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Working memory, map learning, and spatial orientation: The effects of gender and encoding interference on the acquisition of survey knowledge

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Working Memory, Map Learning, and Spatial Orientation: The Effects of Gender and Encoding Interference on the Acquisition of Survey Knowledge

by

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Abstract

The present experiment investigated the effects of gender and encoding interference on the retrieval of spatial knowledge in a group of 24 male and 29 female students aged 18 to 43 (*M* = 23.33; *SD* = 5.78), with 12 to 20 years of education (*M* = 14.33; *SD* = 1.76). Each participant was tested individually on their ability to study a map containing 14 labelled landmarks in 1 of 3 interference conditions (i.e., no interference, articulatory suppression, and spatial interference). Then, the participant was blindfolded and asked to point to different aspects of the environment, varying in degrees of familiarity. Specifically, they were asked to indicate the orientation of 4 familiar cardinal directions (over-learned), 4 obscure cardinal directions (intermediate), and 10 landmarks (novel); the latter were cued verbally or visually. Response latency and accuracy were measured. Mixed ANOVAs were conducted with gender (2) and interference (3) as between-subjects factors and cue modality (2) or level of exposure (3) to the environment as within-subjects factors. The results revealed a marked decrease in orientation error and response latency with increasing degrees of familiarity (exposure). In addition, landmarks cued verbally yielded faster and more accurate responses than landmarks cued visually. Also, the presence of any encoding interference during the map study phase resulted in lower accuracy (higher error), especially in the recall of novel information. Lastly, verbal interference affected the accuracy of females to orient to landmarks more than males and the spatial interference yielded the opposite pattern. The findings are discussed in terms of models of working memory, spatial cognition, and gender differences.

Dedications

This project could not have been possible without my fiancée, Melanie Fielding, for her never-ending support, love and patience throughout this whole process; and my family, especially my parents, for having been great role models and mentors. They are my foundation of strength.

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Table of Contents

Abstract iii
Dedications iv
Acknowledgements v
CHAPTER
I. Spatial Cognition 1
II. Memory 9
III. Gender Differences 24
IV. Method
Experiment 28
Hypotheses 28
Participants 31
Materials 32
Procedure 34
Research Design 35
V. Results
Pointing Bias 36
Accuracy by Cue Modality 36
Accuracy by Level of Exposure 39
Response Time by Cue Modality 44
Response Time by Level of Exposure 45
VI. Discussion 48
References 56
Appendix A 68
Appendix B 69
Appendix C 71
Appendix D 73
Appendix E 75
Vita Auctoris 80

Spatial Cognition

Environmental cognition is the awareness of space, its layout, and components as well as the knowledge of the spatial relations between said components and the ability to interact with them for a purpose (Evans, 1980; Moore, 1979). Spatial cognition is a synonymous term denoting knowledge of one's location in a specific physical environment and the ability to traverse through, make decisions about, or find targets in the environment from a specific point of reference via the use of internal representations. Specifically, to perform any activity or formulate any thoughts about the environment, a person must first formulate and then use appropriate mental representations of that environment. Kuipers described it as "knowledge about the physical environment that is acquired and used, generally without concentrated effort, to find and follow routes from one place to another, and to store and use the relative positions of places" (Kuipers, 1978, p. 129).

Although there has been considerable research in the area of spatial cognition, the components making up different aspects of the constructs are still widely debated. The lack of agreement about universal definitions of constructs is partly due to the different theoretical backgrounds involved (i.e., Environmental and Cognitive Psychology, Geography, Computer Science, Neuroscience, and Animal Behaviour) and has resulted in convoluted interpretations of experimental findings. Consequently, there is still some uncertainty as to which components constitute spatial cognition or which strategies are used for orientation in the environment. Thus, the purpose of the present research project is to investigate the encoding processes involved in spatial orientation. In addition, this study will explore the effects of gender on the ability to identify the locations of specific environmental landmarks.

Cognitive Maps

Since Tolman's seminal study (Tolman, 1948), the term *cognitive map* has been used to denote a mental image of the physical environment. Although there appears to be a consensus in the literature regarding the presence of some type of internal representation necessary to achieve spatial orientation within an environment, controversy remains as to what exactly comprises a cognitive map and how the information it contains is accessed (Evans, 1980; Golledge, 1987). Some theorists believe a cognitive map is a pictorial depiction of space, where the properties of the representation closely resemble the characteristics of the physical object (e.g., "field map"; Tolman, 1948; see Golledge & Stimson, 1987). In this model, there is an analogy between the image and the actual environment, much like a cartographic illustration. In contrast, other theorists believe that a cognitive map is a descriptive representation of space, where the properties of the environment are coded in abstract, language-like, propositional symbols that do not resemble the original stimulus (Baird & Hubbard, 1992; Golledge, 1987). For instance, a cognitive map may be composed of many types of information related to the environment, such as object qualities, route descriptions, relative distances, number of turns, etc. Kosslyn (1980) believes that the format of a cognitive map is most likely a combination of propositional and analogue representations rather than one or the other. Also, Kolers (1983) proposes that these representations include a "sense" of space with an accompanying commentary, together in a conglomerate of spatial symbols and verbal information, which are essential to capture all the information available in a complex environment. Whatever their composition, cognitive maps have been postulated as the critical factors involved in spatial behaviour. A cognitive map can be viewed as the foundation necessary for deciding what spatial behaviour to perform and actually performing it (Downs & Stea, 1973).

Cognitive maps can be formed from many different perceptual and environmental inputs. For example, they can be generated from navigation in a real environment, viewing a map of an area, listening to spatial descriptions of an environment, being exposed to a virtual reality setting, manipulating objects mentally, remembering locations of objects, imagining oneself in a setting, pointing to a hidden target, etc. However, the processes of cognitive mapping and spatial orientation have been difficult to study because they pose a major problem in measurement; that is, how can a person's mental representation be measured for accuracy? To address this problem, many researchers have assessed the by-products and behavioural expressions of these visuospatial skills and abilities. Some examples include assessing the ability of participants to reproduce certain environments on paper via sketch maps, to find their way in novel environments (e.g., building, maze, town, forest) with minimal information, or to recall the sequence of landmarks present in a route (Blajenkova, Motes, & Kozhevnikov, 2005; Lipman, 1991; Lynch, 1960). Other approaches include measuring the number of errors performed during navigation, the reaction times in pointing to landmarks, and the accuracy in giving directions or drawing sketch maps (Golledge & Stimson, 1987). In general, spatial cognition studies have attempted to gauge what is remembered about the environment, the accuracy of its spatial layout, and the practical uses of cognitive maps (Gärling, Böök, & Lindberg, 1984).

According to Gärling et al. (1984), there are three interrelated environmental elements represented in cognitive maps—places, the spatial relations between places, and travel plans. First, the term *places* denotes basic components of the environment, such as streets, crossings, buildings, districts, and landmarks (i.e., "perceptually and symbolically salient places"; p. 10). The authors believe that place units are represented by name, perceptual characteristics, function, and spatial scale (e.g., is it a fire hydrant, house, or town?). Each place is accompanied by psychological attributes, such as pleasantness and aesthetic quality, much like what Golledge describes as *attitudes* (Golledge, 1987). This aspect of the cognitive map includes social biases and predisposed notions about an area (e.g., the neighbourhood is safe). Second, the *spatial relations* component of the cognitive map is comprised of inclusion criteria (e.g., the building is part of the neighbourhood), metric spatial relations (i.e., directions and distances from one place to another), proximity relations (e.g., the school is closer to the library than the hospital), and ordinal spatial relations (e.g., the tower and lake are farther than the church, but the lake is the farthest; Gärling et al., 1984). Lastly, the *travel plans* encoded in a cognitive map involve the specific steps necessary to get from one place to several other places via algorithms (Kuipers, 1978). This last component of the cognitive map presumably makes use of previously stored information regarding similar environments and is the interface between internal processes and actual behaviour (Downs & Stea, 1973; Gärling et al., 1984), much like the central executive in working memory (see Memory section below).

Acquisition of Spatial Knowledge

Many researchers (Siegel & White, 1975; see also Hart & Moore, 1973; Piaget & Inhelder, 1967) have postulated that spatial knowledge is attained through predictable stages (e.g., landmark, route, and survey knowledge) based on the individual's exposure and interaction with the environment over time. The first stage, landmark knowledge, consists of the visual characteristics of the environment that were deemed important and selected as landmarks because of their salient properties. Each landmark can be recognized or remembered as its own unit, much like object recognition, and landmark knowledge can be equated with object memory (Bosco, Longoni, & Vecchi, 2004; Kessels, Kappelle, De Haan, & Postma, 2002). In a sense, landmarks are visual configurations, which act as reference points in wayfinding (Golledge, 1987) and aid in maintaining a course as long as they are spatially significant (Cohen & Schuepfer, 1980). Route knowledge, on the other hand, includes important landmarks, the routes joining them, and the sequence of turns employed in wayfinding (e.g., right, straight ahead, etc.; Schmitz, 1999; Siegel & White, 1975). This stage is normally acquired sequentially via the learning of specific instructions on how to get from one place to another, and the resulting spatial representation takes on an egocentric perspective (Bosco et al., 2004; Thorndyke & Hayes-Roth, 1982). Lastly, survey knowledge involves a geocentric representation of the environment according to a Euclidian system; that is, cardinal directions and constant distances are used as coordinates to plot spatial relationships between specific positions in a system of routes from a global perspective (Golledge, 1987; Schmitz, 1999; Siegel & White, 1975). In this "map-like representation of the environment" (Bosco et al., 2004, p. 522), the person can localize landmarks and routes not readily available and can plan on the most efficient way of getting from one place to another. This type of knowledge includes the topographical characteristics of the environment and has information not available from direct experience but readily acquired from physical maps (Leiser, Tzelgov, & Henik, 1987; Thorndyke & Hayes-Roth, 1982).

Thorndyke and Hayes-Roth (1982) investigated the amount and type of spatial knowledge acquired from navigation and map learning in two groups of female participants. The participants in the map-learning condition had no previous exposure to the setting and were required to study the map until they could redraw it without errors. An additional 30 to 60 minutes of study time was also provided. The participants making up the navigation condition were employees who had worked in the building for different periods of time (i.e., 1-2 months, 6-12 months, and 12-24 months) and thus had different degrees of exposure to the environment. Each participant was required to perform five spatial judgments—route distance (i.e., distance from one point to the next via the hallways), Euclidian distance (i.e., straight line distance from one point to another), orientation (i.e., pointing to a target from the starting point), simulated orientation (i.e., pointing to a destination from an imagined starting position), and location (i.e., paper-based pin-pointing of a third location based on the positions of two others). The results demonstrated that with moderate exposure to the environment, the map-learning group outperformed the navigation group in judgments of Euclidian distances and location. However, with extensive exposure, the navigation group's performance on Euclidian tasks surpassed that of the map-learning group, supporting the hypothesis that a survey representation can be acquired with extended environmental experience to a route. In addition, the navigation group outperformed the map-learning group on tasks requiring route distance estimation and orientation to unseen targets. However, the authors only tested female participants and research shows that males use more Euclidian-based orientation, whereas females benefit more from route and landmark-based orientation (MacFadden, Elias, & Saucier, 2003). Thus, if Thorndyke and Hayes-Roth (1982) had included males in their participant pool, the experiment may have yielded contrasting results. Also, the orientation tasks did not require the participant to be blindfolded, which may have led to the use of walls and other extraneous stimuli to aid in orientation for the navigation group but not the map-learning group.

The general acquisition of spatial knowledge has been proposed to occur in a predictable hierarchical sequence, whereby the locations of landmarks are learned first, followed by the paths connecting them and finally, the incorporation of "anchor-points" into a representation of a larger area (e.g., town; Golledge, 1987; Siegel & White, 1975). However, some research has demonstrated that the process of development of spatial knowledge may take place in a less rigidly sequential manner, in which route and survey knowledge may be acquired simultaneously (Moar & Carleton, 1982; Rovine & Weisman, 1989). Moreover, others have suggested that survey knowledge can be acquired in short periods of time (e.g., 1-2 months of residence in a city; Gärling, Lindberg, Carreiras, & Böök, 1986) and that extended environmental experience does not necessarily increase spatial accuracy (Evans, 1980). In a pair of experiments, Lindberg and Gärling (1981a, 1981b) found that mental representations of unknown routes can be formed in short periods of exposure, leading to accurate formations of Euclidian spatial relations between points of reference. However, these representations did become more complete with extended environmental exposure, as evidenced by decreased errors and latencies in responses to direction and distance estimates. Thus, it is evident that the acquisition of spatial knowledge involves many different sequences depending on the circumstance. For example, when traversing an unknown environment without salient cues, it may be more effective to remember turns and distances, whereas wayfinding in cue-laden environments may yield strategies involving more landmark use.

As indicated by Downs and Stea (1973), one must take into account not only the involvement of environmental input into the cognitive mapping process, but also the "psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment" (p. 9). At first glance, therefore, it seems that there are several components necessary for successful spatial orientation; i.e., perception, attention, memory, and cognitive strategies (Golledge & Stimson, 1987). Perception is the sensation and interpretation of environmental stimuli as meaningful information (e.g., landmarks, turns, sounds, smells, etc.), and attention is required to select pertinent stimuli for further processing. The cognitive strategies are present to manage the perceptual and attentional processes as well as to select and integrate the stimuli with memory of past experiences in similar environments (e.g., successful wayfinding strategies, emotions, attitudes, etc.) into a composite mental system that validly represents the real space (i.e., a cognitive map). According to Rovine and Weisman (1989), successful navigators attend to the spatial nature of the environment, select cues associated with locations, and accurately place landmarks within an established spatial structure.

Although these internal components appear imperative for proper acquisition and use of spatial knowledge, there is a paucity of research in these areas. Instead, research has been geared towards the final product of spatial orientation with minimal emphasis devoted to the encoding and processing of spatial information. Apart from Downs and

Stea (1973), the few exceptions include Kosslyn (1980, 1994) and Lindberg and Gärling (1981a, 1981b), who alluded to the presence of different cognitive operations involved in spatial orientation. Kosslyn (1980, 1994) proposed the presence of separate components in mental imagery—a *visual buffer* coupled with *imagery operations*. The former is responsible for temporarily storing information whereas the latter is capable of generating, maintaining, and transforming images. Furthermore, in the studies mentioned above, Lindberg and Gärling (1981a, 1981b) found that navigation performance was impaired when participants performed a concurrent task (i.e., counting backwards) while walking along a path in an unknown featureless environment. When asked to estimate direction and distances to specific reference points, participants in the interference condition displayed less accuracy and longer response latencies than the participants who were allowed to process the information without disruption (Golledge, 1987). In a follow-up study, Lindberg and Gärling (1982) replicated the findings from their original study. Overall, these findings suggest the presence of a limited capacity cognitive structure that may be involved in cognitive mapping and navigation. Thus, the next section focuses on the encoding processes involved in memory, specifically, the separate subsystems involved in the encoding of phonological and visuospatial memory.

Memory

Memory is in use during all aspects of daily functioning, including wayfinding, recognizing objects, remembering facts, and comprehending language. The extent of memory involvement in daily functioning is so pervasive that it is unfathomable to contemplate any activity not involving some degree of memory processing.

The organization of memory has been a controversial topic in Cognitive Psychology. Memory was considered a unitary construct for many years, but the sophistication of memory functioning has suggested the presence of several memory systems (Atkinson & Shiffrin, 1968; Eysenck, 1993). Accordingly, memory is most likely composed of many different “kinds” or subtypes interacting in dichotomous relationships, where each kind is complementary to the other and together they exhaust the “superordinate category” (Tulving, 1972, p. 383). For example, memory can be divided into short-term and long-term categories, with further subdivisions such as verbal-visual within short-term memory and semantic-episodic within long-term memory. McCarthy and Warrington (1990) focus on the dichotomy found in material-specific memories, such as verbal and nonverbal memories. These two memories can be at play in different ways when traversing a specific environment. For example, these authors believe that verbal memory would be involved in remembering the names of people, streets, hotels, landmarks, districts, and neighbourhoods encountered on the way. On the other hand, recalling the appearances of people, buildings, their locations, views from different reference points, and routes connecting places would all require the use of nonverbal memory—specifically, visuo-spatial memory. In whatever manner memory is organized, however, there is a consensus that the process of memory generally entails the sensation of and attention to external stimuli, their input into the system, and their manipulation, storage and maintenance within the system as well as their retrieval at a later time. For the purposes of this review, memory will be partitioned into short-term/working memory and long-term memory, primarily focusing on the former due to its importance in the encoding process.

Short-term /Working Memory

In the Atkinson-Shiffrin model (see Figure 1; Atkinson & Shiffrin, 1968), the external stimuli first enter a modality-specific (e.g., auditory, visual, haptic, etc.) sensory buffer before being transferred into short-term memory (STM). These components of the system are not memory functions per se but rather different sensory perceptual processes. Attending to specific stimuli in the sensory register results in that information being “transferred” into STM (Atkinson & Shiffrin, 1968), whereas the sensory memory traces of unattended stimuli decay.

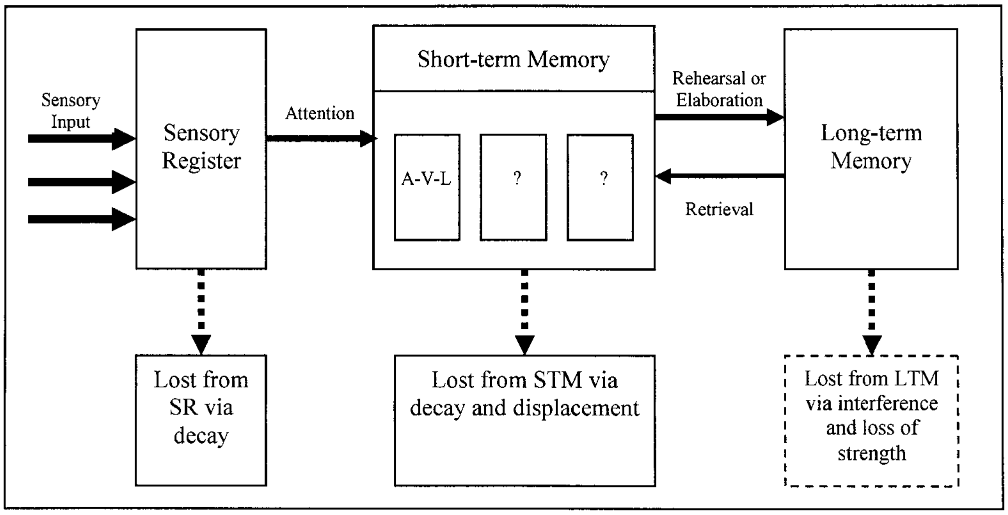


Figure 1: The multi-store model (adapted from Atkinson & Shiffrin, 1968).

STM is a limited capacity memory system (i.e., 7±2 meaningful units or chunks; Miller, 1956) that deals with information for a brief period of time (i.e., at most 30 seconds; Peterson & Peterson, 1959). However, the information can be maintained in storage longer via the use of rehearsal or repetition (Searleman & Herrmann, 1994). Atkinson and Shiffrin (1968) considered rehearsal to take part in a subcomponent of STM called the *auditory-verbal-linguistic* (A-V-L) store, which was responsible for encoding the information into an acoustic format no matter the original modality of the sensory input. The purpose of rehearsal is to prevent the information from decaying and to increase the probability that it will be transferred into long-term memory (LTM; Atkinson & Shiffrin, 1968). Unrehearsed material may also be forgotten via displacement, which occurs when more information enters STM than the capacity allows (Eysenck, 1993).

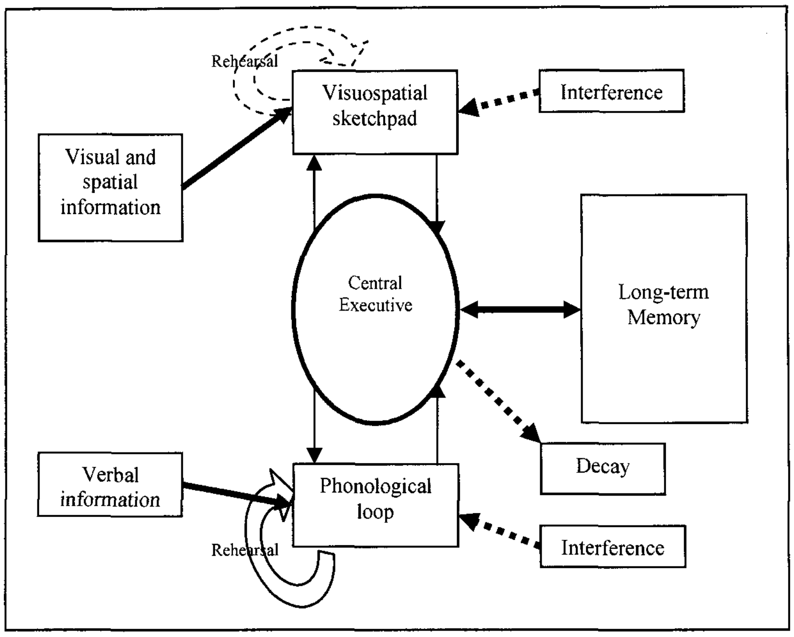


Figure 2: The working memory model of short-term memory (adapted from Baddeley, 1986).

In 1974, Baddeley and Hitch proposed a model of STM whereby information is actively manipulated via three subcomponents: the central executive, phonological loop, and visuospatial sketchpad (see Figure 2 above; Baddeley, 1986). This model, aptly named working memory (WM), involves the storage and processing of information, as well as its active retrieval from long-term storage for immediate processing. Within WM, the central executive is a material-independent processing system in charge of directing attentional resources to the information to be processed, as well as retrieving information from storage and working with it (Thorn & Gathercole, 2000). Much like

Norman and Shallice's (1986) *supervisory attentional system* (SAS), the executive control is most active in situations that are "difficult, novel, or have competing demands" (Feldman Barrett, Tugade, & Engle, 2004, p. 554). The other two material-specific systems (i.e., phonological loop and visuospatial sketchpad) are considered to be subservient to the central executive, which determines how the information is processed and whether their rehearsal systems are engaged (Baddeley, 1986).

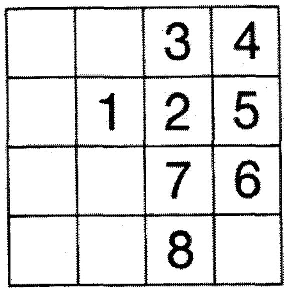
The Phonological Loop

The phonological loop has been the most researched component of the WM model. This component is thought to involve a phonological store containing memory traces which fade quickly (perhaps 2 seconds) if not refreshed via an articulatory control process using subvocal rehearsal (Baddeley & Hitch, 1994; Thorn & Gathercole, 2000). There is substantial evidence supporting the existence of the phonological loop and articulatory rehearsal. First, a list of similar sounding items will be more difficult to recall than one that is composed of dissimilar items—suggesting that items sharing phonemic properties tend not to stand out as distinct entities (i.e., *phonological similarity effect*; Baddeley, 1986). Second, when learning visually-presented verbal information, any speech (including foreign) will reduce the amount of recall. This finding is not due to attentional issues, as loud noises do not produce the same effect (i.e., *irrelevant speech effect*; Baddeley, 1992). Next, with increasing word length, there is a decrease in the likelihood that they will be recalled. This effect is due to the short duration of phonological store (1-2 seconds; Baddeley, 1986). Thus, recall is affected by the number of words that can be rehearsed in 2 seconds; so the longer the words, the fewer can be rehearsed before decay or displacement (i.e., *word-length effect*; Baddeley, 1992).

Lastly, the performance of irrelevant verbal utterances during the rehearsal of verbal information results in interference of the sub-vocal articulatory process, thereby reducing the amount of recall. This phenomenon, called *articulatory suppression*, occurs in acoustically-presented as well as visually-presented verbal information (Baddeley, 1986). Most WM research involves some aspect of articulatory suppression performed to disrupt activity in the phonological loop.

The Visuospatial Sketchpad

The visuospatial sketchpad is the system complementary to the phonological loop. This subcomponent of WM is responsible for the short-term storage and manipulation of visual and spatial information (Baddeley, 1986). Logie (1995) described this system as being composed of passive visual store (i.e., *the visual cache*), containing an image of the physical characteristics of the object, and an active spatial device (i.e., *the inner scribe*) responsible for refreshing the visual store and for planning movements. The key to this construct is that visuospatial information is maintained in the store and it decays if not refreshed. Early research testing this model demonstrated that performance on a visuo-spatial pursuit tracking activity resulted in more errors on a visual-spatial memory task when compared to an abstract memory task (Baddeley, Grant, Wight, & Thomson, 1975). However, it was unclear whether the result was due to interference on the visual or on the spatial component of the sketchpad. Thus, to discern between the subcomponents of the visuospatial sketchpad, Baddeley and Lieberman (1980) tested subjects on their performance on a 4X4 matrix memory span, while concurrently performing tasks involving either nonvisual (i.e., auditory) spatial stimuli or visual judgements with minimal spatial involvement. The participants were asked to imagine a 4X4 matrix and to repeat either nonsense statements or sentences with spatial material describing the locations of 1 to 8 digits in the matrix (Baddeley & Lieberman, 1980). The latter contained adjectives which allowed the sequence to be visualized as a path on the matrix, whereas the former contained different descriptors in place of the spatial adjectives (see Figure 3; Baddeley, 1986).



Spatial material	Nonsense material
In starting square put a 1.	In the starting square put a 1.
In the next square to the *right* put a 2.	In the next square to the *quick* put a 2.
In the next square *up* put a 3.	In the next square to the *good* put a 3.
In the next square to the *right* put a 4.	In the next square to the *quick* put a 4.
In the next square *down* put a 5.	In the next square to the *bad* put a 5.
In the next square *down* put a 6.	In the next square to the *bad* put a 6.
In the next square to the *left* put a 7.	In the next square to the *slow* put a 7.
In the next square *down* put an 8.	In the next square to the *bad* put an 8.

Figure 3: Matrix task used by Baddeley & Lieberman (1980; adapted from Baddeley, 1986).

The auditory spatial disruption task employed by Baddeley and Lieberman (1980) required a blindfolded participant to track a photosensitive sound-emitting pendulum with a flashlight. In this task, the participant was instructed to track the swinging pendulum with a hand-held flashlight, which resulted in the sound changing from a steady tone to a discontinuous bleep when the light was shone on it (Baddeley & Lieberman, 1980). The visual disruption condition required the subject to judge blank screens in terms of their brightness. When the brighter of the two screens was shown, the participant was required to press a single key. The results demonstrated that auditory spatial disruption resulted in impaired performance on the visuo-spatial task but not on the nonsense material task, whereas the visual disruption task yielded non-significant findings (Baddeley & Lieberman, 1980). Thus, the authors concluded that information in the visuospatial sketchpad is coded in a spatial, rather than visual, manner (Baddeley, 1986; Baddeley & Hitch, 1994). However, the visual disruption task employed by Baddeley and Lieberman (1980) may have been too simple to elicit any type of interference. Logie (1986) demonstrated that having the participant simply look at a series of squares with coloured patterns disrupted word recall when the list was processed via an image-based mnemonic but no effect was observed when the list was memorized by rote (as cited in Quinn, 1991 and Baddeley & Hitch, 1994). Furthermore, several researchers have demonstrated that arm movements, haptic exploration and visual-motor responses result in lower recall of visuospatial information when the tasks are performed concurrently or shortly after the primary visuospatial task (Allen, Marcell, & Anderson, 1978; Quinn, 1991; Yuille & Ternes, 1975). Thus, coding in the visuospatial sketchpad can be disrupted by information emerging from any sensory modality (e.g., auditory, visual, and haptic) as long as that information is spatial in nature.

Research on the WM Model

There have been two main approaches in the way researchers employ the concept of WM (Baddeley & Hitch, 1994). The first track focuses on the abilities of WM as a system that simultaneously stores and manipulates information (i.e., the central executive); thus research is geared towards the psychometric aspects of WM in which the adeptness to perform tasks with combined processing and storage demands predicts individual differences in cognitive skills (e.g., reading, reasoning, etc.; Baddeley, 1992; Feldman Barrett et al., 2004; Kessels et al., 2002; Shah & Miyake, 1996). The second approach deals mostly with "dual-task" methodology in order to analyze the structure of WM. Within this course, the participant engages in a primary task while performing a secondary task concurrently or immediately after the primary task. Thus, the fractionation of WM is studied via tasks that encumber either of the subsidiary systems in a specific material. Visual imagery in the visuospatial sketchpad is normally disrupted by the presentation of irrelevant visual material, by having the subject perform eye movements, or by having them track a spot of light or sound during learning (Baddeley, 1986, 1992). The key to these research methods is that materials which do not interfere with one another should theoretically be represented by different encoding paths or memory codes, whereas those that do are presumably competing for the same limited processing or storage capacity.

Dual-task Experiments

Some researchers have attempted to study the separability of the slave systems in WM by administering modality-specific (i.e., auditory and visual) interference tasks concurrently with material-specific (i.e., verbal and spatial) tests. However, the key to the two slave systems rests in the type of material stored and manipulated rather than through which sense the information enters (Allen et al., 1978; Baddeley & Lieberman, 1980; Pellegrino, Siegel, & Dhawan, 1976). Thus, equating auditory processes with verbal information and visual processes with spatial memory are inappropriate practices.

When performing dual-task experiments, many researchers have used concurrent tasks composed of matrices to manipulate visuospatial information, and counting or repeating words to access the phonological loop. These techniques have been shown to interfere with encoding (Allen et al., 1978; Baddeley & Lieberman, 1980; Palladino, Mammarella, & Vecchi, 2003; Murray & Newman, 1973; Yuille & Ternes, 1975). Murray and Newman (1973) found that when the retention interval is filled with a visual task such as copying, forgetting is more evident for the location of objects, whereas when a concurrent verbal task such as counting is employed, the identity of the objects (i.e., triangle, square, and circle) is more easily forgotten. In addition, tasks requiring a combination of activities such as copying and counting yielded lower scores, perhaps due to the demands on attention. Thus, it is apparent that there are two types of encoding, namely visuospatial and verbal, which are susceptible to material-specific interference tasks. In a similar study requiring the subject to identify and locate letter pairs while performing a concurrent task (i.e., visual, auditory or kinaesthetic), Allen et al. (1978) demonstrated that material-specific tasks are adequate to elicit differential interference effects on information processing, indicating the presence of dual encoding. In addition to visual and verbal interference, the authors confirmed that performing a kinaesthetic task results in increased forgetting when paired with a visuospatial primary task. This effect suggests that encoding in the visuospatial sketchpad can be disrupted by a nonvisual, yet spatial activity. Thus, the type of input sensory modality is not as crucial as the manner in which information is coded and processed within WM. Lastly, Yuille and Ternes (1975) showed that even within material-specific interference tasks, those with increasing demands on attention yield lower retention scores. All in all, the results indicate the presence of material-specific interference patterns and differential attention demands as contributors to low retention scores on WM tasks.

Other investigators have focused their research endeavours on dividing the visuospatial sketchpad into subcomponents, such as passive storage versus active processing (Cornoldi, Rigoni, Venneri, & Vecchi, 2000; Vecchi, Monticellai, & Cornoldi, 1995) and colour (ventral) versus spatial (dorsal) processing streams (Mohr & Linden, 2005). Passive storage is associated with retaining the physical properties of the material without making any changes to it, whereas active processing requires the manipulation or reorganization of information, leading to the creation of sequential images or to the assimilation of new images with old ones for a more complete product (Logie, 1995). Vecchi and colleagues (1995) studied the ability of congenitally blind and blindfolded sighted participants to tactually memorize the locations of targets on a 5X5 matrix while following directional statements either independently (phase 1) or concurrently (phase 2). The results showed that both groups performed equally on recalling the location of targets (i.e., passive) but the sighted group performed better on path recall (i.e., active), especially when the number of directional statements increased substantially. This finding implies that the blind subjects may have encountered difficulty in imagining or "seeing" the whole path and supports the notion of partitioning of visuospatial working memory into a passive store and an active imagery process. In another experiment aimed at gauging the capacity of the visuospatial sketchpad, the authors demonstrated that interference effects are readily provoked by material-specific tasks, but this specificity is lost when the interference exceeds attentional capacity. The results indicate that the capacity of visuospatial working memory cannot be simply defined by the number of chunks (i.e., matrices) but also requires consideration of the complexity of each chunk (i.e., number of targets).

Lastly, other researchers have primarily studied the WM processing in wayfinding and route-learning (De Beni, Pazzaglia, Gyselinck, & Meneghetti, 2005; Garden, Cornoldi, & Logie, 2002). In a recent study, participants were tested on their ability to recall and gather inferential information from text (De Beni et al., 2005). The authors demonstrated that recall of spatial text is more readily disrupted by performance of a spatial concurrent task (i.e., tapping) than via articulatory suppression, whereas recall of nonspatial text demonstrated the opposite effect (i.e., worse performance with articulatory suppression). Furthermore, the authors found that even when the responses were answered correctly, slower reaction times were noted when there was a concurrent task present that affected the specific encoding process (e.g., spatial text-spatial interference). Additionally, performing either concurrent task yielded lower recall than the control condition when paired with spatial text, which the authors attributed to articulatory suppression acting on the processing of verbal material (i.e., text) rather than on the content of the text (i.e., spatial). However, the reduced recall could be explained by the fact that the spatial text was more convoluted, nonsensical, and longer than the nonspatial text. Finally, Garden and colleagues (2002) investigated the ability of subjects to either learn a route from a map or to learn a list of nonsense words while either saying a sequence of syllables (e.g., "ba"; articulatory suppression) or tapping sequentially on a keypad (i.e., spatial tapping). The presence of either concurrent task resulted in more errors than in the control condition, but the concurrent task effects differed depending on the material presented. Articulatory suppression affected the recall of nonsense words. In the route-learning task, spatial tapping affected recall more than the articulatory suppression but the latter was nonetheless still disruptive to some degree. This finding indicates that some subjects may have adopted a verbal encoding strategy or that verbal encoding is in use to support spatial encoding. In extending their experiment to a real-life version of the map which required the participant to reproduce a route after having followed the experimenter, the authors demonstrated that there were no material-specific differences related to concurrent tasks. However, as found previously, the presence of any concurrent task yielded more errors (i.e., *direction errors* and *inaccuracies*) than the control condition, suggesting encumbered attentional resources. Before performing the tasks, the participants completed a questionnaire to assess their preferential navigation style, mental representations of space, and strategies for acquiring spatial knowledge. Further analyses of the results established an interaction between the level of spatial ability (i.e., high or low survey knowledge) and the type of concurrent task performed during navigation—that is, the high survey knowledge group displayed more errors, longer pauses, and more inaccuracies when engaged in spatial tapping than articulatory suppression, whereas the reverse was true for the low survey knowledge group. This finding indicates that the low survey knowledge group did not rely on survey-like navigation, but rather on verbal strategies when traversing the route. Also, because the results between the first experiment and the second are comparable, it is apparent that studying wayfinding from maps is possible, although real-life settings contain a multitude of cues which may prompt the use of different encoding strategies. However, both experiments were incompatible in their number of participants and in their gender make-up (i.e., 13 males and 52 females for the first experiment and 7 males and 23 females for the second). This confound is critical to the interpretation of the results because studies have suggested the presence of gender-specific encoding strategies in wayfinding (Lawton & Kallai, 2002; Saucier, Bowman, & Elias, 2003; Saucier, Green, Leason, MacFadden, Bell, & Elias, 2002), which may account for the discrepancies found in the results.

Unfortunately, most of the aforementioned studies have several methodological drawbacks. For example, some studies did not account for practice effects, whereas others had too few participants to draw firm conclusions. In addition, when using different routes, matrices, and lists of words, it was not made clear whether the alternatives were equivalent in their level of difficulty. Lastly, the most serious confound was that none of the studies accounted for gender effects in WM processing and spatial cognition. Gender differences have been shown to be important sources of variability in this domain of cognition (Kimura, 1999). When there was mention of controlling for gender effects, there was a significant discrepancy in the female-to-male ratio of participants (e.g., 13 males to 52 female; Garden et al., 2002). Thus, any studies geared at examining spatial cognition must take into account gender differences in wayfinding strategies and their effects on cognitive maps.

Long-term Memory

There is a consensus in the literature regarding the presence of a long-term storage component in memory (for a review, see Searleman & Herrmann, 1994). Long-term memory (LTM) is stable, long-lasting, and has a virtually unlimited capacity (Eysenck, 1993). However, there is less agreement about the organization of LTM. Multiple modality-specific LTM systems have been proposed (Atkinson & Shiffrin, 1968). Other authors have postulated further divisions in the type of information stored, such as semantic or episodic (Tulving, 1972). Episodic memory involves the remembering of specific events, whereas semantic memory involves general knowledge of concepts and their interrelations from an allocentric perspective. The former is at work when encountering unique personal episodes such as novel stimuli connected by time and place, whereas the latter includes over-learned situations and the meanings of terms. It has been proposed that the acquisition of spatial knowledge begins in an episodic manner and, with extended exposure to the environment, progresses to the formation of semantic representations in memory (Gärling et al., 1984; Siegel & White, 1975). Furthermore, the information within episodic memory has been proposed to contain "records of sensory-perceptual processing derived from working memory" (Conway, 2002, p. 55). Also, Tulving and Thomson (1973) indicate that memory can only be retrieved if it is adequately encoded. More specifically, recall is facilitated when the retrieval context is congruent with the encoding context (i.e., *encoding specificity principle*). In other words, retrieval cues are only effective if the information they contain was encoded as part of the original information, including its physical properties (Dean, Yekovich, & Gray, 1988). Thus, a piece of information can only be retrieved by cues comprising some aspect of the original encoded information. If the cue was never encoded, it will not aid in retrieval.

Unlike STM, information in LTM does not decay. Forgetting occurs due to the inability to retrieve a trace from memory. Apart from the cue not having been originally encoded, retrieval difficulty is caused by one of two types of interference—proactive and retroactive (McGeoch, 1932). As the names indicate, proactive interference results when information learned first interferes with information learned later, whereas retroactive interference results from new information eclipsing the old one (Keppel & Underwood, 1962; Wickens, Born, & Allen, 1963).

Gender Differences

Gender differences have been reported in many cognitive domains (Kimura, 1999; see also Geary, Saults, Liu, & Hoard, 2000; James & Kimura, 1997; Kimura & Clarke, 2002; McGlone, 1980; Moffat, Hampson, & Hatzipantelis, 1998; Tottenham, Saucier, Elias, & Gutwin, 2003; Weiss, Kemmler, Deisenhammer, Fleischhacker, & Delazer, 2003). In general, males outperform females in tasks requiring target-directed motor skills, mental rotations of objects, mathematical reasoning, problem solving, and other spatial abilities (e.g., disembedding a figure from a complex arrangement, maze learning, etc.). Conversely, females outperform males in tasks requiring fine motor coordination, memory for object displacement, mathematical computations, perceptual speed (e.g., matching items), spelling, verbal fluency, and verbal memory.

Within the spatial domain, males have been reported to perform better than females in tasks of spatial ability (e.g., mental rotations), but it is unclear whether this trend extends to tasks of spatial orientation (for a review, see Coluccia & Louse, 2004). As mentioned above, spatial orientation involves many complex skills used for locating oneself with respect to specific points of reference or to a system of spatial coordinates. In this domain of spatial cognition, successful orientation may depend on different strategies and uses of cognitive maps. In fact, there are converging lines of evidence suggesting that males and females use different kinds of information in the environment. Galea and Kimura (1993) found that males and females tend to provide different information when giving directions about a novel map from memory, such that males recall more cardinal directions and distance information than females, whereas females outperform males in memory for the identity and location of landmarks. In other map-learning studies, men reported more cardinal directions and distances (i.e., Euclidian strategy), whereas females included more landmarks and left-right turns (i.e., route-based strategy) when giving directions (Dabbs, Chang, Strong, & Milun, 1998; MacFadden et al., 2003). In addition, MacFadden and colleagues (2003) tracked each participant's eye movements as they studied the map and found no gender differences in map-scanning approaches, which suggests that males and females are attending to the same information but they are processing it differently. The spatial strategies found in map-learning studies are consistent with self-reported wayfinding strategies (Lawton, 1994, 1999; Lawton & Kallai, 2002) and have been replicated in real-world navigation tasks (Saucier et al., 2002) and in tasks requiring navigation in a 3-D model of a town (Hund, 2004). Furthermore, Saucier et al. (2002) demonstrated that females made fewer errors than males when using route-based strategies in wayfinding whereas the opposite trend was observed when the participants were instructed to follow Euclidian directions (i.e., men performed fewer errors than women). Lastly, Hund (2004) showed that participants employing cardinal directions (e.g., go west on Lakeshore Ave.) were significantly faster and more accurate than those following landmark directions (e.g., go to the library). Consequently, males performed faster and more accurately than females on this task.

Other studies have yielded less concrete findings regarding gender-specific wayfinding strategies. Sholl, Acacio, Makar, and Leon (2000) reported a male tendency to orient to south (Euclidian strategy), but no gender differences associated with the ability to orient to distant landmarks. In an indoor wayfinding task, however, Schmitz (1999) found that women recalled more landmarks (e.g., garbage bins, chairs, etc.), whereas men employed a mixture of landmarks and route directions (e.g., right, straight ahead, etc.) in their textual or sketch-map representations of a navigated route. Moreover, she found no gender differences in the number of errors performed during navigation, but reported that men traversed the route segments faster than women. Conversely, Postma, Jager, Kessels, Koppeschaar, and Van Honk (2004) found that women were less precise in distance estimations and made more false turns than men during wayfinding. In this task, no gender differences were observed in the ability to recall landmarks or to place them in the proper locations throughout the route. Although this result does not support Galea and Kimura's (1993) finding of a female advantage in landmark knowledge, the discrepancy between the studies may be due to the uneven make-up of Postma et al.'s participant groups. In Postma et al.'s (2004) study, 9 males traversed route A and 23 males route B, whereas the female participants performed both routes in a counterbalanced fashion. Thus, the fact that all females performed both routes could have resulted in interference effects in learning the routes and landmarks. Overall, these findings suggest that males may encode their environment spatially (i.e., Euclidian-based) whereas females may encode it verbally (i.e., landmark-based), which is not unexpected in light of the gender differences reported in language skills and spatial abilities (Kimura, 1999). To investigate the involvement of language and spatial skills in wayfinding, Saucier et al. (2003) performed a dual-task interference study, whereby participants were instructed to either repeat the days of the week (i.e., articulatory suppression) or perform a sequential tapping task (i.e., visuospatial interference) as they completed a wayfinding task following two types of instructions (Euclidian versus landmark-based). The stimulus involved a 10x10 grid with each cell containing 1 of 10 symbols representing common English nouns (e.g., fish; see Figure 4).

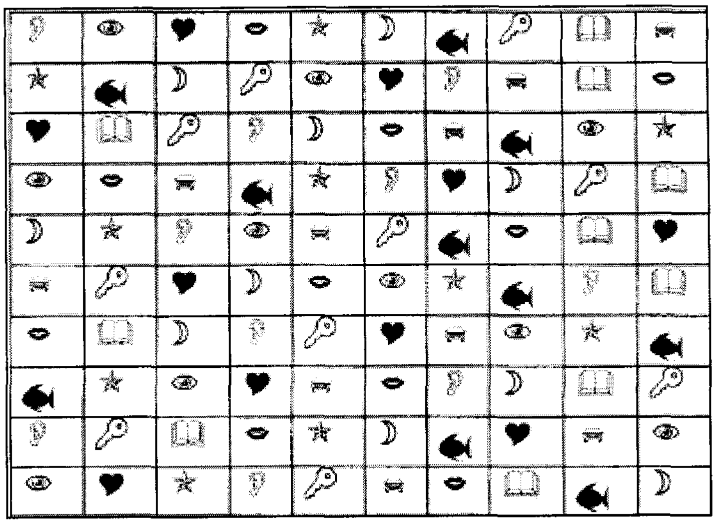


Figure 4: Grid used by Saucier et al. (2003).

The Euclidian instructions consisted of cardinal directions and distances in number of blocks (e.g., "move three blocks west and turn north"), whereas the landmark-based instructions required the use of the symbols and turns (e.g., "go up to the 🐟 and make a left"). In this task, men performed best when they were engaged in articulatory suppression while following Euclidian instructions. In contrast, women performed best when following landmark-based instructions while partaking in the spatial interference task. All in all, articulatory suppression selectively impaired women's ability to complete the navigation task no matter the type of instruction employed, whereas the presence of any concurrent task did not selectively affect the ability for men to execute the navigation task. Although innovative and informative, this study had some drawbacks. First, it is unclear whether the same results would be observed in a more ecologically valid paper-and-pencil task. Moreover, it has been suggested that males may have a greater capacity for manipulating information in visuospatial working memory (Vecchi & Girelli, 1998). Thus, due to the lack of a control group in Saucier et al.'s (2003) study, it is uncertain whether the findings resulted from differential responses to task difficulty.

Method

Experiment

In order to investigate the encoding processes involved in spatial orientation, the following experiment requires the participant to study a map while performing one of two concurrent tasks designed to encumber one of the slave systems in WM. The auditory spatial task is designed to interfere with visuospatial working memory (VSWM), whereas the articulatory suppression task is designed to interfere with verbal working memory (VWM). Furthermore, the targets involving novel stimuli (i.e., landmarks) are cued visually and verbally (i.e., within subjects) in order to test for encoding specificity effects. This study is also geared towards investigating any differential effects between novel, intermediately-learned and over-learned stimuli. Novel stimuli are hypothesized to be represented in episodic memory whereas over-learned stimuli are postulated to correspond to semantic memory. Finally, males and females are assessed for differential encoding strategies. The measures used include pointing accuracy (i.e., magnitude of orientation error) and response time.

Hypotheses

H_1: Gender Differences

It is hypothesized that accuracy and response latency associated with the present blindfolded pointing task will differ by gender. However, the performances within each study group will depend on the type of encoding interference used during the study phase as well as the type of cue modality used during retrieval.

H_{1a}: Encoding interference. The spatial interference condition should selectively impede the expected spatial encoding in men, resulting in lower accuracy and longer

response times than in women. On the other hand, the verbal interference condition should selectively impede verbal encoding typically employed by women, resulting in lower accuracy and longer response times than in men (see Figure 5).

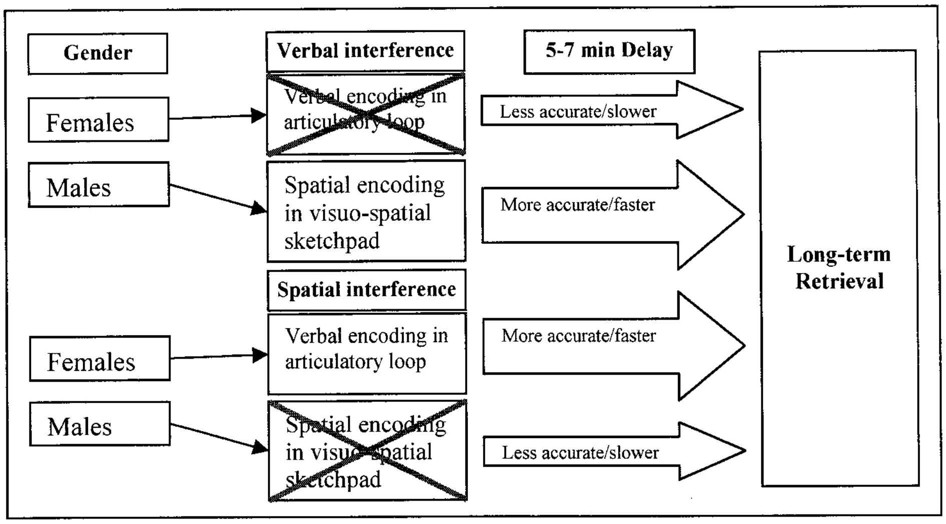


Figure 5: Illustration of hypothesis 1a.

H_{1b}: Cue modality. Because women typically rely on verbal encoding strategies (i.e., landmark and route knowledge), better accuracy is predicted with verbal rather than visual cues in keeping with the encoding specificity principle. Conversely, men are more likely to use visuospatial encoding strategies (i.e., survey knowledge) and thus are predicted to benefit more from visual than verbal cueing (see Figure 6).

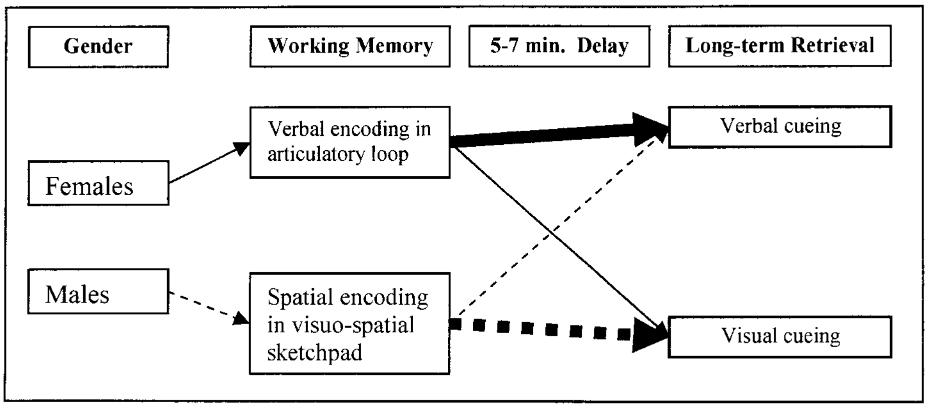


Figure 6: Illustration of hypothesis 1b.

H_2: Overall Effects and Interactions

H_{2a}: Level of exposure. Accuracy is expected to vary with degree of exposure, with responses to over-learned stimuli (e.g., south) resulting in more accurate scores than those associated with novel stimuli (i.e., landmarks). Lastly, novel stimuli are predicted to be associated with slower response times, and over-learned stimuli with faster response times (see Figure 7).

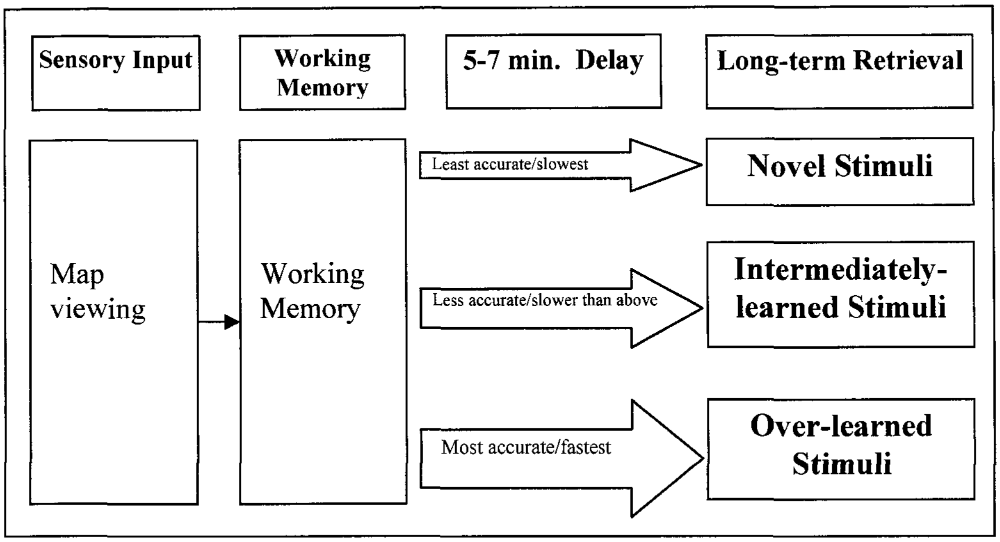


Figure 7: Illustration of hypothesis 2a.

H_{2b}: Encoding interference. As per Tulving (1972), novel stimuli are hypothesized to be represented in episodic memory whereas over-learned stimuli are postulated to correspond to semantic memory. Thus, the presence of any encoding interference during the study phase is expected to affect the orientation error and response latencies associated with novel stimuli but not the orientation error and response latencies associated with intermediately-learned or over-learned stimuli.

H_{2c}: Disparately difficult concurrent tasks. If the concurrent tasks vary in difficulty level, accuracy and response times are predicted to reflect their difference. Specifically, if the spatial interference condition is more difficult than the articulatory

suppression condition, the control (no interference) condition should yield accuracy scores significantly better than the concurrent task conditions, with the spatial interference condition yielding the worst results (see Figure 8).

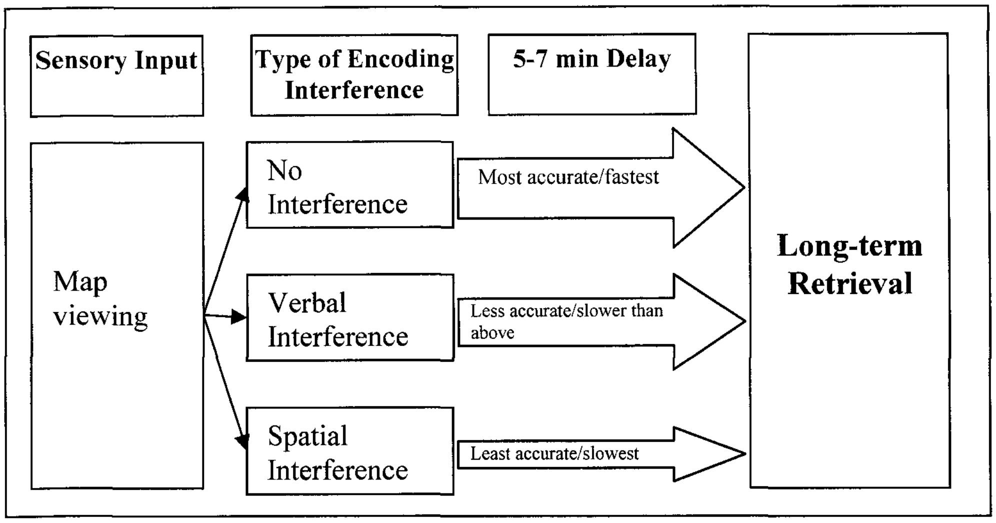


Figure 8: Illustration of hypothesis 2c.

Participants

The participants were 59 students. Four participants were removed due to motivational issues observed during testing (e.g., the participant indicated that they were merely present to earn the bonus mark). Of the remaining 55 participants, 1 male was removed due to an extensive history of closed head injuries and 1 female was removed post statistical analyses because she was an outlier in almost all categories, as explored by descriptive statistics, scatterplot diagrams and Stem and Leaf plots. Thus, the participants involved in this study were 53 (24 male, 29 female) between the ages of 18 to 43 and ranging in education from 12 to 20 years. There were no significant differences in the age of males ($M = 23.92$, $SD = 5.76$) and females [$M = 22.85$, $SD = 5.84$; $t(49) = 0.65$, $p = .517$], or in the years of education in males ($M = 14.57$, $SD = 2.21$) and females [$M = 14.14$, $SD = 1.30$, $t(33.97) = 0.81$, $p = .424$].

The participants were randomly divided into three independent groups according to the type of encoding interference they received while studying a novel map—(1) no interference (8 male, 9 female); (2) verbal interference (8 male, 10 female); and (3) spatial interference (8 male, 10 female). A one-way between-groups analysis of variance yielded no significant differences for the three groups in age [$F(2,48) = 0.37, p = .693$] or years of education [$F(2,48) = 0.59, p = .561$]. See Table E1 in Appendix E for descriptive information.

The participants were recruited from the Research Participant Pool at the University of Windsor. Each participant was eligible to receive 1 bonus mark towards a specific course and a ticket for a raffle with a $60 prize.

Materials

A stopwatch, a metronome, a swivel chair secured to the floor, a laser pointer, a laser level and tripod system, a laptop computer with digital auditory stimuli, five speakers with a five-channel analog switcher, a map, a blindfold, five picture cue cards, and trial markers were used to conduct this experiment.

Map

A 17” by 22” black-and-white laminated paper map of a fictitious town was used. A novel map was employed to eliminate the effects of prior exposure on landmark recall and spatial orientation. The map included cardinal indicia, a river crossing through it, a lake on the northeast corner, a railway track on the west border, a bridge in the centre, unlabeled streets and 14 pictures of prominent landmarks along with their respective names (e.g., courthouse, lighthouse, etc.). The landmarks were equally dispersed in all four quadrants. There was a “star” sticker denoting the centre of the map. The streets of the map were arranged in an irregular format (i.e., non-grid) to avoid facilitating the acquisition of survey knowledge via a route-learning strategy (Gärling et al., 1986; Thorndyke & Hayes-Roth, 1982). Because the map was fictitious, exposure to the campus was irrelevant; thus, allowing any student to participate. See Figure A1 in Appendix A for a representation.

Auditory Spatial Stimuli

The auditory stimulus consisted of a 100 ms tone administered at 2 s intervals for 60 s (i.e., 30 presentations). The tone was created using Adobe Audition 1.5 and emitted from a Sony VAIO PII laptop computer. The digital signal coming from the laptop was redirected, in a randomized pre-set sequence, via a customized analog switcher to one of five speakers set in a semi-circular array. The azimuths of the speakers were spaced equidistantly beginning at 90 degrees counter clockwise from north (i.e., speaker 1, left) and progressing clockwise in 45-degree intervals until 90 degrees clockwise from north (i.e., speaker 5, right). In other words, they were placed at -90°, -45°, 0°, 45°, and 90° from north, where the minus indicates a counter clockwise rotation. See Figure A2 in Appendix A for a representation. The sequence of administration was created in such a manner so as to minimize the number of adjacent tone emissions (see Study phase in Appendix D).

Picture Cue Cards

Five pictures of specific landmarks (i.e., lighthouse, mansion, courthouse, factory, and clock tower) were presented as stimuli for the visual cueing condition. These landmarks were selected in a semi-random manner so as to maximize their representation from all four quadrants of the map. They were 8.5" by 11" in size, laminated, and arranged in a landscape orientation. See Appendix B for scaled down representations of the picture cards.

Procedure

All participants were first asked to read and sign informed consent forms. Each participant was tested independently in a windowless room. The first part of the experiment required the participant to study the map for one minute (see Appendix C). The participants were assigned to one of three interference conditions while learning the map (described below). The assignment of participants to test conditions was done in a manner so as to spread them evenly between cells to minimize clustering of individuals at similar times during the day (e.g., participants from the verbal interference condition were not all administered the test in the mornings). The experimenter was always located to the right of the participant.

At the end of the study phase of the experiment, the participant was asked to sit on a swivel chair in the middle of the room and was blindfolded. The swivel chair was fixed to the floor in the same place for every administration, so as to minimize recording error. The purpose of blindfolding the participant was to prevent the use of visual cues and thus maximize reliance on proprioceptive spatial orientation (e.g., Berthoz & Viaud-Delmon, 1999; Siegler, 2000; Viaud-Delmon, Ivanenko, Berthoz, & Jouvent, 1998). The participant received visually, physically and verbally guided practice on how to properly point the laser pen, how to quickly remove and replace the blindfold, and how to rotate on the swivel chair effectively. Then, the participant was told to imagine he or she was in the middle of the map, where the “star” was, facing "north" and asked to point with the laser pen to specific aspects of the environment. There were 4 sets of 8 cardinal directions (i.e., N, S, E, W, NW, NE, SW, and SE) and 10 specific landmarks. Two sets of cardinal directions were administered before the landmark cues and two sets were administered after. Each set of cardinal directions began with a different direction (i.e., counterbalanced) so as to account for a possible order-of-administration effect. Each participant received half of the landmark cues verbally (such as, "where is the clock tower?"), whereas the other half of the landmarks were cued (visually) in the form of pictorial cues (such as, "where is this"). For each pictorial cue, the participant was briefly shown the image (~1 s) and immediately asked to blindfold themselves prior to rotating and pointing. Participants were always instructed to respond as fast as possible, without sacrificing accuracy. For each response, the examiner timed the latency and then put a mark on the wall with the appropriate trial number. At the end of every test cue, the participant was brought back to face “north” and the procedure was repeated. The participant was always brought back to “north” because responses are facilitated when the testing perspective matches the frame of reference acquired during the study phase (Shelton & McNamara, 2004; Waller, Montello, Richardson, & Hegarty, 2002). After the participant completed all the trials, was debriefed and sent on their way, the examiner measured all the trial angles with the laser level system.

Research Design

Study Conditions

There were six study conditions based on type of encoding interference and gender. The interference conditions were designed to encumber working memory; thus, selectively hindering the encoding process. The verbal interference condition required that the participant recite the days of the week sequentially once every two seconds as guided by a metronome. In the spatial interference condition, the participant had to point to the location of a tone emerging from five speakers located in front of him or her. The last condition involved no encoding interference and made up the control group.

Dependent Variables

Response time. Response time was defined as the time necessary to initiate pointing motion and confirm the location of a cued target.

Accuracy. Accuracy was determined by the absolute difference, in degrees, between the subject's response and the actual bearing of a cued target (i.e., landmark or cardinal direction).[1]

Results

Pointing Bias

A two-way between-groups analysis of variance was conducted to explore the impact of gender and type of encoding interference on the ability to point straight ahead (i.e., north). The deviations in pointing to north were averaged across four trials. There were no main effects for gender [$F(1, 52) = 0.23, p = .633$] or type of interference [$F(2, 52) = 0.87, p = .426$], as well as no interaction effect [$F(2, 52) = 2.00, p = .146$].

Accuracy by Type of Cue Modality

A mixed between-within subjects analysis of variance was conducted to explore the impact of gender and type of encoding interference on orientation error across two types of retrieval modalities used for cueing novel environmental stimuli (i.e., landmarks). Orientation error was calculated as the mean absolute value of the angular deviation from the correct angle of the target that was cued. Subjects were divided into three groups according to the type of interference and their scores were compared by the

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[1] A LAZERPRO® laser level system with a protractor on its base was used to measure the angles of orientation.

type of cue modality used in retrieval. The means and standard deviations for each group are presented in Table E2 in Appendix E. Also, see Table 1 below for a summary of effects and interactions.

Table 1

Analysis of Variance for Accuracy by Cue Modality

Source	*df*	*F*	Partial η^2	*p*
		Between subjects		
Gender (G)	1	0.00	.000	.972
Type of Interference (I)	2	7.67†	.246	.001
G X I	2	0.21	.009	.811
Error	47	(1473.86)		
		Within subjects		
Cue Modality (M)	1	36.16‡	.435	.000
M X G	1	0.01	.000	.919
M X I	2	0.06	.002	.946
M X G X I	2	0.87	.036	.425
Error (M)	47	(964.46)		

Note: Values enclosed in parenthesis represent mean square errors.

$^{*}p < .05$. $^{**}p < .01$. †$p < .001$. ‡$p < .0005$.

There was a main effect for type of cue modality used in retrieval [$F(1, 47) = 36.16, p < .0005$, partial $\eta^2 = .435$; see Figure 9]. Post-hoc comparisons using the Bonferroni adjustment ($\alpha = .05$) indicated that the mean error score (in degrees) for responses cued verbally ($M = 46.18$, $SD = 33.84$) was significantly different from the error score for responses cued visually ($M = 82.71$, $SD = 39.27$). There were no within-subjects interactions with gender [$F(1, 47) = 0.01, p = .919$], encoding interference [$F(2, 47) = .06, p = .946$] or gender and encoding interference [$F(2, 47) = 0.87, p = .425$].

There was also a main effect for type of encoding interference [$F(2, 47) = 7.67, p = .001$, partial $\eta^2 = .246$; see Figure 10]. Post-hoc comparisons using the Bonferroni adjustment ($\alpha = .05$) indicated that the mean error score for the no interference group ($M = 43.82$, $SD = 28.87$) differed significantly from the verbal interference group ($M =$

69.77, *SD* = 4.35) as well as the spatial interference group (*M* = 78.58, *SD* = 43.44). The mean scores for the verbal and spatial interference groups did not differ significantly from each other. The main effect for gender [*F*(1, 47) = 0.00, *p* = .972] and the interaction effect [*F*(2, 47) = 0.21, *p* = .811] did not reach statistical significance.

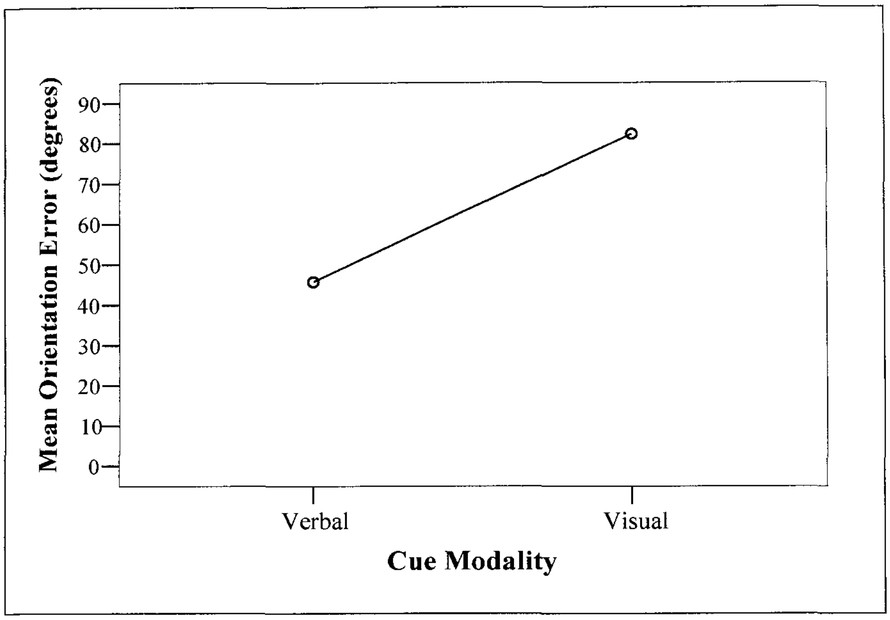

Figure 9: Mean orientation error (in degrees) by the type of cue modality used in retrieval.

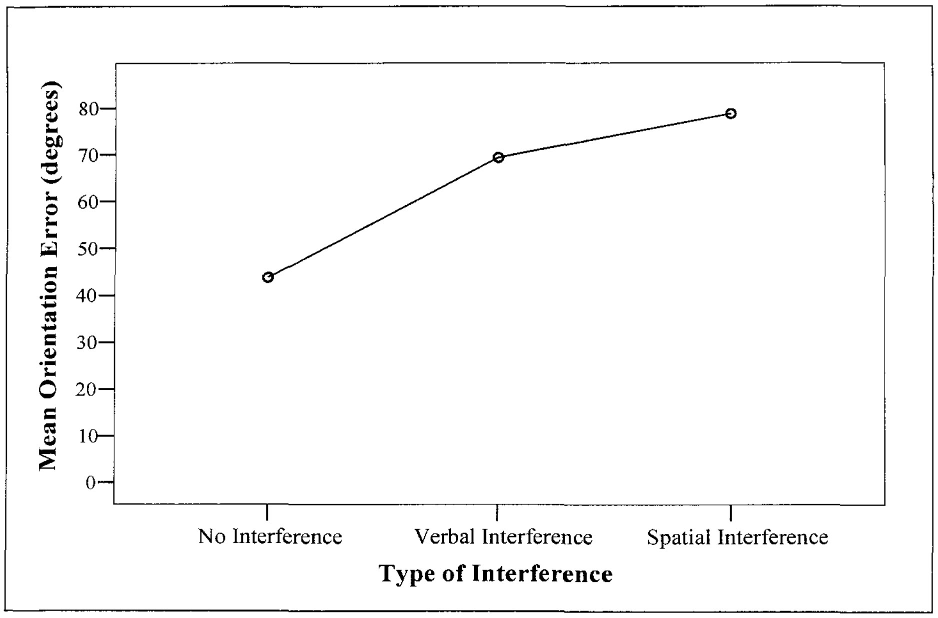

Figure 10: Mean orientation error (in degrees) by the type of interference used during study phase.

Accuracy by Level of Exposure

A mixed between-within subjects analysis of variance was conducted to explore the impact of gender and encoding interference on accuracy across three levels of exposure to environmental stimuli. Accuracy was determined by the magnitude of orientation error (i.e., absolute mean deviation from actual target, in degrees). Subjects were divided into three groups according to the type of encoding interference and their scores were compared when exposed to novel stimuli (errors in orienting to landmarks cued verbally), intermediately learned stimuli (errors in pointing to somewhat obscure cardinal directions, such as NE), and over-learned stimuli (errors in pointing to familiar cardinal directions, such as S). The novel stimuli were only composed of verbally cued landmarks because the orientation error differed by the type of cue modality used in the retrieval of landmark location (see above). The means and standard deviations for each group are presented in Table E3 in Appendix E. Also, see Table 2 below for a summary of effects and interactions.

Table 2

Analysis of Variance for Accuracy by Level of Exposure

Source	*Df*	*F*	Partial η^2	*p*
Between subjects				
Gender (G)	1	0.25	.005	.623
Type of Interference (I)	2	5.09**	.178	.010
G X I	2	0.57	.024	.571
Error	47	(403.72)		
Within subjects				
Level of Exposure (E)	2	49.03‡	.681	.000
E X G	2	0.22	.010	.801
E X I	4	3.26*	.124	.015
E X G X I	4	2.47*	.097	.050
Error (E)	92	(311.62)		

Note: Values enclosed in parenthesis represent mean square errors.

*$p < .05$. **$p < .01$. †$p < .001$. ‡$p < .0005$.

There was a main effect for level of exposure [$F(2, 46) = 49.03, p < .0005$, partial $\eta^2 = .681$; see Figure 11]. Post-hoc comparisons using the Bonferroni adjustment ($\alpha = .05$) indicated that the mean error scores (in degrees) were significantly different for all three levels of exposure; that is, the error score attained when exposed to the novel stimuli ($M = 46.18$, $SD = 33.84$) was significantly different from the error score for the intermediately-learned stimuli ($M = 13.81$, $SD = 6.85$), which was significantly different from the error score for over-learned stimuli ($M = 9.15$, $SD = 4.43$).

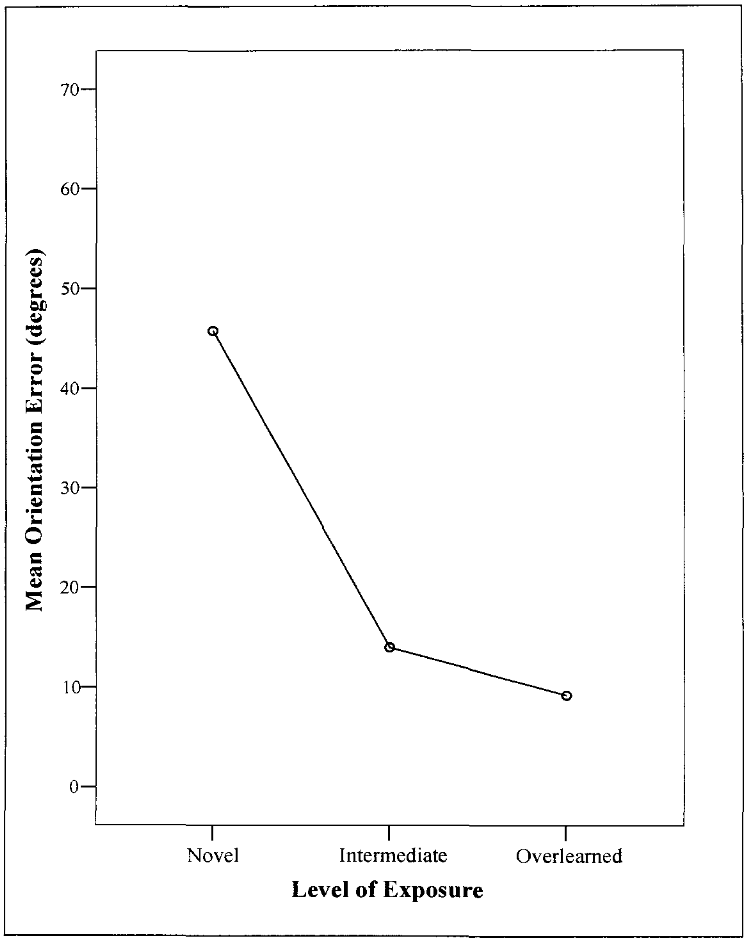

Figure 11: Mean orientation error (in degrees) by level of exposure to environmental stimuli.

In addition, there was an interaction effect between levels of exposure and type of encoding interference [$F(4, 92) = 3.26, p = .015$, partial $\eta^2 = .124$; see Figure 12].

Analyses of simple effects performed on each level of exposure revealed that the effect of encoding interference was confined to the novel stimuli only; that is, orientation error for intermediately-learned and over-learned stimuli did not differ by type of encoding interference. Furthermore, there was an interaction effect of levels of exposure with gender and encoding interference [$F(4, 92) = 2.47$, $p = .050$, partial $\eta^2 = .097$; see Figures 13, 14, and 15]. Analyses of simple effects demonstrated that the females performed worse than males in the verbal interference condition (see Figure 14), whereas the opposite pattern was observed in the spatial interference condition (see Figure 15). The interaction effect of levels of exposure and gender [$F(2, 46) = 0.22$, $p = .801$] did not reach statistical significance.

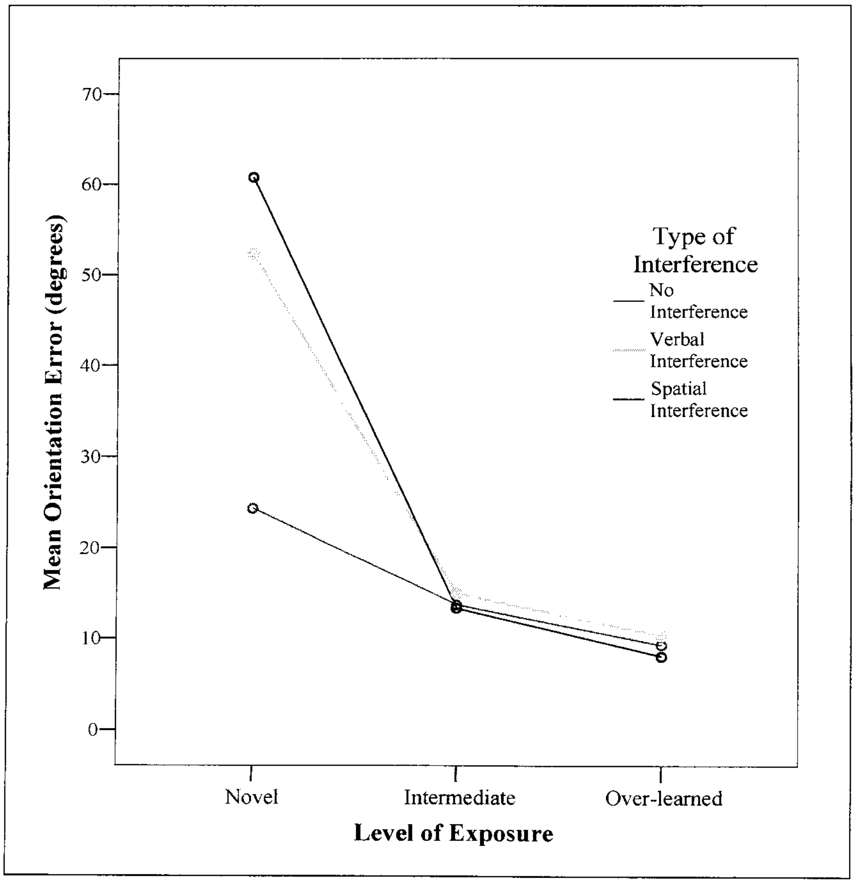

Figure 12: Mean orientation error (in degrees) by type of interference used during study phase and level of exposure to environmental stimuli.

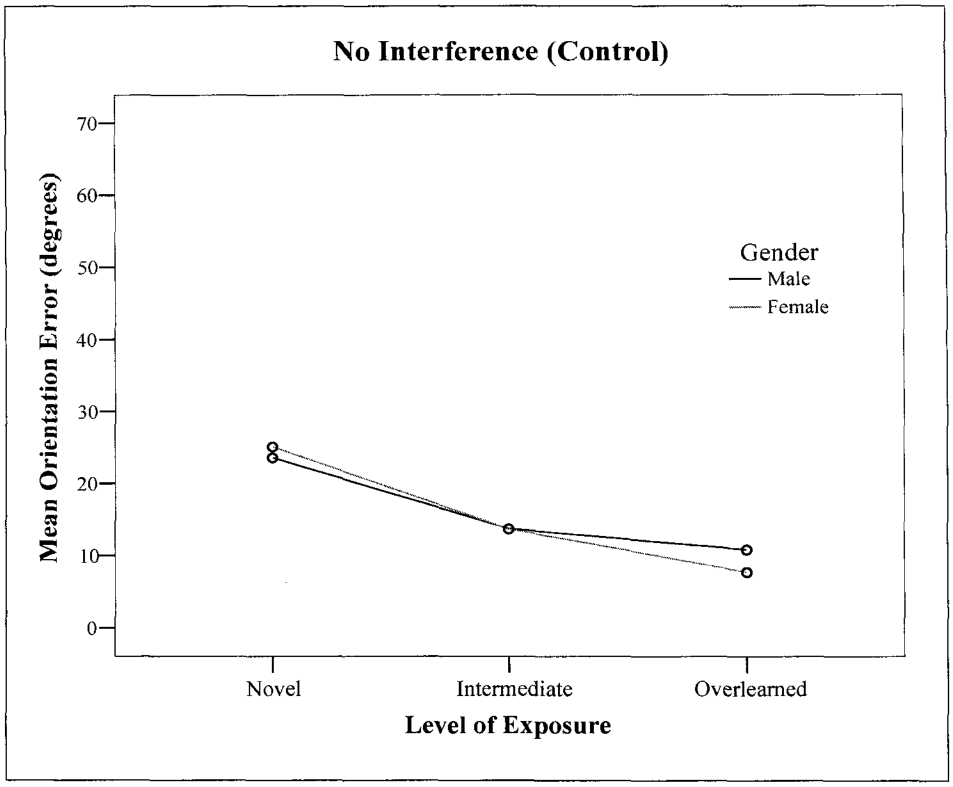

Figure 13: Mean orientation error (in degrees) by participants in the control condition.

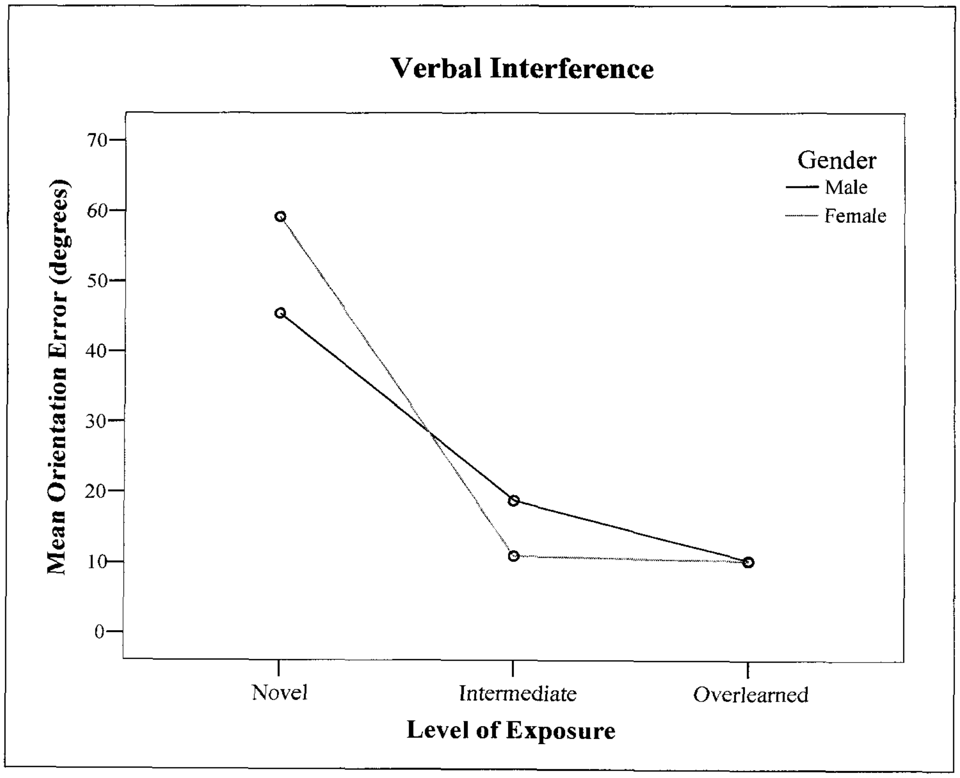

Figure 14: Mean orientation error (in degrees) by participants in the verbal interference condition.

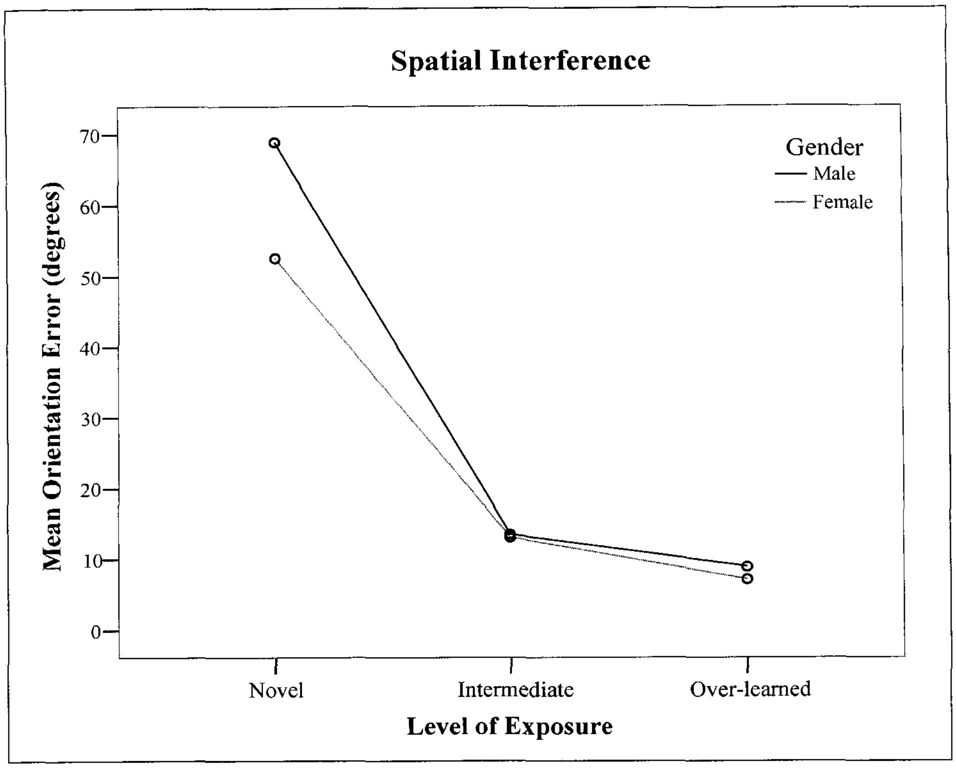

Figure 15: Mean orientation error (in degrees) by participants in the spatial interference condition.

There was also a between-subjects main effect for type of encoding interference [*F*(2, 47) = 5.09, *p* = .010, partial $\eta^2 = .178$; see Figure 16]. Post-hoc comparisons using the Bonferroni adjustment ($\alpha = .05$) indicated that the mean error score for the control group (*M* = 15.77, *SD* = 9.09) differed significantly from the verbal interference group (*M* = 25.84, *SD* = 13.82) as well as the spatial interference group (*M* = 27.37, *SD* = 16.93). The mean scores for the verbal and spatial interference groups did not differ significantly from each other. However, univariate analyses exploring the effect of encoding interference on each level of exposure yielded significant findings for the novel stimuli only. The main effect for gender [*F*(1, 47) = 0.25, *p* = .623] and the interference by gender interaction [*F*(2, 47) = 0.57, *p* = .571] did not reach statistical significance.

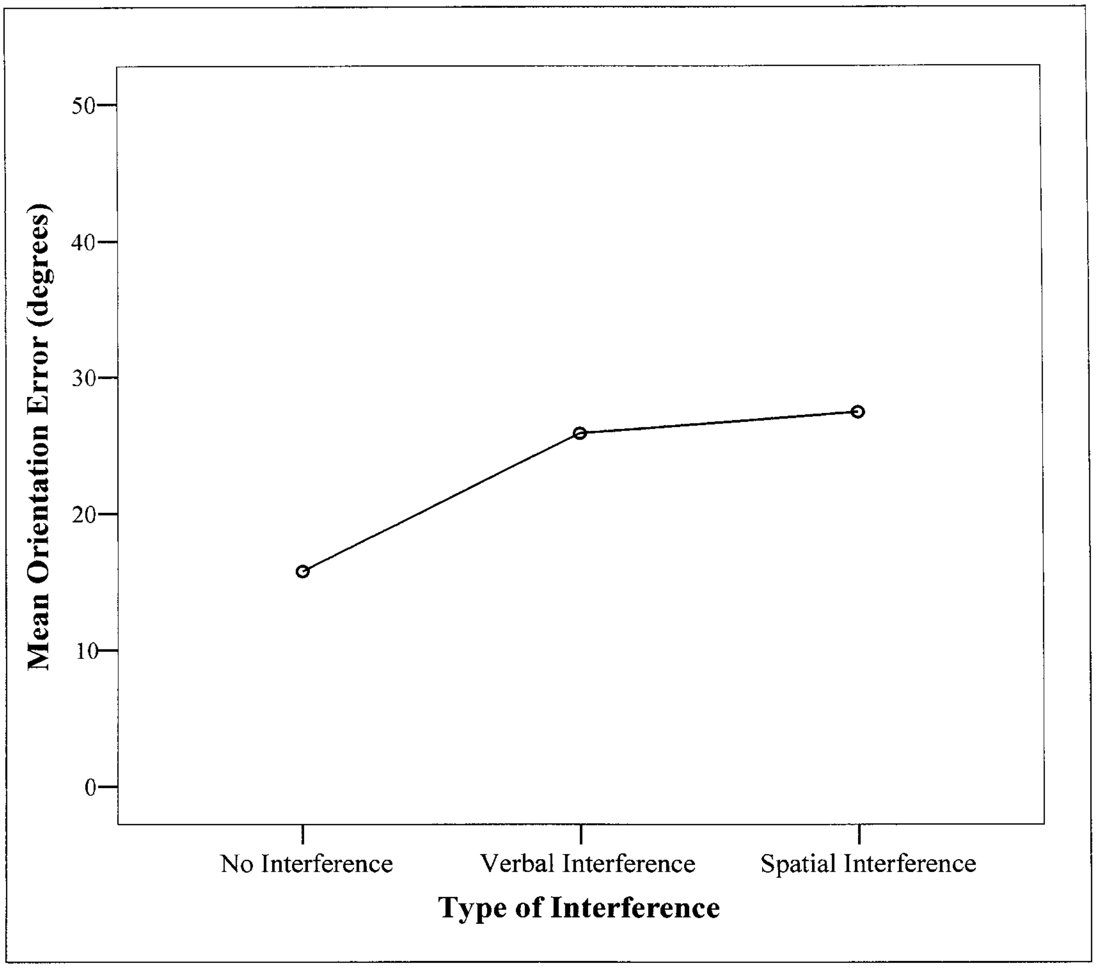

Figure 16: Mean orientation error (in degrees) by type of interference used during study phase.

Response Time by Cue Modality

A mixed between-within subjects analysis of variance was conducted to explore the impact of gender and encoding interference on response times (in seconds) across two types of retrieval cues. Subjects were divided into three groups according to the type of interference and their response times were compared by the type of retrieval cues employed to locate landmarks. The means and standard deviations for each group are presented in Table E4. Also, see Table 3 below for a summary of effects and interactions.

Table 3

Analysis of Variance for Response Time by Cue Modality

Source	*df*	*F*	Partial η^2	*p*
		Between subjects		
Gender (G)	1	0.42	.009	.520
Type of Interference (I)	2	1.34	.054	.272
G X I	2	0.10	.004	.902
Error	47	(6.58)		
		Within subjects		
Cue Modality (M)	1	7.81**	.142	.008
M X G	1	0.00	.000	.951
M X I	2	0.90	.037	.415
M X G X I	2	0.33	.014	.720
Error (M)	47	(1.10)		

Note: Values enclosed in parenthesis represent mean square errors.

$*p < .05$. $**p < .01$. †$p < .001$. ‡$p < .0005$.

There was a main effect for type of cue modality used in retrieval [$F(1, 47) = 7.81, p = .008$, partial $\eta^2 = .142$; see Figure 17]. Post-hoc comparisons using the Bonferroni adjustment ($\alpha = .05$) indicated that the mean response time (in seconds) to targets cued verbally ($M = 5.93, SD = 1.85$) was significantly faster than the mean response time to targets cued visually ($M = 6.49, SD = 2.01$). There were no within-subjects interactions with gender [$F(1, 47) = 0.00, p = .951$], encoding interference [$F(2, 47) = 0.90, p = .415$] or gender and encoding interference [$F(2, 47) = 0.33, p = .720$]. The main effects for type of encoding interference [$F(2, 47) = 1.34, p = .272$] and gender [$F(1, 47) = 0.42, p = .520$], as well as the interaction effect [$F(2, 47) = 0.10, p = .902$], were not statistically significant.

Response Time by Level of Exposure

A mixed between-within subjects analysis of variance was conducted to explore the impact of gender and encoding interference on response times (in seconds) across three levels of exposure to environmental stimuli. Subjects were divided into three groups according to the type of encoding interference and their response times were compared when required to point to novel stimuli, intermediately learned stimuli, and over-learned stimuli. The means and standard deviations for each group are presented in Table E5. Also, see Table 4 below for a summary of effects and interactions.

Table 4

Analysis of Variance for Response Time by Level of Exposure

Source	*df*	*F*	Partial η^2	*p*
Between subjects				
Gender (G)	1	0.25	.005	.623
Type of Interference (I)	2	5.09**	.178	.010
G X I	2	0.57	.024	.571
Error	47	(403.72)		
Within subjects				
Level of Exposure (E)	2	76.32‡	.768	.000
E X G	2	0.21	.009	.808
E X I	4	1.86	.075	.124
E X G X I	4	1.09	.045	.367
Error (E)	92	(0.66)		

Note: Values enclosed in parenthesis represent mean square errors.

$*p < .05$. $**p < .01$. †$p < .001$. ‡$p < .0005$.

There was a main effect for level of exposure [$F(2, 46) = 76.32, p < .0005$, partial $\eta^2 = .768$; see Figure 18]. Post-hoc comparisons using the Bonferroni adjustment ($\alpha = .05$) indicated that the mean response times (in seconds) were significantly different for all three levels of exposure; that is, the time required to respond to the novel stimuli ($M = 5.93$, $SD = 1.85$) was slower than the response time to intermediately learned stimuli ($M = 4.08$, $SD = .88$), which was slower than the response time to over-learned stimuli ($M = 3.69$, $SD = .80$). There were no within-subjects interactions with gender [$F(2, 46) = 0.21$, $p = .808$], type of encoding interference [$F(4, 92) = 1.86, p = .124$], or with gender and encoding interference [$F(4, 92) = 1.09, p = .367$]. The main effects for gender [$F(1, 47)$

= 0.46, p = .500] and type of encoding interference [F(2, 47) = 0.95, p = .395], as well as the interaction effect [F(2, 47) = 0.05, p = .954], did not reach statistical significance.

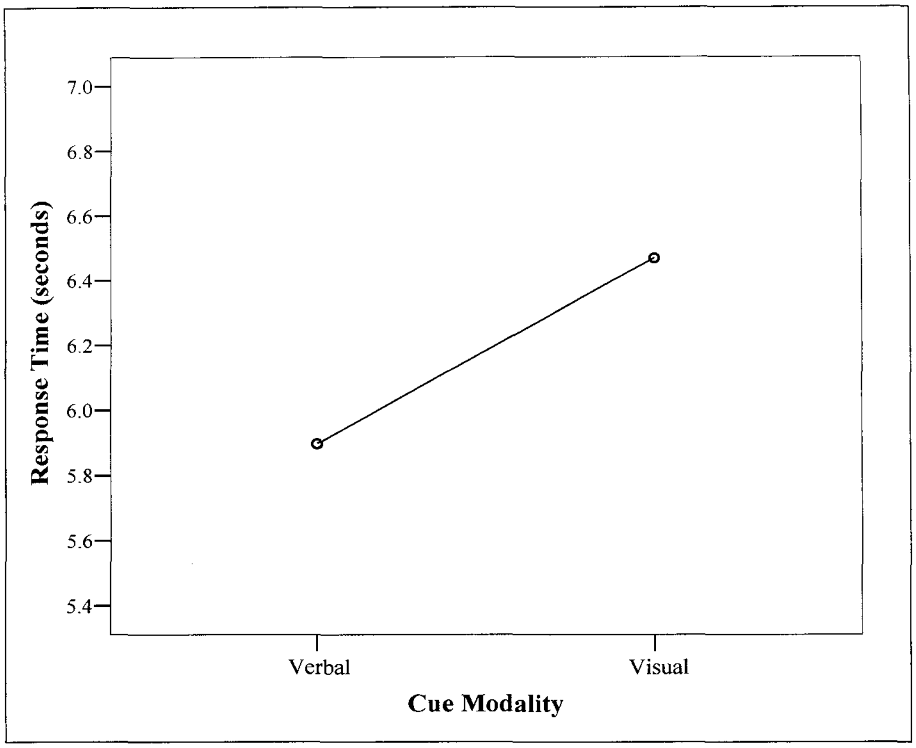

Figure 17: Response time (in seconds) by the type of cue modality used in retrieval.

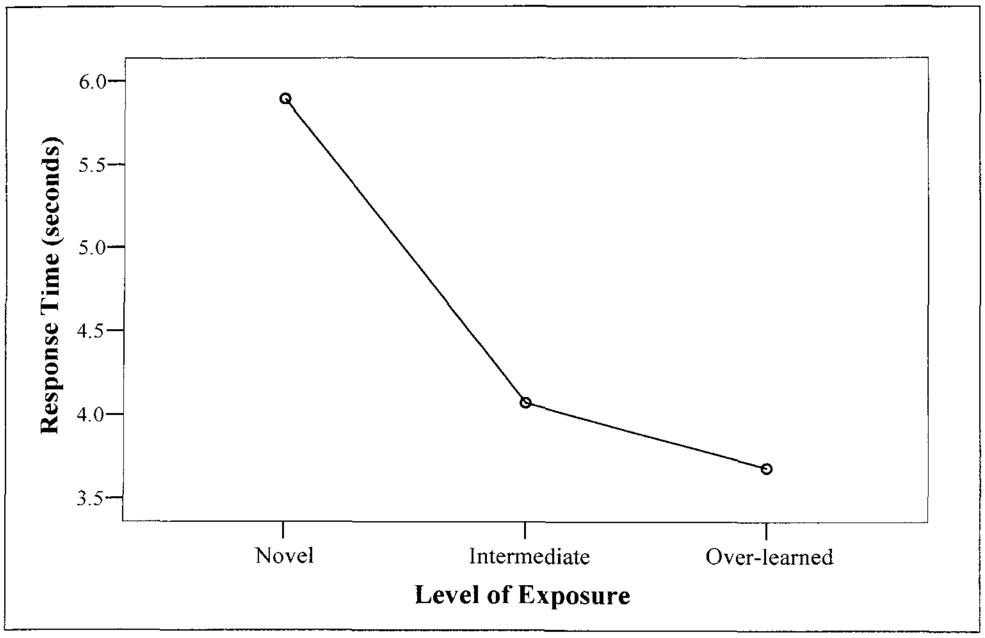

Figure 18: Response time (in seconds) by level of exposure to environmental stimuli.

Discussion

The present study investigated the effects of encoding interference and gender on the retrieval of survey knowledge. The purpose of encoding interference was to differentially encumber each of the WM slave systems (Baddeley & Hitch, 1974) while the participant studied a novel map of a town. The degree of retrieval of survey knowledge was gauged by the accuracy and speed of response exhibited by each participant when required to identify the orientation of specific environmental landmarks of differing familiarity. In addition, this study explored the effects of exposure (or familiarity) on the degree of encoding of spatial information as per Tulving's (1972) dichotomous theory of long-term memory (i.e., semantic and episodic).

First, the data from this study support the hypothesis that recall of spatial information increases with extended exposure to the environment (H_{2a}). This was evidenced by the presence of decreased orientation errors and response latencies with increasing familiarity to environmental stimuli; that is, participants were more accurate and faster in orienting to targets when the targets were over-learned than when they were novel. Such a result should be expected, as increased degrees of use and familiarity have been postulated to result in deeper levels of processing of information and subsequently more elabo rate, longer-lasting and stronger memory traces (Craik & Lockhart, 1972). Similar findings regarding better performances on spatial tasks with increasing familiarity to environmental stimuli have been reported in the literature (Albert, Rensink, & Beusmans, 1999; Gärling et al., 1986; Lindberg & Gärling 1981a, 1981b, 1982; Thorndyke & Hayes-Roth, 1982). Furthermore, in spite of the effect of familiarity on accuracy and response latency, the results also suggest that at least some survey knowledge can be acquired from a single exposure to a map, consistent with the literature (Thorndyke and Hayes-Roth, 1982).

Second, as hypothesized, the present study showed that encoding interference affected the accuracy of retrieval of novel information but not the retrieval of over-learned information (H_{2b}). This finding is not unusual because the participants only partook in concurrent tasks when studying the map and the interference should have only hindered their encoding. On the other hand, the items making up the over-learned environmental stimuli (i.e., cardinal directions) were supposedly already ingrained in semantic memory (Gärling et al., 1984; Siegel & White, 1975; Tulving, 1972) prior to the experiment and, thus, should not have been affected by any encoding interference.

The present research study confirmed that using a concurrent task requiring formulation of the days of the week adequately interferes with the rehearsal process in the phonological loop, as previously reported (Baddeley & Hitch, 1994; Saucier et al., 2003). In addition, it was demonstrated that auditory spatial stimuli can indeed interfere with proper spatial encoding. Although the task used in this experiment differed from Baddeley and Lieberman's (1980) photosensitive pendulum set-up, it nevertheless elicited the desired result. However, it is unclear whether the present task was encumbering VSWM because of its auditory-spatial properties or because of the kinaesthetic-motor properties involved in pointing to the target speakers, as the latter type of action has been shown to interfere with proper spatial coding (Allen et al., 1978; Garden et al., 2002; Quinn, 1991; Yuille & Ternes, 1975).

The hypothesis stating that the concurrent tasks would vary in difficulty (H_{2c}) was not supported by the results. In general, participants in the control (no interference) condition performed significantly better than participants in either of the interference conditions; that is, the presence of either encoding interference (verbal or spatial) during the study phase resulted in lower accuracy (higher orientation error) than the absence of interference. This finding is consistent with the extent literature (Allen et al., 1978; De Beni et al., 2005; Garden et al., 2002; Lindberg & Gärling 1981a, 1981b, 1982; Yuille & Ternes, 1975). This result suggests that the presence of any interference may have acted as a diversion from the primary task at hand (i.e., studying the map) and may have resulted in increased attention demands, likely overwhelming the central executive's capacity to coordinate the activity of each subsidiary system to encode the information in WM. This inference is probable since the limited capacity attentional system has been reported to be most active during situations of novelty, difficulty, time pressure or competing demands (Feldman Barrett et al., 2004; Norman & Shallice, 1986). Although the present study did not demonstrate differences in accuracy according to specific concurrent tasks, it should not be assumed that the tasks used in this study are equally difficult under all situations. The tasks may have been difficult enough to surpass a limited attentional threshold under the current study conditions but under other circumstances (e.g., a simpler primary task), the tasks may have evidenced differential effects between each type of encoding interference. In other words, the present experimental parameters (i.e., study a map for 1 minute) may have demanded extensive attentional resources due to the study time constraints, the complex set-up of the town's grid, as well as the abundance of landmarks and other competing stimuli (e.g., train track, river, etc.). Consequently, the presence of any additional attentional demands (i.e., concurrent tasks) could have easily exhausted the capacity of the WM system and resulted in an overall decrease in performance. Further research with this dual-task methodology should focus on a similar but less attention-demanding primary task, such as the as the *Standardized Road-Map Test of Direction Sense* (Money, Alexander, & Walker, 1965). Not only would using a such measure allow for further examination of the differential effects of the concurrent tasks, but it would also allow for the validation of the present experimental design with an established standardized measure of perspective-taking ability, route knowledge and spatial orientation.

In contrast to previous work (Coluccia & Louse, 2004; Galea & Kimura, 1993; Lawton, 1996; Moffat et al., 1998), overall gender differences in spatial orientation and pointing (H_1) were not supported by the present study. Also, males and females did not differ in response time or accuracy with respect to the type of modality that was used in cueing spatial information (H_{1b}). While unanticipated, however, retrieval of verbally-cued landmarks yielded faster and more accurate responses than retrieval of landmarks cued visually. This may have occurred because visual cueing in this setting is a somewhat novel experience, whereas responding to verbal cueing may be more of an over-learned and expected scenario. Furthermore, the results may have been affected by the rather cumbersome action required to remove and replace the blindfold when the landmarks were cued visually, but not when they were cued verbally because no such action was required. Also, despite the fact that there were differences associated with the modality employed in cueing landmarks, the methodology used in this study failed to account for visually-cued cardinal directions to balance the cue modality across within-subject factors. Thus, over-learned and intermediately-learned stimuli were only cued verbally. Therefore, the levels of exposure (familiarity) could only be analyzed across verbally-cued stimuli. However, if there were a way to cue cardinal directions visually, the design could have allowed the use of multiple within-subjects factors rather than breaking the analyses into 3-level (exposure) and 2-level (cue modality) factors.

While no cue-specific gender differences were observed in this study, the data partially confirmed the presence of gender differences in spatial orientation under varying concurrent tasks (H_{1a}). Specifically, no gender differences in accuracy or response time were observed in the absence of encoding interference. However, concurrent articulatory suppression during the study phase resulted in lower accuracy for females than males, whereas spatial interference yielded lower accuracy in males than females. Thus, the gender differences were only evident when the expected gender-specific cognitive mapping strategies were hindered. These results were not due to differences in each group's ability to point straight ahead, as analyses of pointing bias showed no significant findings. These findings support studies reporting a male tendency to encode landmark and survey information spatially and a female tendency to encode it verbally (Dabbs et al., 1998; Galea & Kimura, 1993; Lawton & Kallai, 2002; Saucier et al., 2002, 2003; Sholl et al., 2000) because the differences were only evident when the expected gender-specific cognitive mapping strategies were hindered via material-specific interferences. In addition, the fact that any differential interference effects on information processing were elicited adds support to the presence of dual encoding in WM (i.e., verbal and spatial; Baddeley, 1986; De Beni et al., 2005). Nonetheless, it is important to note that the presence of any concurrent task affected either gender's performance more than the absence of encoding interference, indicating an overall effect on the capacity of the system.

The reason response time was incorporated as a dependent variable in this study was to add another source of evidence for the formation of a cognitive map from the map-learning task. If a participant generated an adequate cognitive map of the environment (e.g., map components, orientation of self to cardinal directions, etc.), then the information regarding the orientation of targets in space should have been readily and quickly accessed. On the other hand, not having properly encoded the information because of a concurrent task should have resulted in difficulty accessing the memory trace, yielding longer response latencies. Analyses of response times yielded fewer significant findings than those involving accuracy. This may have been due to the relatively larger variability of scores associated with angle deviations. The response latencies were both smaller in value and characterized by much less disparity. A different analytical approach would be to use the mean response latencies associated with the control condition as a baseline against which the latencies from the interference conditions could be compared.

Furthermore, future studies using this design should make use of questionnaire data as well as a landmark recognition task in addition to the performance-based methodology used in the present experiment. Coupling the present findings with self-report measures of spatial anxiety, spatial competence, and sense of direction, as well as preferential navigation style, mental representations of space, and strategies for acquiring spatial knowledge (Garden et al., 2002; Lawton, 1994, 1996; Lawton & Kallai, 2002; Pederson, 1999; Schmitz, 1997, 1999; Sholl et al., 2000) would have allowed for further comparisons between study groups and may have revealed individual differences in the present study. Also, by adding a landmark recognition task (Bosco et al., 2004), comparisons could have been made between the acquisition of survey and landmark knowledge, perhaps allowing for more definitive gender differences.

Although the current study did not attempt to shed light into the origins of gender differences in spatial cognition, biological determinants have been proposed to account for gender differences in cognitive abilities (Kimura, 1987, 1999; McGlone, 1980). Thus, a possible avenue of research with this dual-task paradigm should focus on the biological differences between the sexes, namely hormonal concentrations and fluctuations (Liben, Susman, Finkelstein, Chinchilli, Kunselman, Schwab, et al., 2002; Ostatnikova, Putz, Celec, & Hodosy, 2002). Thus, because sex hormones have been implicated as sources of discrepancy in spatial performance between the sexes, it would be ideal to collect serum or saliva samples at the time of testing. Additionally, because hormone levels have been reported as following a lunar cycle for women as well as a diurnal, circalunar and seasonal cycle for men, (Kimura & Hampson, 1994; Liben et al., 2002; Ostatnikova et al., 2002), serial assessments of spatial orientation using alternate forms of the present study as well as evaluating the effect time of testing may yield interesting findings.

All things considered, the present experiment expands research in the areas of spatial cognition, working memory and gender differences because of its innovative design and methodology. Although research studies have been conducted involving pointing to unseen targets (e.g., Blanjekova et al., 2005; Gärling et al., 1981b, 1982), blindfolded orientation (e.g., Lindberg & Gärling, 1981a; Wang & Brockmole, 2003), map-learning (e.g., Thorndyke & Hayes-Roth, 1982; Leiser et al., 1987), dual-task methodology (e.g., De Beni et al., 2005; Garden et al., 2002), and gender differences in spatial knowledge (e.g., Galea & Kimura, 1993; Saucier et al., 2002, 2003), no study combines all of the above parameters. Also, no study in the gender differences research has combined blindfolded orientation to landmarks learned from a map while performing material-specific concurrent tasks. Lastly, no study has employed an auditory spatial concurrent task like the one used here.

Finally, because this study supports the literature regarding gender-specific wayfinding strategies, it may aid the civil engineering industry by bringing light to the need for better signage of landmarks and perhaps the use of strategically-placed "compass" signs along crowded streets, especially in downtown areas of cities where it is difficult to identify landmarks or properly orient oneself to grids.

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Appendix A

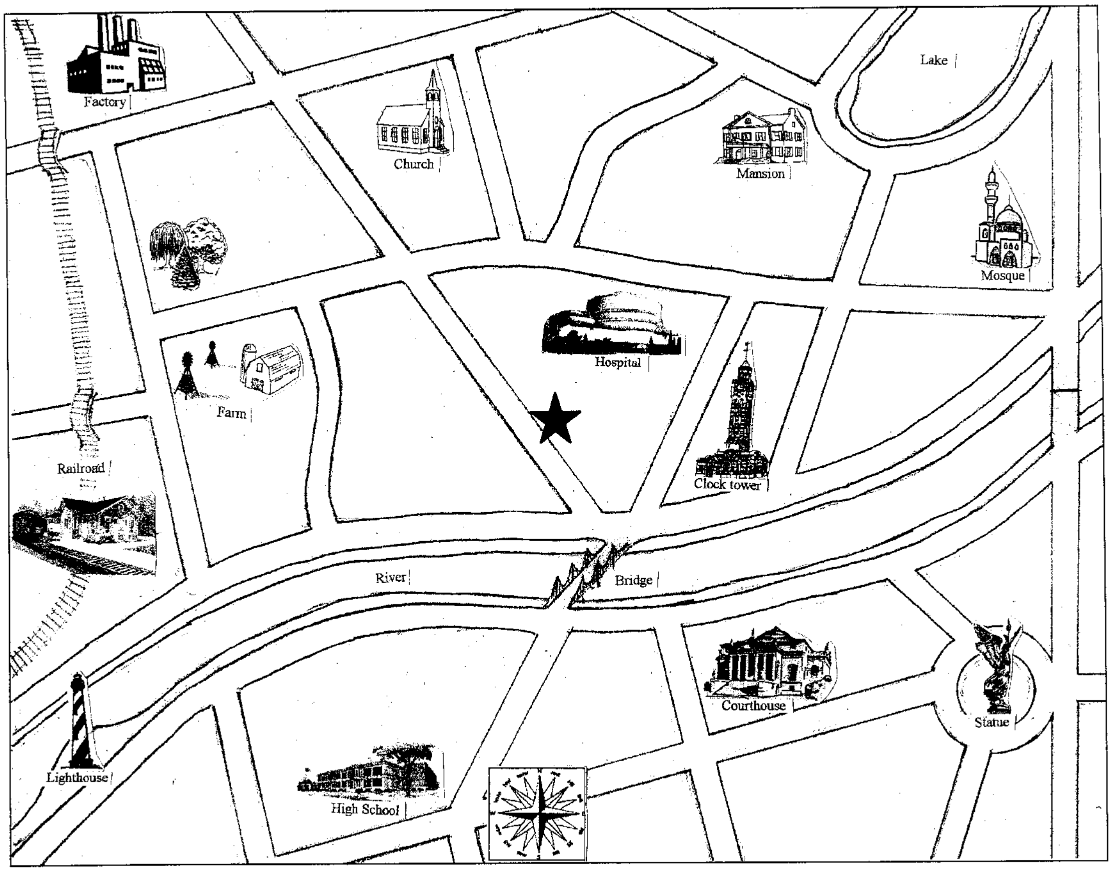

Figure A1: Scaled representation of map used for testing (original: 17" by 22").

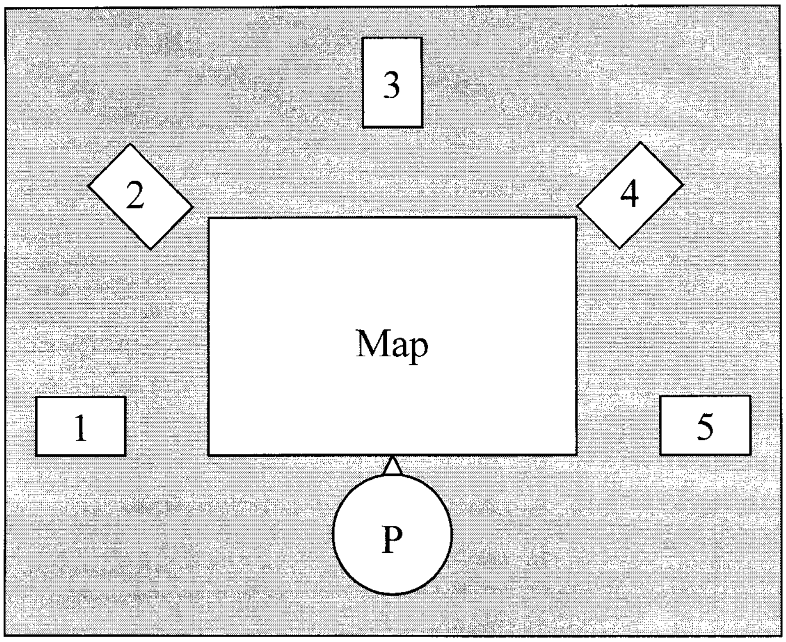

Figure A2: Speaker and map orientation during study phase.

Appendix B

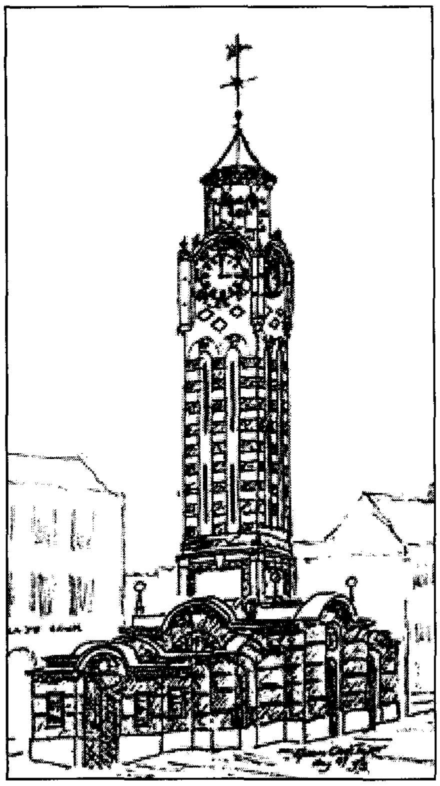

Figure B1: Scaled representation of the Clock Tower cue.

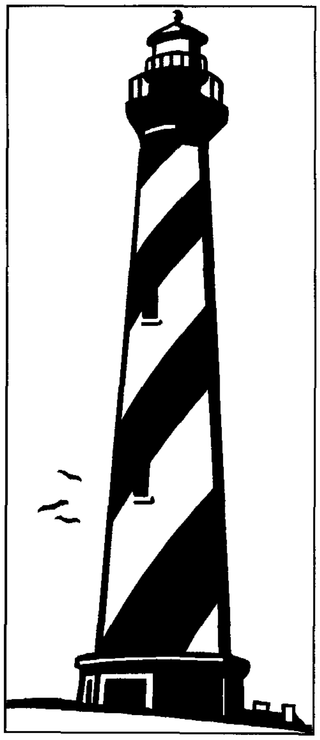

Figure B2: Scaled representation of the Lighthouse cue.

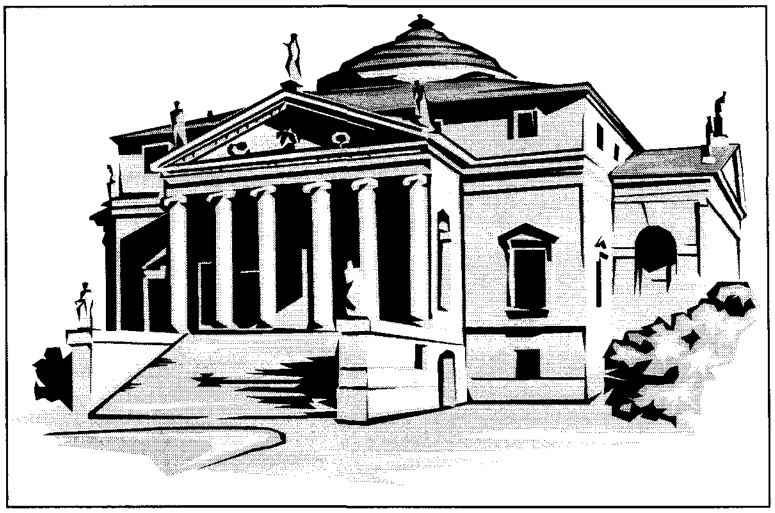

Figure B3: Scaled representation of the Courthouse cue.

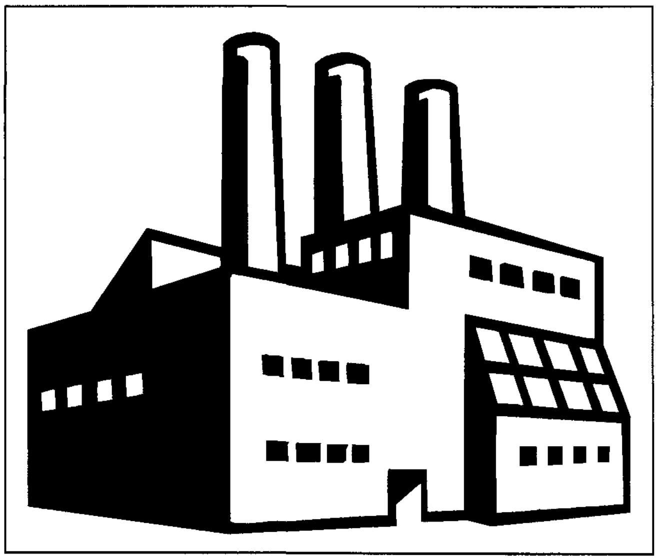

Figure B4: Scaled representation of the Factory cue.

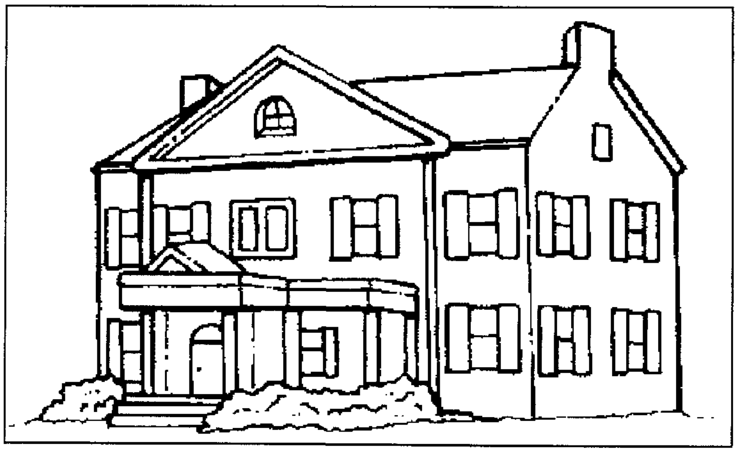

Figure B5: Scaled representation of the Mansion cue.

Appendix C

Administration Instructions

Thank you for volunteering to participate. Today, we are going to be doing several activities. First, I will ask you to study a map. Then, I will ask you to point to certain aspects of the environment while blindfolded. Let's begin.

Study Phase

No interference	Verbal interference	Spatial interference
Here is a map of a town (*point to upside down map*). When I say begin, I would like you to study the map and try to remember as much about it as you can because I will ask you questions about it later on. You will have one minute. Remember, you are to study the map. Any questions? *Turn map over.* Please note that this is the centre of the map (*point to star).* Begin. *Begin timing. Stop after 60 seconds.*	Here is a map of a town (*point to upside down map*). When I say begin, I would like you to study the map and try to remember as much about it as you can because I will ask you questions about it later on. You will have one minute. This is a metronome (*point to metronome*). It is used to keep a beat and it is set to make a "tick" noise every two seconds. Every time you hear a "tick", I'd like you say a day of the week in order starting with Monday. For example, (*start metronome*) "Monday, Tuesday, etc." After you say Sunday on tick number seven, please continue with Monday on the next one and so on. Now you try a few. (*Allow for 10 trials of practice. Stop metronome*). Remember, you are to study the map while you are doing this. Any questions? *Turn map over.* Please note that this is the centre of the map *(point to star).* Begin. *Start metronome and say begin. Begin timing. Stop after 60 seconds.*	Here is a map of a town (*point to upside down map*). When I say begin, I would like you to study the map and try to remember as much about it as you can because I will ask you questions about it later on. You will have one minute. Here are 5 speakers (*point to each* speaker). Every two seconds, you will hear a tone coming from one of these 5 speakers. Every time you hear a tone, I'd like you to point to the speaker that emitted the tone. Let's try a few (*Run 10 trials*). Remember, you are to study the map while you are doing this. Any questions? *Prepare to run sequence. Turn map over.* Please note that this is the centre of the map (*point to star).* Begin. *Start tone and begin timing. Stop after 60 seconds.* sequence: 35142; 51243; 14352; 42531; 25314; 13425

Testing Phase

For this part of the study, we are going to use this blindfold and a laser pointer (*point to blindfold and laser pointer*). I will ask you to point to certain aspects of the environment. Sometimes, I will ask you to point in a specific direction whereas other times I will show you a picture and ask you to point to where it is in the map you just studied. If I show you a picture, I will show it to you very briefly and then ask you to put the blindfold on immediately after. If I ask you to point to a specific place, just keep you blindfold on. In either case, I'd like you to turn your chair towards the destination, stick your arm out and point in the direction you think the structure or object can be found (*show how to do*). Please tell me when you are sure of the place and I will stop the timer. It is important that you remember to do it as fast as possible but try your best to get the right answer. When you are sure of the location, keep pointing at shoulder height until we say stop. After each question, you will be brought back to the starting point, facing north.

Any questions? Let's begin.
Picture you are in the middle of the map, where the star was. You are facing north. Remember to turn, point, and tell me when you are done. (*Start timing and stop once the participant is sure*) (*Every time they point, put a sticker and write Test type, trial number, and visual or verbal if applicable).*

You are in the middle of the map where the star was. You are facing North, where is...

1. South? West? East? North? South-West? South-East? North-West? North-East?
2. South? West? East? North? South-West? South-East? North-West? North-East?
3. the bridge?
4. this? (*show clock tower, blindfold*)
5. the farm?
6. this? (*show lighthouse, blindfold*)
7. the mosque?
8. this? (*show courthouse, blindfold*)
9. the statue?
10. this? (*show factory, blindfold*)
11. the train station?
12. this? (*show mansion, blindfold*)
13. South? West? East? North? South-West? South-East? North-West? North-East?
14. South? West? East? North? South-West? South-East? North-West? North-East?

Thank you for participating. The results will be posted in August, 2005. Please check the REB website at that time.

Appendix D

Scoring Sheet

Participant #: ________ Date (MM/DD/YY): ________ Age (*years-months*): ________

Gender (*circle*): M F Education (*years*): ________

History of neurological disease or brain injury (*circle*): Yes No
If yes, please specify in the comments section.

Study Phase
Condition type (*circle*): No Int. Verbal Int. Spatial Int.

If Spatial Int., (*circle errors; put line through omissions*)

1	5	3	2	4	5	3	1	4	2
3	5	1	4	2	5	1	2	4	3
1	4	3	5	2	4	2	5	3	1
2	5	3	1	4	1	3	4	2	5

If Verbal Int., (*Allow some practice with metronome. circle errors; put line through omissions*)

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday
Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday

Apparent motivation during study phase (*circle*): 1 2 3 4 5

Test Phase

Direction	**Response time (s)**		**Degrees from "north" (°)**		**Degrees off actual (°)**	
Trials	1	2	1	2	1	2
South						
West						
East						
North						
South-West						
South-East						
North-West						
North-East						

Landmark (*italics*=visual)	**Response time (s)**	**Degrees from "north" (°)**	**Quadrant**	**Degrees off actual (°)**
1. bridge				
2. *clock tower*				
3. farm				
4. *lighthouse*				
5. mosque				
6. *courthouse*				
7. statue				
8. *factory*				
9. train station				
10. *mansion*				

Direction	**Response time (s)**		**Degrees from "north" (°)**		**Degrees off actual (°)**	
Trials	3	4	3	4	3	4
South						
West						
East						
North						
South-West						
South-East						
North-West						
North-East						

Apparent motivation during test phase (*circle*): 1 2 3 4 5

Self-reported confusion/disorientation during task (*circle*): 1 2 3 4 5

Comments:

Appendix E

Table E1

Group Composition by Age and Education

Gender	Type of Interference		*n*	*M*	*SD*
Male	No Interference	Age	8	24.34	6.04
		Education	8	15.00	2.67
	Verbal Interference	Age	7	22.95	4.33
		Education	7	14.71	2.56
	Spatial Interference	Age	8	24.33	7.11
		Education	8	14.00	1.41
	Total	Age	23	23.92	5.76
		Education	23	14.57	2.21
Female	No Interference	Age	9	23.80	7.40
		Education	9	14.33	1.50
	Verbal Interference	Age	9	24.09	7.12
		Education	9	14.11	1.17
	Spatial Interference	Age	10	20.87	1.35
		Education	10	14.00	1.33
	Total	Age	28	22.85	5.84
		Education	28	14.14	1.30
Total	No Interference	Age	17	24.06	6.59
		Education	17	14.65	2.09
	Verbal Interference	Age	16	23.59	5.91
		Education	16	14.38	1.86
	Spatial Interference	Age	18	22.41	4.99
		Education	18	14.00	1.33
	Total	Age	51	23.33	5.78
		Education	51	14.33	1.76

Note: There were 2 missing age and education values.

Table E2

Mean Error Scores (in Degrees) for Responses to Landmarks via Different Cueing Modalities

Gender	Type of Interference	Retrieval Modality	*n*	*M*	*SD*
Male	No Interference	Verbal	8	23.58	9.57
		Visual	8	65.45	39.95
	Verbal Interference	Verbal	8	45.46	23.34
		Visual	8	86.53	40.51
	Spatial Interference	Verbal	8	68.90	48.37
		Visual	8	93.49	30.48
	Total	Verbal	24	45.98	35.54
		Visual	24	81.82	37.63
Female	No Interference	Verbal	9	25.09	20.19
		Visual	9	61.33	35.55
	Verbal Interference	Verbal	10	59.21	31.70
		Visual	10	86.38	41.53
	Spatial Interference	Verbal	10	52.59	36.61
		Visual	10	100.40	40.28
	Total	Verbal	29	46.34	32.99
		Visual	29	83.44	41.23
Total	No Interference	Verbal	17	24.38	15.64
		Visual	17	63.27	36.53
	Verbal Interference	Verbal	18	53.10	28.39
		Visual	18	86.44	39.86
	Spatial Interference	Verbal	18	59.84	41.74
		Visual	18	97.33	35.41
	Total	Verbal	53	46.18	33.84
		Visual	53	82.71	39.27

Table E3

Mean Error Scores (in Degrees) in Pointing to Targets at Different Levels of Exposure to Environmental Stimuli

Gender	Type of Interference	Level of Exposure	*n*	*M*	*SD*
Male	No Interference	Novel	8	23.58	9.57
		Intermediately-learned	8	13.69	6.05
		Over-learned	8	10.83	4.30
	Verbal Interference	Novel	8	45.46	23.34
		Intermediately-learned	8	18.82	9.20
		Over-learned	8	10.35	6.33
	Spatial Interference	Novel	8	68.90	48.37
		Intermediately-learned	8	13.50	5.34
		Over-learned	8	8.96	3.27
	Total	Novel	24	45.98	35.54
		Intermediately-learned	24	15.33	7.20
		Over-learned	24	10.04	4.66
Female	No Interference	Novel	9	25.09	20.19
		Intermediately-learned	9	13.67	8.38
		Over-learned	9	7.74	4.36
	Verbal Interference	Novel	10	59.21	31.70
		Intermediately-learned	10	10.97	4.70
		Over-learned	10	10.25	4.40
	Spatial Interference	Novel	10	52.59	36.61
		Intermediately-learned	10	13.13	6.16
		Over-learned	10	7.16	3.46
	Total	Novel	29	46.34	32.99
		Intermediately-learned	29	12.55	6.39
		Over-learned	29	8.41	4.17
Total	No Interference	Novel	17	24.38	15.64
		Intermediately-learned	17	13.68	7.15
		Over-learned	17	9.19	4.48
	Verbal Interference	Novel	18	53.10	28.39
		Intermediately-learned	18	14.46	7.91
		Over-learned	18	10.30	5.17
	Spatial Interference	Novel	18	59.84	41.74
		Intermediately-learned	18	13.29	5.65
		Over-learned	18	7.96	3.40
	Total	Novel	53	46.18	33.84
		Intermediately-learned	53	13.81	6.85
		Over-learned	53	9.15	4.43

Table E4

Mean Response Times (in Seconds) to Landmarks via Different Cueing Modalities

Gender	Type of Interference	Retrieval Modality	*n*	*M*	*SD*
Male	No Interference	Verbal	8	5.28	1.73
		Visual	8	6.04	2.09
	Verbal Interference	Verbal	8	6.12	1.90
		Visual	8	6.67	2.43
	Spatial Interference	Verbal	8	5.79	1.49
		Visual	8	6.23	1.54
	Total	Verbal	24	5.73	1.68
		Visual	24	6.31	1.98
Female	No Interference	Verbal	9	5.31	1.42
		Visual	9	6.23	2.09
	Verbal Interference	Verbal	10	6.63	2.15
		Visual	10	7.44	1.61
	Spatial Interference	Verbal	10	6.26	2.24
		Visual	10	6.21	2.35
	Total	Verbal	29	6.09	1.99
		Visual	29	6.64	2.05
Total	No Interference	Verbal	17	5.29	1.52
		Visual	17	6.14	2.03
	Verbal Interference	Verbal	18	6.40	2.00
		Visual	18	7.10	1.99
	Spatial Interference	Verbal	18	6.05	1.90
		Visual	18	6.22	1.98
	Total	Verbal	53	5.93	1.85
		Visual	53	6.49	2.01

Table E5

Mean Response Times (in Seconds) to Targets of Different Levels of Exposure to Environmental Stimuli

Gender	Type of Interference	Level of Exposure	*n*	*M*	*SD*
Male	No Interference	Novel	8	5.66	1.76
		Intermediately-learned	8	3.75	.90
		Over-learned	8	3.63	1.15
	Verbal Interference	Novel	8	6.39	2.09
		Intermediately-learned	8	4.24	.94
		Over-learned	8	3.62	.69
	Spatial Interference	Novel	8	6.01	1.45
		Intermediately-learned	8	4.03	.90
		Over-learned	8	3.55	.79
	Total	Novel	24	6.02	1.74
		Intermediately-learned	24	4.01	.90
		Over-learned	24	3.60	.86
Female	No Interference	Novel	9	5.77	1.68
		Intermediately-learned	9	3.97	.67
		Over-learned	9	3.64	.61
	Verbal Interference	Novel	10	7.03	1.54
		Intermediately-learned	10	4.17	.52
		Over-learned	10	3.82	.54
	Spatial Interference	Novel	10	6.23	2.20
		Intermediately-learned	10	4.26	1.31
		Over-learned	10	3.82	1.06
	Total	Novel	29	6.36	1.84
		Intermediately-learned	29	4.14	.88
		Over-learned	29	3.77	.75
Total	No Interference	Novel	17	5.72	1.67
		Intermediately-learned	17	3.87	.77
		Over-learned	17	3.63	.88
	Verbal Interference	Novel	18	6.75	1.78
		Intermediately-learned	18	4.20	.71
		Over-learned	18	3.74	.60
	Spatial Interference	Novel	18	6.13	1.86
		Intermediately-learned	18	4.16	1.12
		Over-learned	18	3.70	.93
	Total	Novel	53	6.21	1.79
		Intermediately-learned	53	4.08	.88
		Over-learned	53	3.69	.80

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