
	A	1	**5**	4	8	2	4	2	1	0	27	0.68	3.19
	B	3	**13**	6	1	0	0	1	0	3	27	0.43	4.56
	C	0	**0**	10	7	1	2	5	1	1	27	0.84	2.96
3													
	A	0	1	**14**	6	0	2	1	1	2	27	0.47	3.26
	B	1	1	**2**	7	6	4	3	0	3	27	0.89	2.74
	C	1	1	**11**	11	1	0	0	0	2	27	0.39	3.74
4													
	A	1	1	4	**8**	5	4	2	0	2	27	0.60	3.37
	B	1	0	0	**14**	7	0	2	2	1	27	0.46	3.70
	C	1	1	1	**8**	13	3	0	0	0	27	0.40	3.04
5													
	A	2	1	0	5	**8**	4	3	1	3	27	0.68	2.96
	B	1	1	3	5	**4**	5	4	3	1	27	0.73	3.07
	C	3	9	8	3	**0**	1	0	1	2	27	1.17	4.26
6													
	A	0	0	1	2	3	**16**	3	2	0	27	0.27	3.11
	B	0	0	0	0	11	**14**	1	1	0	27	0.22	3.81
	C	1	2	4	6	7	**2**	3	1	1	27	0.83	1.96
7													
	A	0	0	4	4	4	9	**5**	1	0	27	0.64	3.11
	B	1	2	7	2	3	4	**4**	4	0	27	0.89	2.44
	C	1	1	9	3	3	4	**3**	3	0	27	0.96	2.85
8													
	A	0	2	0	0	3	12	7	**2**	1	27	0.61	3.59
	B	1	1	2	1	0	8	9	**4**	1	27	0.61	4.04
	C	2	2	5	5	4	2	3	**4**	0	27	1.03	3.04
9													
	A	1	2	1	1	2	11	6	2	**1**	27	0.81	2.85
	B	3	1	2	1	6	0	4	7	**3**	27	0.81	2.93
	C	1	2	6	5	1	4	5	3	**0**	27	1.04	2.22
Total		39	62	115	123	100	124	86	53	27			
	Average											0.70	3.16

Table 6.4: Frequency of location recall for each of the 27 stimuli and computed RMS_c scores for Experiment 7, Group 2 (2 week delayed recall).

Target location and stimulus identifier		Location given as response									Total	RMS_c Score	Mean Confidence
		1	2	3	4	5	6	7	8	9			
						2 week delayed recall							
1													
	A	**5**	4	4	3	1	2	7	1	0	27	0.78	3.11
	B	**0**	2	6	6	4	6	2	1	0	27	0.90	3.19
	C	**0**	1	5	7	5	1	8	0	0	27	0.97	2.04
2													
	A	1	**3**	4	7	2	3	4	3	0	27	0.86	2.59
	B	4	**5**	9	2	0	1	6	0	0	27	0.59	3.74
	C	1	**1**	5	7	0	10	3	0	0	27	0.86	2.67
3													
	A	0	1	**4**	8	1	7	4	2	0	27	0.81	2.67
	B	0	0	**6**	5	5	7	3	1	0	27	0.74	3.11
	C	0	0	**4**	10	4	7	1	1	0	27	0.67	2.85
4													
	A	0	2	7	**8**	1	5	2	1	1	27	0.59	2.48
	B	0	0	1	**5**	13	5	2	1	0	27	0.54	3.63
	C	0	0	0	**3**	17	6	1	0	0	27	0.51	3.04
5													
	A	0	2	4	4	**7**	5	4	1	0	27	0.57	2.33
	B	0	1	5	5	**4**	6	3	2	1	27	0.67	2.70
	C	3	7	7	5	**1**	2	1	1	0	27	0.98	3.70
6													
	A	0	0	5	7	3	**7**	4	1	0	27	0.60	2.52
	B	0	0	2	8	9	**6**	1	0	1	27	0.56	3.11
	C	0	0	9	4	2	**8**	2	2	0	27	0.68	2.30
7													
	A	0	2	2	7	6	8	**1**	1	0	27	0.83	2.93
	B	0	1	8	5	5	3	**3**	2	0	27	0.93	1.93
	C	0	1	5	13	5	0	**2**	1	0	27	1.04	2.70
8													
	A	0	1	3	2	1	11	8	**1**	0	27	0.71	3.52
	B	0	0	7	2	6	2	7	**3**	0	27	0.83	2.63
	C	0	3	3	6	1	9	4	**1**	0	27	0.94	2.15
9													
	A	0	1	0	3	4	11	4	3	**1**	27	0.76	3.00
	B	0	2	5	2	1	7	6	2	**2**	27	0.86	2.22
	C	1	2	5	4	0	9	6	0	**0**	27	1.03	1.93
Total		15	42	125	148	108	154	99	32	6			
	Average											0.77	2.77

Appendix 13

Confusion matrices of location responses for Experiment 8

Table 6.7: Frequency of location recall for each of the 27 stimuli and computed RMS_c scores for Experiment 8, Group 1 (immediate recall).

Target location and stimulus identifier	Location given as response									Total	RMS_c Score	Mean Confidence
	1	2	3	4	5	6	7	8	9			
					Immediate recall							
1												
A	**16**	7	0	1	1	0	0	1	0	26	0.20	4.38
B	**2**	9	8	0	1	1	3	1	1	26	0.64	3.54
C	**12**	8	4	1	0	0	1	0	0	26	0.24	3.96
2												
A	2	**8**	8	4	1	2	1	0	0	26	0.41	3.65
B	1	**10**	10	4	0	0	0	1	0	26	0.30	4.31
C	0	**0**	16	9	0	1	0	0	0	26	0.45	3.77
3												
A	0	0	**15**	10	0	0	1	0	0	26	0.20	3.58
B	0	4	**16**	3	2	0	0	1	0	26	0.23	3.50
C	0	1	**11**	9	4	1	0	0	0	26	0.30	3.73
4												
A	0	0	4	**16**	6	0	0	0	0	26	0.16	3.88
B	0	0	0	**16**	9	0	1	0	0	26	0.20	4.00
C	1	0	1	**19**	5	0	0	0	0	26	0.15	3.96
5												
A	1	0	3	8	**9**	5	0	0	0	26	0.40	2.73
B	0	0	1	2	**10**	12	0	0	1	26	0.35	3.81
C	4	10	6	4	**0**	2	0	0	0	26	1.11	3.77
6												
A	0	0	0	3	1	**17**	3	1	1	26	0.25	3.42
B	1	0	0	0	10	**13**	1	0	1	26	0.31	3.88
C	0	0	1	2	9	**12**	2	0	0	26	0.30	3.38
7												
A	0	3	1	0	0	6	**10**	6	0	26	0.45	3.73
B	0	1	4	1	2	9	**8**	1	0	26	0.55	2.81
C	1	0	2	2	2	16	**2**	1	0	26	0.59	3.08
8												
A	0	2	0	0	1	11	9	**2**	1	26	0.56	3.69
B	1	0	1	1	0	5	17	**1**	0	26	0.51	3.81
C	0	1	2	1	0	3	5	**14**	0	26	0.37	3.38
9												
A	0	1	1	2	2	2	3	10	**5**	26	0.51	3.12
B	0	2	1	1	1	4	8	5	**4**	26	0.60	3.00
C	0	3	0	1	0	4	0	6	**12**	26	0.42	3.58
Total	42	70	116	120	76	126	75	51	26			
Average											0.40	3.61

RMS_c = root-mean-square (corrected). Correct location recalls are highlighted in **bold**.

Table 6.8: Frequency of location recall for each of the 27 stimuli and computed RMS$_c$ scores for Experiment 8, Group 1 (1 week delayed recall).

Target location and stimulus identifier		Location given as response									Total	RMS$_c$ Score	Mean Confidence
		1	2	3	4	5	6	7	8	9			
						1 week delayed recall							
1													
	A	**10**	9	4	0	0	1	2	0	0	26	0.33	3.77
	B	**2**	5	9	5	0	1	2	1	1	26	0.67	3.08
	C	**4**	9	7	2	0	1	3	0	0	26	0.50	3.23
2													
	A	0	**6**	5	8	1	3	2	1	0	26	0.62	2.50
	B	1	**11**	10	3	0	0	0	1	0	26	0.27	4.00
	C	0	**1**	7	9	0	5	3	1	0	26	0.79	2.65
3													
	A	0	1	**12**	11	1	1	0	0	0	26	0.25	3.12
	B	0	1	**10**	7	4	3	1	0	0	26	0.42	3.31
	C	0	1	**4**	9	5	4	3	0	0	26	0.63	3.23
4													
	A	0	0	4	**14**	5	2	0	0	1	26	0.30	3.50
	B	0	0	3	**9**	9	5	0	0	0	26	0.36	3.46
	C	0	0	1	**14**	11	0	0	0	0	26	0.20	3.69
5													
	A	0	0	7	8	**5**	4	2	0	0	26	0.52	2.27
	B	0	0	2	4	**6**	10	3	1	0	26	0.47	3.00
	C	3	7	7	5	**1**	1	2	0	0	26	0.99	3.35
6													
	A	0	1	1	4	3	**8**	9	0	0	26	0.45	2.65
	B	0	0	3	0	9	**11**	2	1	0	26	0.36	3.46
	C	0	0	1	3	6	**9**	4	2	1	26	0.43	3.35
7													
	A	0	0	4	0	4	9	**7**	2	0	26	0.50	3.27
	B	0	1	3	1	4	4	**13**	0	0	26	0.46	2.04
	C	1	0	3	5	6	10	**1**	0	0	26	0.79	2.77
8													
	A	0	0	0	3	2	12	7	**2**	0	26	0.58	3.58
	B	0	0	1	4	4	10	6	**1**	0	26	0.70	3.08
	C	0	2	1	5	1	3	4	**8**	2	26	0.62	2.42
9													
	A	0	0	2	2	2	8	5	4	**3**	26	0.65	2.69
	B	0	1	1	4	2	5	6	3	**4**	26	0.68	2.46
	C	0	1	0	3	1	2	8	7	**4**	26	0.53	2.85
Total		21	57	112	142	92	132	95	35	16			
	Average											0.52	3.07

Table 6.9: Frequency of location recall for each of the 27 stimuli and computed RMS_c scores for Experiment 8, Group 2 (immediate recall).

Target location and stimulus identifier		Location given as response									Total	RMS_c Score	Mean Confidence
		1	2	3	4	5	6	7	8	9			
						Immediate recall							
1													
	A	**16**	4	0	0	0	0	0	0	1	21	0.14	4.71
	B	**0**	6	7	2	2	3	0	1	0	21	0.67	3.57
	C	**4**	8	1	1	0	4	1	1	1	21	0.64	4.00
2													
	A	1	**11**	4	3	0	0	1	0	1	21	0.34	3.71
	B	1	**11**	6	1	0	0	1	0	1	21	0.31	4.33
	C	0	**0**	9	7	2	2	1	0	0	21	0.62	3.24
3													
	A	0	0	**9**	7	1	1	1	0	2	21	0.50	3.62
	B	1	1	**14**	4	0	1	0	0	0	21	0.18	3.76
	C	0	0	**5**	13	1	2	0	0	0	21	0.38	3.67
4													
	A	0	0	1	**15**	2	0	1	0	2	21	0.33	3.95
	B	0	0	3	**10**	6	1	0	0	1	21	0.33	4.14
	C	1	0	0	**17**	1	1	0	0	1	21	0.22	4.14
5													
	A	1	0	2	9	**5**	1	3	0	0	21	0.51	3.67
	B	0	0	0	4	**8**	6	0	1	2	21	0.45	3.14
	C	0	6	7	2	**2**	0	1	0	3	21	1.03	3.52
6													
	A	1	0	0	1	5	**10**	4	0	0	21	0.33	3.43
	B	0	1	0	1	12	**7**	0	0	0	21	0.37	3.95
	C	1	0	0	1	8	**9**	1	0	1	21	0.39	4.05
7													
	A	2	3	0	0	2	3	**9**	1	1	21	0.66	3.62
	B	0	1	3	1	1	6	**7**	1	1	21	0.55	2.90
	C	1	0	0	3	2	12	**3**	0	0	21	0.55	3.43
8													
	A	0	0	0	2	0	9	10	**0**	0	21	0.53	3.67
	B	0	0	1	0	1	5	12	**2**	0	21	0.44	4.00
	C	1	1	1	1	1	5	8	**3**	0	21	0.64	3.10
9													
	A	0	0	1	1	2	4	5	5	**3**	21	0.55	3.57
	B	0	2	3	0	0	3	5	7	**1**	21	0.69	3.10
	C	0	0	2	0	0	2	2	5	**10**	21	0.32	4.10
Total		31	55	79	106	64	97	76	27	32			
	Average											0.47	3.71

Table 6.10: Frequency of location recall for each of the 27 stimuli and computed RMS_c scores for Experiment 8, Group 2 (2 week delayed recall).

Target location and stimulus identifier		Location given as response									Total	RMS_c Score	Mean Confidence
		1	2	3	4	5	6	7	8	9			
		2 week delayed recall											
1													
	A	**4**	8	6	1	2	0	0	0	0	21	0.37	3.48
	B	**0**	3	4	6	0	4	4	0	0	21	0.87	3.62
	C	**1**	5	4	3	0	6	1	1	0	21	0.77	2.81
2													
	A	1	**3**	7	3	3	3	0	1	0	21	0.61	3.24
	B	1	**6**	9	4	0	0	0	1	0	21	0.35	4.00
	C	0	**0**	2	8	2	6	3	0	0	21	0.93	2.62
3													
	A	0	0	**3**	9	3	3	1	2	0	21	0.68	2.95
	B	0	0	**6**	5	5	4	1	0	0	21	0.55	3.48
	C	0	2	**2**	8	6	2	1	0	0	21	0.57	2.76
4													
	A	1	1	2	**7**	7	1	1	0	1	21	0.49	3.14
	B	0	0	4	**6**	6	4	1	0	0	21	0.43	3.14
	C	0	0	0	**8**	7	4	1	1	0	21	0.45	3.62
5													
	A	0	0	2	2	**9**	7	1	0	0	21	0.32	2.81
	B	0	0	1	2	**6**	8	2	1	1	21	0.49	2.71
	C	0	5	8	4	**1**	1	1	0	1	21	0.90	3.33
6													
	A	0	0	0	3	5	**7**	5	0	1	21	0.39	2.48
	B	0	0	2	2	12	**4**	1	0	0	21	0.47	3.00
	C	0	1	1	3	5	**8**	2	1	0	21	0.45	2.86
7													
	A	0	2	3	1	3	8	**4**	0	0	21	0.70	3.52
	B	0	1	5	4	2	3	**4**	1	1	21	0.84	2.05
	C	1	1	1	4	4	7	**3**	0	0	21	0.75	2.90
8													
	A	0	0	0	2	0	11	7	**0**	1	21	0.56	3.43
	B	1	0	4	3	2	5	6	**0**	0	21	0.90	2.71
	C	0	1	1	3	1	2	10	**2**	1	21	0.61	2.33
9													
	A	0	0	1	1	2	9	5	3	**0**	21	0.70	2.76
	B	0	0	1	6	1	3	4	6	**0**	21	0.75	1.95
	C	0	1	2	0	2	7	4	1	**4**	21	0.68	2.86
Total		10	40	81	108	96	127	73	21	11			
	Average											0.61	2.98

Appendix 14

Experiment 7: Analysis 1: Experimental reliability

Chapter six: effects of delay on memory for location. Experiment 7.

Analysis 1: Experimental reliability

As a first stage of analysis, should the experimental findings presented within this thesis be reliable, then they should be easily replicated. In order to establish that the data elicited from the immediate recall condition of both experimental groups (groups 1 and 2) of Experiment 7 is comparable to data from the methodologically identical Experiment 1, contrasts were made between the overall recall performance, as indicated by mean RMS_c scores for each location tested[36]. Overall mean RMS_c values for the present experiment were shown to be similar across the two Experiments (Experiment 7: 0.62 for group 1, and 0.70 for group 2 respectively, compared with 0.65 for Experiment 1). For individual locations tested, a large correlation for the RMS_c scores for each of the 27 stimuli images between Experiment 1 and Experiment 7 (group 1), (r (26) = 0.951, $p < .01$) and Experiment 7 (group 2), (r (26) = 0.934, $p < .01$), were revealed (see Figures 6.1 and 6.2). This indicates, as expected, that the immediate recall responses in Experiment 7 were very similar in terms of location recall accuracy to the responses witnessed in Experiment 1. As such, the experimental findings of Experiment 1 are shown to be replicable, and the data elicited from the current experiment robust. Correlations are presented within Figures 6.1 and 6.2, and location recall data and RMS_c values for each of the images are presented within Appendix 12.

[36] Data matrices including RMS_c values for each of the stimuli in Experiment 7 are presented within Appendix 12.

Figure 6.1: Scatter plot showing mean RMS_c scores for each of the 27 stimuli in both Experiment 1 and Experiment 7 (group 1: Immediate recall)

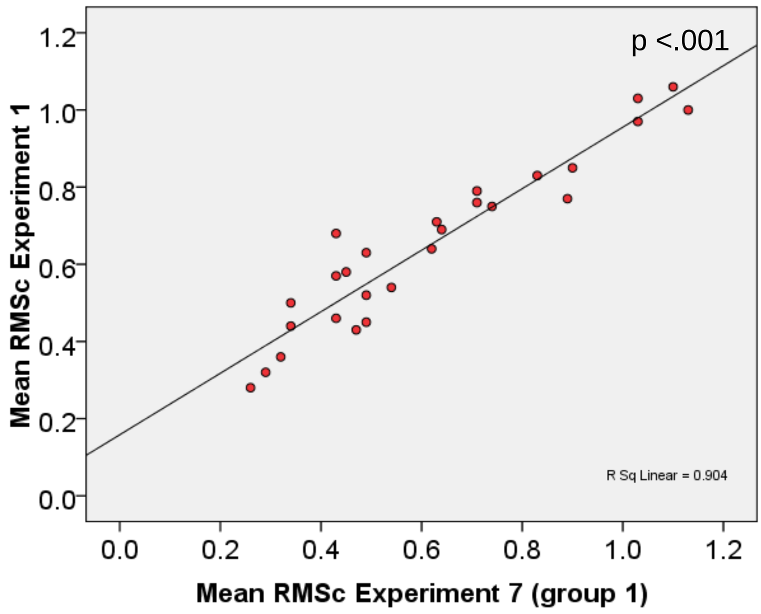
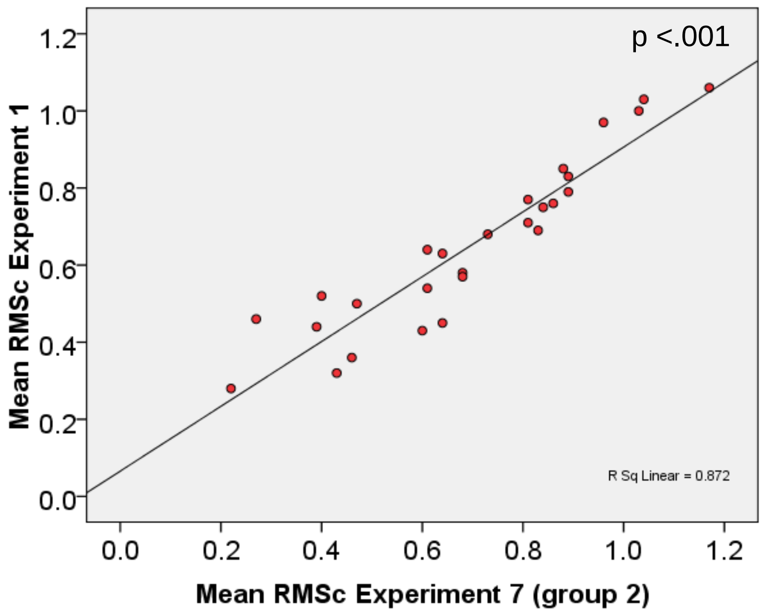


Figure 6.2: Scatter plot showing mean RMS_c scores for each of the 27 stimuli in both Experiment 1 and Experiment 7 (group 2: Immediate recall).



Appendix 15

Experiment 8: Analysis 1: Experimental reliability

Chapter six: effects of delay on memory for location. Experiment 8.

Analysis 1: Experimental reliability

As with the previous experiment, should the experimental findings presented within this thesis be reliable, then they should be easily replicated. In order to establish that the data elicited from the immediate recall condition of both experimental groups (groups 1 and 2) of Experiment 8 is comparable to data from the methodologically identical Experiment 2, contrasts were made between the overall recall performance, as indicated by mean RMS_c scores for each location tested.[37]

Location recall data and RMS_c values for each of the images are presented within Appendix 13, Tables 6.6-6.9. Reliability of responses across experiments for immediate recall was confirmed by a large correlation for the RMS_c scores for each of the 27 stimuli images between Experiment 2 and Experiment 8: group 1, (r (26) = .927, $p < .001$) and similarly for Experiment 2 and Experiment 8: group 2 (r (26) = .895, $p < .001$). As such, the experimental findings of Experiment 2 are shown to be replicable, and the data elicited from the current experiment robust. Data are presented within Figures 6.8 and 6.9, and location recall data and RMS_c values for each of the images are presented within Appendix 13.

[37] Data matrices including RMS_c values for each of the stimuli in Experiment 8 are presented within Appendix 13.

Figure 6.8: Scatter plot showing distribution of mean RMS_c scores for each of the 27 stimuli in both Experiment 2 and Experiment 8 (group 1: immediate recall).

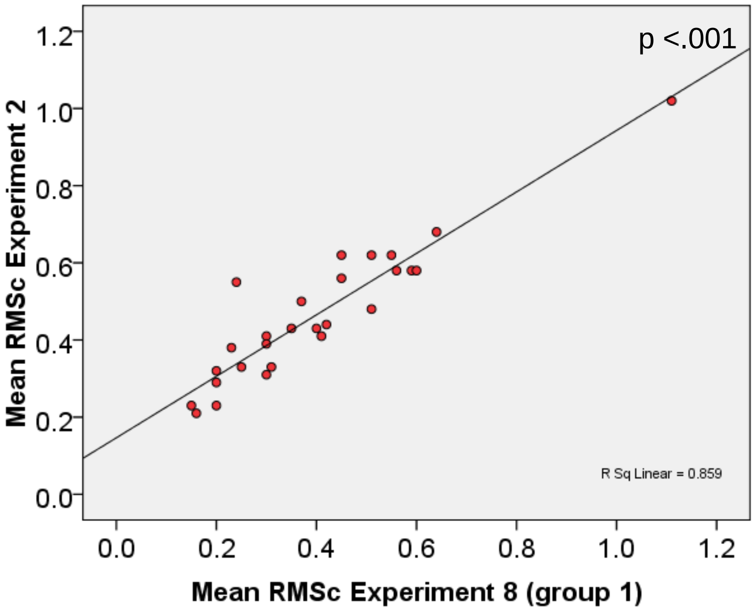
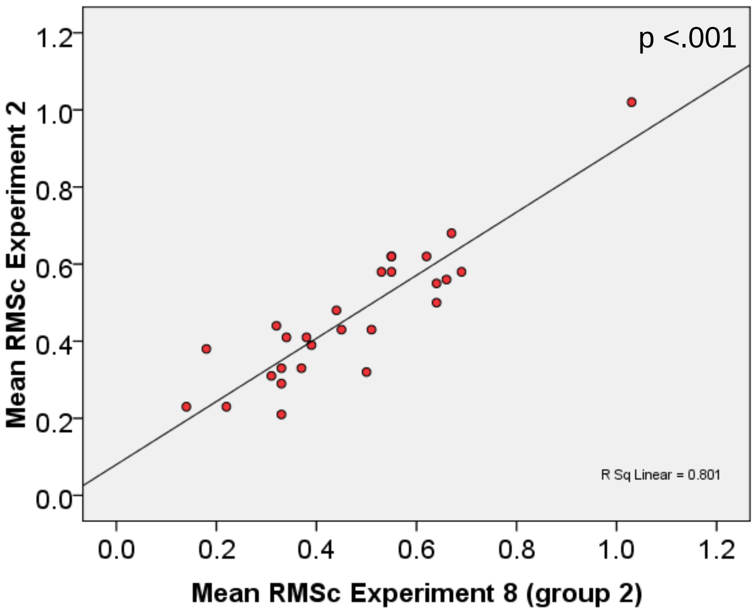


Figure 6.9: Scatter plot showing distribution of mean RMS_c scores for each of the 27 stimuli in both Experiment 2 and Experiment 8 (group 2: immediate recall).



Appendix 16

Electronic copies of HELM, Cluster Model and HELM2 on CD

Appendix 17

Ethical approval from Nottingham Trent University

NOTTINGHAM
TRENT UNIVERSITY

Helen Henshaw
Psychology (PhD Student)
York House

Professor Mark Davies
Chair: BLSS College Research Ethics Committee
Tel: +44 (0)115 8485600
Email: mark.davies@ntu.ac.uk

12 October 2007

Dear Helen

Thank you for you recent resubmission of your application (No. 2007/14) to the College Research Ethics Committee (CREC) on 24 September requesting ethical clearance for the project entitled: Exploiting spatial cognition in picture database design: Extraction of location memory in later inspection process. I am pleased to inform you that the CREC was happy to confirm that in its judgement there were no outstanding ethical concerns that required further discussion or exploration prior to data collection. The committee would like to wish you well in the completion of your project.

Yours sincerely

MDavies

Professor Mark N. O. Davies, CPscyhol.; CBiol, MIBiol.
Chair of the CREC

Appendix 17

Ethical approval from the University of Leicester

____
From: De Lillo, Dr C. [cdl2@leicester.ac.uk]
Sent: 05 June 2008 16:35
To: 'hlh11@le.ac.uk'
Subject: FW: PC_ethics2006 - Helen Henshaw

Dear Helen Henshaw,

Your project "Exploiting Spatial Cognition in Picture Database Design: Extraction of location memory in later inspection processes" has been approved by the Psychology Departmental Research Ethics Officer.

This e-mail is the official document of ethical approval and should be printed out and kept for your records or attached to the research report if required - this includes all undergraduate and postgraduate research.

We wish you every success with your study.

Carlo De Lillo
Psychology Departmental Ethics Officer

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