SPATIAL MEMORY CHANGES IN ADULTHOOD

by

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Abstract

The main goal of the research was to increase our understanding of spatial memory changes in adulthood. Four questions were examined in two experiments. Do age-related changes in spatial memory occur in real-life situations? If so, do they increase linearly across the adult life-span? Do older adults benefit more than young adults from being informed about an upcoming memory test? Do age-related changes in performance depend on the type of spatial memory test?

The first experiment involved a real-life setting--a science center exhibit on memory. Subjects were 302 visitors to the exhibit (approximately equal numbers of men and women), and ranged in age from 15 to 74 years. They were asked to recollect the locations of items displayed in the exhibit. For these subjects, spatial memory remained stable until about 60 years of age, and then declined sharply.

The second experiment, conducted in a laboratory, was designed to examine age-related changes in spatial memory under more controlled conditions, while keeping the tasks as similar as possible to a real-life situation. For that purpose, subjects were asked to play the role of a secretary in a simulated office. Subjects were 64 university undergraduates (mean age = 20.1 years) and 32 adults over 65 years of age (mean age = 71.2 years). Half of subjects in each age-group were informed that spatial memory would be tested, whereas others were not. Subjects were required to recollect the locations of items they had used to complete a series of secretarial tasks, either by indicating their locations

on a map of the office (the map test), or by relocating them in the office (the relocation test). The results of this experiment showed that (1) the intentional instructions improved spatial memory test performance of older but not young adults, (2) both older and young adults performed higher on the relocation test than on the map test, but (3) advantage due to the relocation test was larger for older than for young adults.

The results of both experiments are discussed within a modified transfer-appropriate-processing (TAP) view (cf., Morris, Bransford, & Franks, 1977). This view claims that performance on any memory test is dependent on the degree of overlap between mental operations employed at study and test (Kolers, 1975, 1979). An extension of this view states (Craik, 1983) that study and test tasks can be arranged on a continuum that reflects the extent to which performance depends on subject-initiated processing, and the extent to which it is initiated and guided by the environment. The environmental support includes the cues present at test and instructions given to subjects (Graf, 1990, 1991). According to the modified TAP view, older adults experience difficulty carrying out self-initiated processing, and are, therefore, more dependent than young adults on environmental support to initiate and guide processes required for effective remembering (Craik, 1983; Graf, 1990).

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Chapter one

INTRODUCTION AND OVERVIEW

Introduction

Remembering spatial information is an important skill in everyday life. We use spatial memory to recollect the locations of objects around us, and to find our way around places. In this way, spatial memory helps us, for example, to find where we left the car keys, where we parked the car at the supermarket, or to find our way around a new neighborhood.

Two important distinctions are relevant to my research on spatial memory. One is between episodic and semantic memory proposed by Tulving (1972, 1983), and the other is between small-scale space and large-scale space (Kirasic & Allen, 1985). According to Tulving's definition, episodic memory is memory for information about temporally dated personal episodes or events, and temporal-spatial relations among them. By contrast, semantic memory is memory for knowledge and facts, the meanings of words, concepts, and relations among them. By these definitions, recollecting where we left the car at a shopping mall is an episodic memory task, whereas recollecting the geographical location of Vancouver on a map of North America is a semantic memory task.

Spatial memory tasks can involve a large- or small-scale space. A large-scale space has been defined as an area that cannot be perceived in its entirety from a single standpoint within the boundaries of the space itself (Kirasic & Allen, 1985). Thus, large-space tasks require movement through the area, and integration of spatial information obtained from many viewpoints. An example of a large-space task is learning about a new shopping mall. Small-space tasks do not have any such requirements because we can perceive small-scale spaces in their entirety from a single viewpoint. An example of a small-space task is learning about a table top array of objects.

My thesis focuses on spatial memory for objects encountered at a particular time and place with objects distributed across a large-scale space. It examines age-related changes in performance on large-space, episodic spatial memory tasks. It is well established that older adults experience difficulties on many episodic memory tasks (Craik, 1977). The question is whether they experience similar difficulties on episodic spatial memory tasks. Research on age-related changes in spatial memory has been growing in the last decade, but many questions still remain. The goal of the research described in this thesis is to answer some of these questions, and thereby to extend our understanding of age-related changes in spatial memory.

Motivation

A number of questions can be asked about age-related changes in spatial memory. Is spatial memory of old people inferior to that of young people? How does spatial memory change across the adult life-span? Do age-related changes in remembering of spatial information reflect the use of different study and test strategies by different age-groups? When compared to young people, do old people benefit more when informed about an upcoming memory test than when not so informed, or when to-be-remembered materials and their environments are made distinctive?

These and related questions have been examined by many laboratory studies. The result showed that when compared to young people, old people experience difficulties on a variety of spatial memory tasks (e.g., Cherry & Park, 1989; Hess & Slaughter, 1990; Light & Zelinski, 1983; Naveh-Benjamin, 1987, 1988; Park, Puglisi, & Sovacool, 1983; Perlmutter, Metzger, Nezworski, & Miller, 1981; Pezdek, 1983; Schear & Nebes, 1990; Thomas, 1987; Waddell & Rogoff, 1981; West, 1992; Zelinski & Light, 1988). They also suggest that performance of older adults improves more than that of young adults when subjects are informed about a forthcoming spatial memory test (e.g., Naveh-Benjamin, 1987, Park et al., 1983, Waddell & Rogoff, 1987), or when to-be-remembered materials and their environments were made more distinctive (Sharps & Gollin, 1987). These general findings must be interpreted with caution, however, for several reasons.

The most important reason for caution is the fact that a typical study has only two groups of subjects: elderly adults around 70 years of age, and university students around 20 years of age. Consequently, the results from such a study cannot tell us what is the specific nature of age-related changes in spatial memory performance, that is, whether spatial memory performance declines gradually across age groups, or whether it remains intact until a certain age and then declines rapidly. Another major reason for interpretive caution is the fact that most laboratory studies use objects and tasks that do not resemble those encountered by people in real-life situations. To illustrate, some laboratory studies ask subjects to view and later recollect various arrays of cards with drawings or names of objects. It is unclear whether recollection of locations of such cards provides an index of spatial memory for objects and places, or more generally, whether the findings from such laboratory studies generalize to real-life situations.

To remedy some of the shortcomings of the extant laboratory research, this thesis examined spatial memory performance across a wide range of ages, in a real-life setting. The goal of the research was to examine how spatial memory changes across the adult-life span, and to find out whether findings from laboratory research generalize to a real-life situation.

Two experiments examined these issues. The first was conducted in a real-life setting--as part of a memory exhibit. Subjects were visitors to the exhibit. Spatial memory performance was assessed by asking them to recollect locations of items displayed at the exhibit. The experiment also examined how spatial memory is affected by an intentional vs. incidental manipulation. In the intentional condition, subjects were informed about an upcoming spatial memory test prior to entering the exhibit; in the incidental condition, they were not so informed.

The second experiment, conducted in the laboratory, was designed to validate the findings from the first under more controlled conditions while keeping the tasks as similar as possible to a real-life situation. For that purpose, an office was set up, and subjects were asked to play the role of a secretary. Spatial memory performance was assessed by asking subjects to recollect the locations of items they had used earlier to complete a series of secretarial tasks. The experiment included two different kinds of spatial memory tests thereby giving insight into more general aspects of test performance.

Overview

The thesis has four additional chapters. Chapter two reviews previous research on spatial memory; it briefly identifies the main issues in spatial memory research, and reviews in detail research on age-related changes in spatial memory and the conditions that promote remembering of spatial information in the elderly. In addition, the chapter outlines the theoretical framework that guided my research, and it specifies the goals of my research in detail.

Chapter three describes a naturalistic study that examined age-related changes in spatial memory as part of an exhibit on memory. Subjects of this study were visitors to the exhibit, and were from a wide range of ages (15-74 years). When they left the exhibit, they were asked to recollect the locations of items displayed in the exhibit. There were two basic conditions. In an intentional condition, subjects were informed about the impending spatial memory test before they entered the exhibit; in an incidental condition, they were not so informed.

Chapter four describes a laboratory study, designed to validate the findings of the previous study, but under more controlled conditions. In this study, subjects were asked to play the role of a secretary. They were placed in an office and were asked to carry out tasks that a secretary might do on a typical day, such as filing mail. Subjects' spatial memory performance was assessed by asking them to recollect the location of items they had used to complete the secretarial tasks. The study examined different ways of testing spatial memory by asking subjects either (a) to relocate the items where they had appeared during study (called the *relocation test*), or (b) to indicate their locations on a map (called the *map test*).

The final chapter, the general discussion, summarizes the main findings, discusses their implications, and it addresses some of the limitations of the two experiments. The discussion also relates my findings to previous research on age-related changes in spatial memory.

Conclusion

The overall goal of the thesis is to advance our understanding of age-related changes in spatial memory by examining how it changes across a wide range of the adult life-span, and by generalizing previous laboratory findings to a real-life situation. Furthermore, the thesis also contributes to our understanding of spatial memory by bringing a new method--the office/secretary scenario--to this research area, and by comparing performance across different spatial memory tests.

Chapter 2

REVIEW OF EMPIRICAL AND THEORETICAL WORK ON SPATIAL MEMORY CHANGES ACROSS THE ADULT LIFE-SPAN

Introduction

Remembering spatial information is one of the most important skills that is used by all people in many everyday situations. We rely on spatial memory to recollect where we left things such as car keys or glasses, and to find our way around places such as a route to the restaurant that we have visited only once before. Although spatial memory is revealed in many other instances, it is here defined as memory for locations of objects encountered at a particular time and place.

This chapter reviews the previous research on spatial memory changes across the adult life-span. It outlines a theoretical notion--the automaticity view--that has guided research on spatial memory in adulthood, and reviews the major findings that have emerged. The chapter also outlines the theoretical framework that guided my research, and specifies the goals of my work.

Automaticity view and age-related changes in spatial memory

The focus of the previous research on age-related changes in remembering of spatial information was to examine whether or not the encoding of such information is automatic. This type of research was motivated by a proposal that the encoding of spatial information is genetically "prepared" and thus automatic (Hasher & Zacks, 1979). This section outlines this proposal and describes how it explains age-related changes in memory.

Hasher and Zacks (1979) formulated an influential framework that has guided many studies on age-related changes in memory performance. Their view is based on two assumptions. The first is that memory processes vary in degree of attentional requirements. Hasher and Zacks distinguished between automatic and effortful processes. Automatic processes operate without a need for attentional resources. This is because at least some automatic processes are genetically prepared; their function is to encode episodic information fundamental to human existence including spatial, temporal, and frequency-of-occurrence information. Due to their nature, automatic processes operate equally well under intentional and incidental study conditions, and are not influenced by instructions or by practice. In contrast, effortful processes demand attentional resources; they are initiated and guided by subject's intention, and include rehearsal, elaborative, and organizing processes. Because effortful processing is under conscious control, subjects may be induced to use effortful processes for solving a memory task.

The second assumption of Hasher and Zacks's (1979) view, and also of other theories of cognitive aging (e.g., Craik, 1983, 1991; Salthouse, 1982, 1985, 1988), is that the amount of attentional resources available for processing diminishes with aging. Consequently, an age-related decrease in performance can be expected on tasks that involve effortful processes. In contrast, no age-related changes in performance are anticipated on tasks that involve mainly automatic processes since automatic processes are not dependent on the limited pool of attentional resources. By this view, it follows that older adults should perform as well as young adults on tests that require them to remember spatial, temporal, and frequency-of-occurrence information, since such information is assumed to be processed automatically.

The automaticity view was very influential in research on aging and memory performance. However, the research findings accumulated during the last decade often contradict the automaticity view. Kausler (1991) reviewed research on aging and performance on tasks that are supposedly automatic. He concluded that, contrary to the automaticity view, aging is associated with a decrease in performance on tests that require remembering of the frequency with which specific events occurred or the time when they occurred. In the frequency-of-occurrence memory tests, subjects are typically asked to study lists of digits, words, or pictures. The tested items appear with various frequencies in such study lists. In the subsequent test, subjects are asked to judge how many times each item has occurred at study (e.g., Warren & Mitchell, 1980) or, alternatively, they are given two items and asked which one has occurred more frequently (e.g., Salthouse, Kausler, & Saults, 1988a). In the temporal memory tests, subjects are again presented with lists of words or pictures. After the presentation, they are tested on their knowledge of the temporal sequencing of target items. For example, they are presented with two items from the list and asked to decide which one had occurred most recently (e.g, Perlmutter et al., 1981). Thus, these findings suggest that the automaticity view as proposed by Hasher and Zacks (1979) needs to be modified.

Review of empirical work on age-related changes in spatial memory

Most studies that examined age-related changes in spatial memory performance were guided by the automaticity view. However, the results of these studies are inconsistent; age-related changes are absent in some studies of spatial memory (Waddell & Rogoff, 1981, 1987; Sharps & Gollin, 1987; Ellis, Katz, & Williams, 1987), whereas they are present in many others (e.g., Light & Zelinski, 1983; Naveh-Benjamin, 1987, 1988; Park et al., 1983; Perlmutter et al., 1981; Read, 1987; West, 1992; Zelinski & Light, 1988).

What are the possible sources of these ambiguous findings? Close examination of the literature suggests that age effects in spatial memory performance depend (1) on the method of locating target items in space, and (2) on the type of processing at study.

Effects due to the method of locating targets. Age-related changes in spatial memory performance have been examined by means of several different spatial memory tests. The findings reveal that the size of the age effect varies across the different tests. It then becomes important to identify the specific characteristics of these tests which mediate variations in the size of age-related differences in performance on spatial memory tasks.

The size of age-related changes in spatial memory test performance seems to vary according to how targets are located, either in an abstract grid or matrix, or in a concrete, familiar context like a room with furniture. Table 1 lists various methods for locating targets: matrix, map, real-life, 2-field, and 4-field methods. The most commonly used method for locating targets is the *matrix method.* It presents subjects with small, common objects arranged in 6x6 or 36-field matrix. Not all cells of the matrix are occupied by targets, which prevents subjects from increasing their performance on the test by simply remembering the order of the targets (e.g., Naveh-Benjamin, 1987; Puglisi, Park, Smith, & Hill, 1985). Another method of locating targets in space involves the use of a *map.* Subjects are shown a small section of a simple tourist-like city map containing drawings of city buildings and monuments such as townhouses, the city hall, and fountains (e.g., Light & Zelinski, 1983). The *real-life method* presents subjects with real-life objects or their toy counterparts placed either in real-life settings or in elaborate models of such settings (e.g., Waddell & Rogoff, 1981). The *two-field method* presents subjects with simple drawings of objects, or words, placed in either the left or right half of slides (e.g., Park, Puglisi, & Lutz, 1982). The *four-field* method locates drawings or photographs of objects in the different quadrants of slides, cards, or double-pages of a picture book (e.g., McCormack, 1982; Park et al., 1982).

Table 1

Methods of locating targets in space used by the studies that examined age-related changes in spatial memory.

Name Description	Target materials	Examples
MATRIX Subjects are presented with targets arranged in the cells of a 6x6 or 36 field matrix.	words line-drawings objects	Naveh-Benjamin (1987, 1988); Puglisi et al. (1985)
MAP Subjects are shown targets as part of a tourist-like city map. Targets are pictures of city buildings such as the city hall.	line-drawings	Perlmutter et al. (1981); Light & Zelinski (1983); Zelinski & Light (1988)
REAL-LIFE Subjects are presented with targets placed either in a real-life setting or in elaborate models of such settings.	objects	Bruce & Herman (1986); Sharps & Gollin (1987); Waddell & Rogoff (1981, 1987)
2-FIELD Subjects view a long series of slides, each slide containing one target placed in either the left or right half of a slide.	words line-drawings	Park et al. (1982)
4-FIELD Subjects view a long series of slides, each slide containing 4 targets placed in different quadrants.	words line-drawings photographs	Ellis et al. (1987); McCormack (1982); Park et al. (1982)

A comparison of the methods of locating targets shows that they can be ordered in terms of familiarity of target locations. In some methods, the target locations are specified in very abstract terms, whereas in others they are given in concrete, everyday terms. For example, a location of a toy car placed in a cell of 6x6 matrix is identified as the cell in the third row from the bottom and in the second column from the left. Identifying locations in this way is abstract and not common in everyday situations. In contrast, the location of a toy car parked in the driveway of a real-life model is easily described in concrete everyday terms. Similarly, target locations in the two- and four-field methods can also be identified in relatively concrete, familiar terms; the locations are easily identified as being, for example, on the left side of a slide, or in the upper left corner of a slide.

While older and young adults are likely to be equally familiar with locating targets in concrete contexts such as room with furniture, older adults may be less familiar with locating targets in an abstract context such as a 6x6 matrix. Older adults do not ordinarily practice solving abstract tasks in everyday situations--a skill relevant to locating targets in abstract contexts, whereas young adults such as college students exercise solving abstract tasks in academic settings (Kausler, 1982; Labouvie-Vief, 1977; Schaie, 1978).

The familiarity of target locations may mediate variations in the size of age effects in performance. Logan (1985, 1988a, 1988b) suggested that automaticity is the result of experience and use rather than being a special genetic endowment. He assumes that encoding of information into memory and retrieval from memory are necessary consequences of attending to a target stimulus. It follows from this assumption that with experience we build up a large collection of memories surrounding any familiar common situation. Logan argues that because of these memories, information processing occurs more automatically in familiar situations. By this reasoning, and the assumptions about aging outlined earlier, we might expect no or only small age-effects on some spatial memory tasks (e.g., real-life), and larger age-effects on more abstract tasks (e.g., matrix).

A meta-analysis of the findings from previous studies supports this idea. Figure 1 shows the performance of older adults as a proportion of the performance of young adults for the different methods of locating targets. The proportions were obtained by averaging the findings across the studies that used the same method for locating targets (for a list of the included studies see Appendix A). Relative to young adults, older adults perform poorly on the matrix and map methods but older adults' performance is almost as high as that of young adults on the real-life model and four-field methods. Thus, these findings suggests that the size of age related changes in performance are smaller when target locations are more easily discriminated in concrete, familiar, everyday terms.

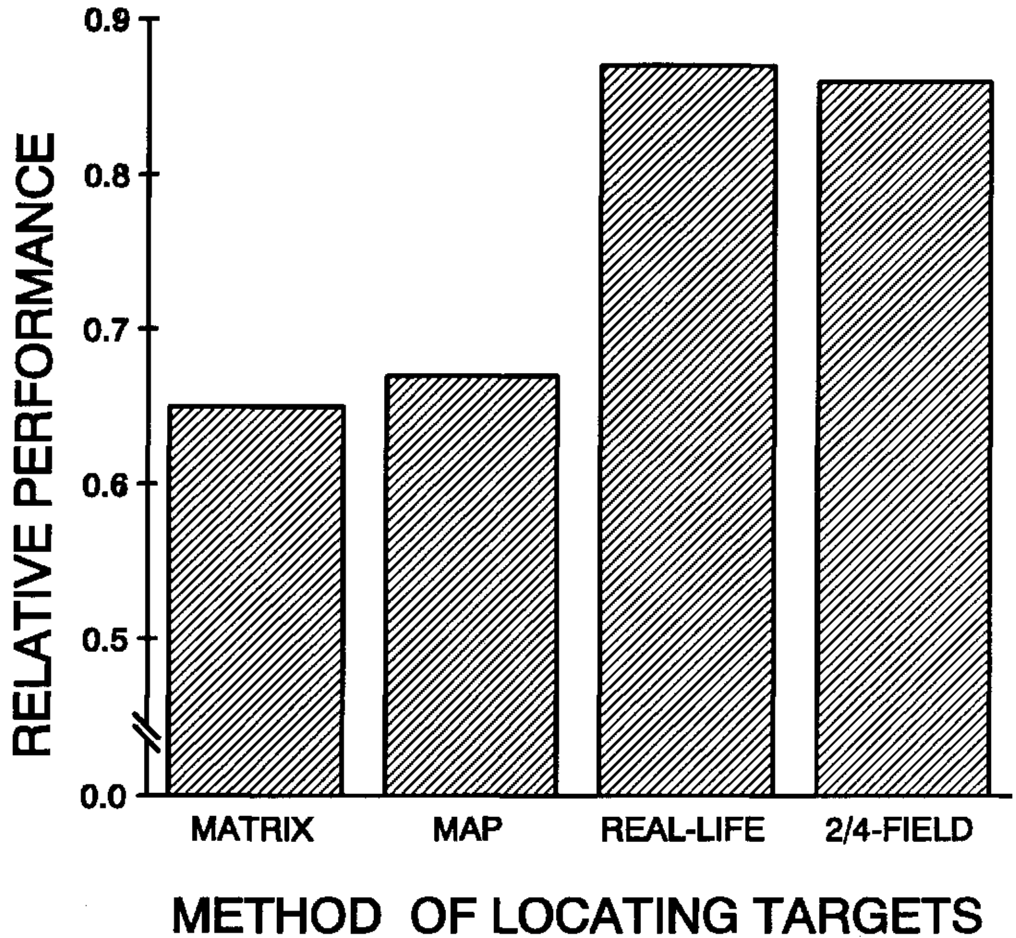

Figure 1. Spatial memory test performance of older adults relative to that of young adults for different method of locating targets in space. The proportions were obtained by averaging the results of various studies that used the same method of locating targets. Relative to young adults, older adults performed poorly on the matrix and map methods, whereas they performed almost as high as young adults on the real-life and 2-/4-field methods.

Effects due to a type of processing at study. The automaticity view claims that the encoding of spatial information is independent of attention and thus, is not improved by the intent to remember such information (Hasher & Zacks, 1979). This claim has been examined by many studies. Several studies have examined both the effects of aging and the effect of intentional/incidental instructions on spatial memory test performance (e.g., Naveh-Benjamin, 1987, 1988; Park et al., 1983), and thus, they reveal how performance varies across age-groups. In this section, I will present evidence that the effects of study task instructions on spatial memory test performance depend on the type of processing induced by the intentional versus incidental instructions, and that the size of this effect changes with age. Older adults appear to benefit more from being informed about the upcoming spatial memory test.

According to the automaticity view, performance should be the same when subjects are informed about an upcoming spatial memory test (intentional instructions) and when they are not so informed (incidental instructions). However, the research findings are inconsistent. While some studies did not find any effect of instructions on spatial memory test performance (e.g., McCormack, 1982), others found that such instructions facilitated performance on the test (e.g., Mandler, Seegmiller, & Day, 1977; Naveh-Benjamin, 1987, 1988).

Mandler et al. (1977) have shown that the major reason for the inconsistent findings is the different types of instructions used in various studies. In a typical study, the standard intentional instructions require subjects to memorize target items and their locations, whereas the standard incidental instructions (cf. Mandler et al., 1977) only ask them to memorize the target items. Mandler et al. (1977) demonstrated that subjects who are given the standard incidental instructions often spontaneously process spatial information either because it is beneficial for the encoding of the targets themselves or because, in combination with a presentation method, such instructions induce subjects to anticipate a spatial memory test. It follows, Mandler and colleagues argued, that the standard incidental instructions do not guarantee a truly incidental encoding of spatial information.

According to Mandler et al. (1977), for true incidental encoding, a task must not lead subjects to anticipate any memory test for presented items, or for any information about their location in space. For example, one true incidental study task would be to ask subjects to estimate the price of individual target items (Mandler et al., 1977). Presumably, when subjects are given such a study task, they would not attempt to intentionally process spatial information since this is irrelevant to their task. Mandler and colleagues supported their argument by experimental evidence. Using the matrix method, they showed that subjects in an intentional condition performed better on this spatial memory test, but only when compared to subjects in the true incidental condition. No differences in performance were found between subjects in the intentional and standard incidental conditions. Thus, the Mandler et al. study established that the standard incidental instructions are inappropriate for examining the effect of intentional versus incidental processing of spatial information on a subsequent spatial memory test.

Subjects in the incidental condition can also be led to believe that processing of spatial information is irrelevant to their study task by giving them a practice study and test task first. Using the map method for locating targets, Light and Zelinski (1983) presented subjects in the intentional and standard incidental conditions with a practice map first, and tested them only for the information specified in the study instructions. Subjects in the standard incidental condition were tested both for memory of the targets and memory for their locations; therefore, they expected a final spatial memory test. In contrast, subjects in the incidental condition were tested only for memory of targets. Zelinski and Light argued that these subjects did not expect a final spatial memory test, and thus were not likely to spontaneously process spatial information during the study period. The results of the study were consistent with Light and Zelinski's expectations: subjects in the intentional condition performed better than those in the standard incidental condition on the spatial memory test.

The above evidence shows that the effect of intentional versus incidental manipulation depends on the type of processing induced by the intentional and incidental study tasks. Subjects in an incidental condition may process spatial information because it is beneficial to their study task. They may also process it because a study task context elicits such processing. By Logan's (1985, 1988a, 1988b) view of automaticity, subjects may process spatial information spontaneously in familiar, real-life situations since such processing may have become automatic through practice in such contexts. Thus, informing subjects about an upcoming spatial memory test may have little or no effect on their test performance. In contrast, when an incidental study task and its context does not lead subjects to process spatial information, informing them about an upcoming spatial memory test seems to improve their performance.

Contrary to the Hasher and Zacks' (1979) automaticity view, the examination of the previous research also suggests that, when compared to young adults, older adults may benefit more from being informed about an upcoming spatial memory test. Table 2 lists several studies that examined both the effects of age and study instructions on spatial memory performance. Some of these studies are not appropriate for assessing whether older and young adults are influenced differently by being informed about an upcoming spatial memory test. These are the studies that used inappropriate, standard incidental instructions, that failed to employ a practice task, or that suffer from ceiling or floor effects in performance. Only three studies are free of such problems and only these address the relationship between intentional/incidental processing and aging. The relevant studies are indicated in the last column of Table 2 (i.e., Naveh-Benjamin, 1987; Park et al., 1983 ; Waddell & Rogoff, 1987).

Table 2

Studies that examined both the effect of age and intentional vs. incidental study instructions on spatial memory test performance, and their relevance to the issue of whether older adults benefit more than young adults from being informed about an upcoming spatial memory test.

Author(s)	Were appropriate incidental instructions or a practice task used?	Were the means reported by age and by instructions?	Is the study free of the ceiling or floor effects?	Are the results of the study relevant to the issue?
McCormack (1982)	no	no	?	no
Park et al. (1985)	no	no	?	no
Light & Zelinski (1983)	yes	yes	no	no
Naveh-Benjamin (1988)	yes	yes	no	no
Naveh-Benjamin (1987)	yes	yes	yes	yes
Park et al. (1983)	yes	yes	yes	yes
Waddell & Rogoff (1987)	yes	yes	yes	yes

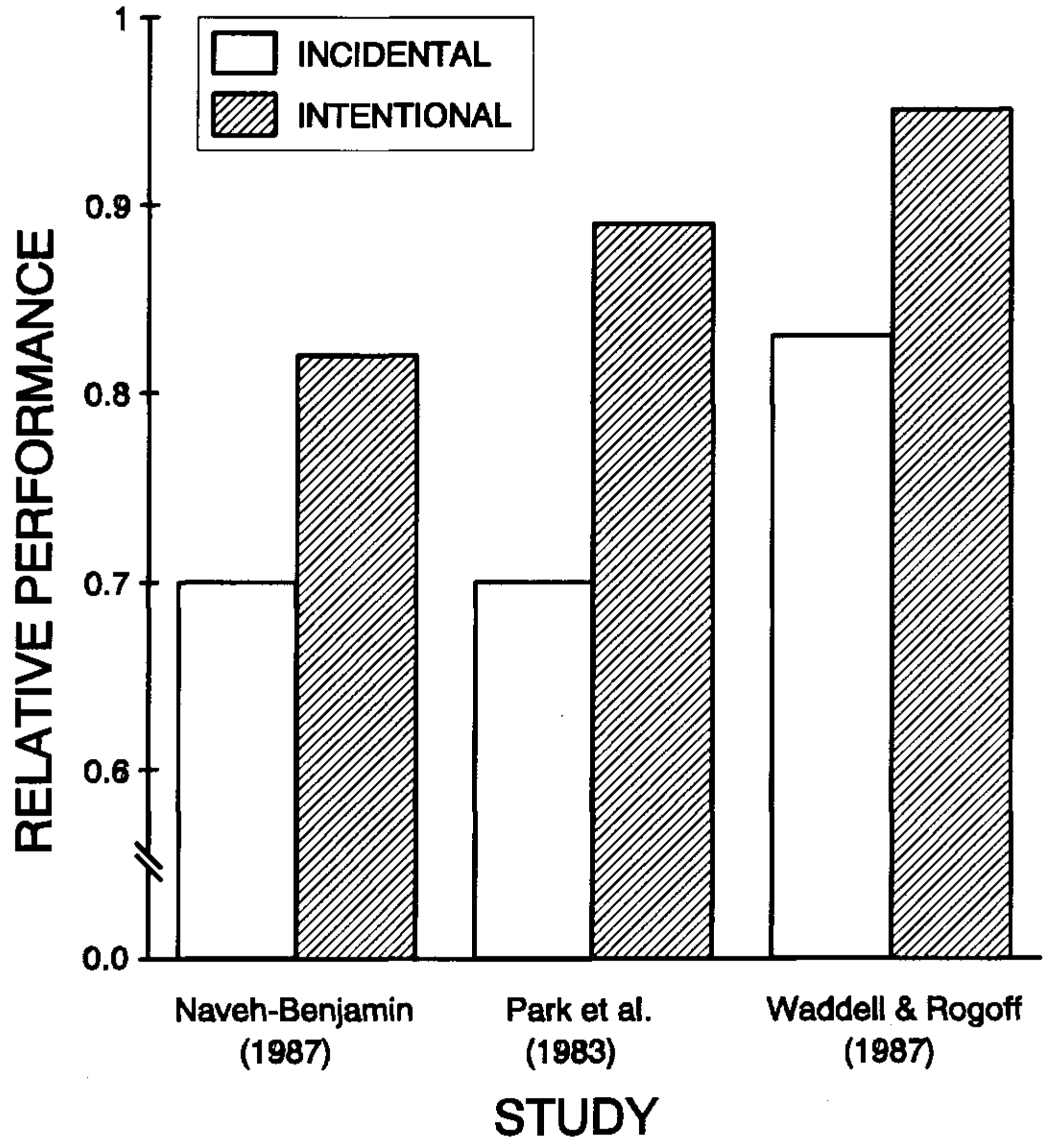

Figure 2. Spatial memory test performance of older adults relative to that of young adults by study condition in three spatial memory studies indicated in Table 2. The figure shows that the gap between the performance of older and young adults is smaller in the intentional than in the incidental condition. This suggests that older adults benefit more than young adults from being informed about an upcomming spatial memory test.

Figure 2 shows the mean levels of performance on spatial memory tests by age and by intentional versus incidental instructions for these three studies. The results show that the gap between the performance of older and young adults was smaller in the intentional than in the incidental condition in all three studies. Thus, they suggest that older adults may benefit more than young adults when informed about an upcoming spatial memory test. This interaction of age by study instruction was not significant for any of these studies. However, they were not designed to examine such interactions and thus suffered from low statistical power. The power to find a significant interaction of age by study instruction was less then .20 in all three experiments.

Summary and implications. The above review shows that age-related changes in spatial memory performance vary with the method of locating targets and with the type of processing induced by intentional and incidental study instructions. It suggests that the magnitude of age effects in performance may be reduced (1) when target locations are more easily discriminated in concrete and familiar as opposed to abstract terms, and (2) when subjects are informed about an upcoming spatial memory test.

The above findings are not consistent with the automaticity view (Hasher & Zacks, 1979) which maintains that the processing of spatial information is neither affected by age nor by intentional versus incidental manipulation. The automaticity view is also unable to explain why age effects vary across different methods for locating targets.

What are the alternative views? Logan (1988a, 1988b) has suggested an alternative view of the automaticity. In his view, automaticity is the result of repeated experience with relevant aspects of stimuli encountered in particular contexts. Thus, processing of spatial information may be more automatic in familiar, real-life situations, whereas it may require subject-initiated processing in unfamiliar situations. This view also suggests that different age-groups may benefit to different degrees from automatic processing since members of such groups may be differentially familiar with certain tasks and their contexts.

Theoretical view guiding my research: Transfer-appropriate-processing

This section presents the theoretical framework that has guided my research on age-related changes in spatial memory--a variation of Craik's (1983, 1991) transfer-appropriate-processing (cf. Morris, Bransford, & Franks, 1977) based view (Graf, 1990, 1991). Craik argued that memory is best understood in terms of operations involved in remembering and that age-related changes in performance reflect changes in operations that older versus young adults perform. In the following paragraphs, I will first briefly outline a TAP framework for memory research and then present Craik's extension for age effects in memory performance.

The transfer-appropriate-processing view of memory (Morris et al., 1977) conceptualizes remembering in terms of sensory, perceptual, and conceptual mental operations engaged by different study and test activities (Kolers, 1975, 1979; Kolers & Roediger, 1984). It argues that each task recruits a particular set of mental operations and that employing these operations increases the fluency with which they can be reapplied at a later time. Therefore, performance on a memory test will be facilitated to the extent to which the test task recruits the same operations as those engaged during the study. In other words, the TAP view claims that remembering is dependent on the degree of overlap between mental operations employed at study and test.

Craik (1983, 1991) extended this TAP view to account for age-related changes in performance on various memory tasks. He suggested that both study and test tasks differ in the degree to which they depend on subject-initiated or on environment-induced processing of relevant information. He argued that older people experience difficulties in carrying out self-initiated processing because such processing is dependent on the available capacity of processing resources that diminishes with aging. As a result, older adults are more dependent on environment-induced processing to support their memory performance. By this view, age-related changes in memory performance are minimized when the appropriate processing is induced or supported by the environment both at the time of study and at the time of test. In contrast, age-related changes may be large when the appropriate processing must be initiated by subjects themselves.

Craik (1983, 1991) proposed that all tests can be arranged on a continuum ranging from tests where performance is dependent on subject-initiated activities to those where it is supported by the test environment. Elaborating on Craik's ideas, Graf (1990, 1991) suggested that environmental support at test also includes the cues and instructions given to subjects. By this view, free recall tests are clustered at the subject-initiated activities end. On free recall tests subjects are given almost no cues and asked to think back and reconstruct the material they have encountered at study. In contrast, priming tests are clustered at the environment-supported activities end. On the identification test, for example, subjects are presented with the original study materials and asked to simply identify them. Finally, recognition tests are in between the two end-points of the continuum since they offer some environmental support but still involve a considerable amount of self-initiated processing. Subjects are presented with the original study materials, and required to decide whether or not they had encountered them at study.

How do we quantify the environmental support provided by various study tasks? Craik (1983, 1991) has suggested that environmental support at study is dependent on aspects such as the compatibility of tasks and materials with subjects' skills and knowledge, and on the instructions that are given to subjects. To illustrate, consider paired-associate learning. In order to be successfully associated in the subjects' minds, easy word pairs, for example "East-West", require little subject-initiated processing since such associations are very familiar, whereas difficult word pairs, such as "Interest-Spirit", require a considerable amount of subject-initiated processing. The environmental support at study can also be increased by study instructions. Subjects can be directed to process the relevant aspects of study materials, the aspects that they may not process on their own initiative.

Craik (1983, 1991) believed that older adults engage less in self-initiated elaborative processing required by a particular study or test task because such processing is dependent on some type of resources that irreversibly diminish with aging. However, it is not necessary to invoke the resource based explanation. Older adults may engage less in self-initiated processing because such processing requires the coordinated application of a number of component processes and older adults are no longer as fluent as they once were in executing and coordinating them (Graf, 1990, 1991).

Goals, hypotheses, and overview of the present research

In order to gain more insight into the nature of age-related changes in spatial memory, my research examined five specific questions: Are age-related changes in spatial memory performance found in real-life situations? How does spatial memory change across the adult life-span? Do older versus young adults benefit more from being informed about an impending memory test? Do age-related changes in performance depend on the type of spatial memory test? How are age-related changes in performance on spatial memory tests related to age-related changes in performance on other, traditional memory tests? In the following paragraphs, I will discuss the motivation behind each of these questions in detail.

Are age-related changes in spatial memory performance found in real-life situations? It has been argued that no age effects in spatial memory performance are observed in real-life situations (Waddell & Rogoff, 1981, 1987; Sharps & Gollin, 1987), but the evidence from individual studies that modeled real-life settings is inconsistent (e.g., Park, Cherry, Smith, & Lafronza, 1990; Read, 1987; Rohling, Ellis, & Scogin, 1991; Sharps, 1991; West, 1992). However, when laboratory models of real-life situations emulated real-life situations, they did not model people's interaction with objects and their settings. To illustrate, in lab models of real-life situations, subjects are typically asked to view a display of target items and later to recollect their locations. In contrast, in real-life situations, people actively interact with to-be-remembered items; they place car keys in a particular place, and later have to find them in their location. In view of the inconsistent findings and differences between laboratory models and actual real-life situations, it is unclear whether the findings from laboratory studies generalize to real-life situations. To remedy this shortcoming in previous research, this thesis examined age-related changes in spatial memory performance under conditions where subjects interact with real-life target materials in a real-life setting--in a science exhibit (Experiment 1), and in a model of a real-life setting--in a laboratory analogue of a secretary's office (Experiment 2).

How does spatial memory performance change across the adult life-span? Studies of spatial memory typically examine age-related changes in performance using only two groups of subjects: a group of young college students between the ages of 18 and 25, and a group of older, mostly retired adults over 65 years of age. As a result, it is not known precisely how spatial memory changes across the adult life-span. Does spatial memory performance decline gradually with age, or does it follow another, non-linear function?

At least two types of age-functions have been suggested in the literature. Salthouse (1982, 1988; Salthouse et al., 1988a) suggested that performance on memory and other cognitive tasks declines gradually with age since it is dependent on the available capacity of processing resources that diminishes linearly with age. In contrast, several researchers have suggested that performance on cognitive tasks may decline only after retirement, at about 65-70 years of age (Baltes & Labouvie-Vief, 1973; Labouvie-Vief, 1977; Labouvie-Vief & Chandler, 1978). By their view, age-related changes in performance may reflect changes in expectations, opportunities, life events, and environmental demands associated with age that lead older adults to adopt different modes of processing presented information. In comparison to young adults, older adults may prefer to process different aspects of presented information than young adults. For example, they may focus on meaning, or aesthetic aspects of presented stimuli, whereas younger adults may focus on quantitative aspects. Since the retirement age is a major event in an adult's life, it is possible that the most changes in cognitive performance come at retirement and thus, performance on memory and other cognitive tasks may decline only after retirement.

Do older versus young adults benefit more from being informed about an impending spatial memory test? If the encoding of spatial information is an automatic process as suggested by Hasher and Zacks (1979), the intentional versus incidental manipulation is expected to have little effect on spatial memory performance of either older or young adults. Alternatively, if age-related changes in spatial memory performance are mediated by changes in subject-initiated, strategic processing, informing all subjects about an upcoming spatial memory test is expected to induce both groups to focus on and/or to increase the processing of spatial information. However, if young adults are likely to process such information on their own initiative, informing them about an upcoming spatial memory test may not benefit them. In contrast, if older adults are less likely than young adults to process spatial information when left to their own devices but are able to process such information, informing them about an upcoming spatial memory test is more likely to improve their performance.

Do age-related changes in performance depend on the type of spatial memory test? The TAP based view of age-related changes in memory performance suggests that age effects vary with the type of test. It predicts that both older and young adults will perform better on tests that provide more environmental support, and that benefits will be larger for older than young adults. This thesis (Experiment 2) examines age-related changes in performance on two types of spatial memory tests: a map test and relocation test. On the map test, subjects are asked to indicate target locations on a map of the study settings; on the relocation test, they are asked to relocate targets in their original, study settings. Because of their nature, the relocation test provides more environmental support than the map test. Thus, I hypothesized that the overall level of spatial memory test performance would be higher on the relocation than on the map test, and that the difference between performance on the two tests would be larger for older than young adults. In another words, age-related changes in performance were expected to be smaller on the relocation test.

How are age-related changes in performance on spatial memory tests related to age-related changes in performance on other, traditional memory tests? A dominant view of cognitive aging claims that age-related changes in memory performance are due to decline in the available capacity of some general processing resources (e.g., Salthouse, 1988). By this view, an index of the processing resources available to each individual should account for age-related changes in memory performance. It has been suggested that an individual's performance on the digit span backward is one such index (Salthouse1988; Light, 1991). By this latter assumption, if age-effects on memory tasks are due to changes in the available capacity of processing resources, statistically controlling for the performance on the digit span backward should decrease the correlations between age and performance on memory tasks to zero. To examine this issue, this thesis examined the relationship between age, performance on spatial memory tests, and performance on the digit span backward test. In addition, the thesis compares spatial memory test performance with performance on two other traditional memory tests: the paired-associate test and the digit span forward.

Overview of my research. Two experiments were conducted in order to examine the above questions and hypotheses. The first was conducted in a real-life setting--as part of a science exhibit on memory. Subjects were visitors to the exhibit, and were from a wide age-range: 15 to 74 years. After exploring the exhibit, they were asked to recollect the locations of items displayed there. The second experiment, conducted in the laboratory, was designed to validate the findings of the first study under more controlled conditions while keeping the tasks as similar as possible to a real-life situation. For that purpose, an office was set up, and subjects were asked to play the role of a secretary. To obtain an index of their spatial memory performance, subjects were required to recollect the locations of items they had used to complete a series of secretarial tasks.

Chapter three

EXPERIMENT ONE

Introduction

The experiment had two specific goals. The first was to examine how spatial memory changes across the adult life-span. The second goal was to find out whether laboratory results showing that performance of older adults is inferior to that of young adults would generalize to a real-life situation. In addition, the study examined the effect of an intentional vs. incidental manipulation, and the effect of target distinctiveness on remembering of spatial information.

The experiment was part of a public memory exhibit in Vancouver. The subjects were visitors to the exhibit and were from a wide age range. Upon leaving the exhibit, subjects were given a floor plan of the exhibit and a booklet with photographs of the displayed items. A letter label was attached to each photograph. Subjects used the letter-labels to mark the locations of items on the floor plan. The measure of spatial memory performance was the number of items correctly located.

Method

Subjects. Subjects were 302 visitors to the exhibit, and ranged in age from 15-74 years. Males and females were approximately equally represented in each age decade. The distribution of subjects by age and gender is shown in Figure 3. All subjects participated on a voluntary basis.

Setting and materials. The study took place at the memory exhibit in Vancouver. A floor plan of the exhibit is shown by Figure 4. The size of the exhibit room was approximately 12 x 10 meters.

The items displayed in the exhibit served as the to-be-remembered materials. There were 52 items, including 29 paintings, 8 text panels, 8 panels of photographs, and 4 tables (3 tables displayed 2 items each, 1 table displayed only 1 item). Twenty-two of these items were selected for testing spatial memory performance. The locations of these items are indicated in Figure 4 by letter labels. Some displayed items were more distinctive than others. An abstract painting (item R), only one of its kind in the exhibit, was singled out as the most distinctive item.

A floor plan and a booklet with photographs of the displayed items (see Appendix B for examples) were used to assess subjects' spatial memory performance. The floor plan was printed on an 28 x 43 cm sheet of paper. Two booklets with photographs of 22 displayed items were made: one contained only black-and-white photographs and the other only color photographs. The photographs were placed in the booklets in a random order. A unique letter label was attached to each photograph. All photographs were 10 x 15 cm in size.

A card with a Likert-type scale was made in order to find out how much the subjects liked the exhibit. The choices listed on the card were:

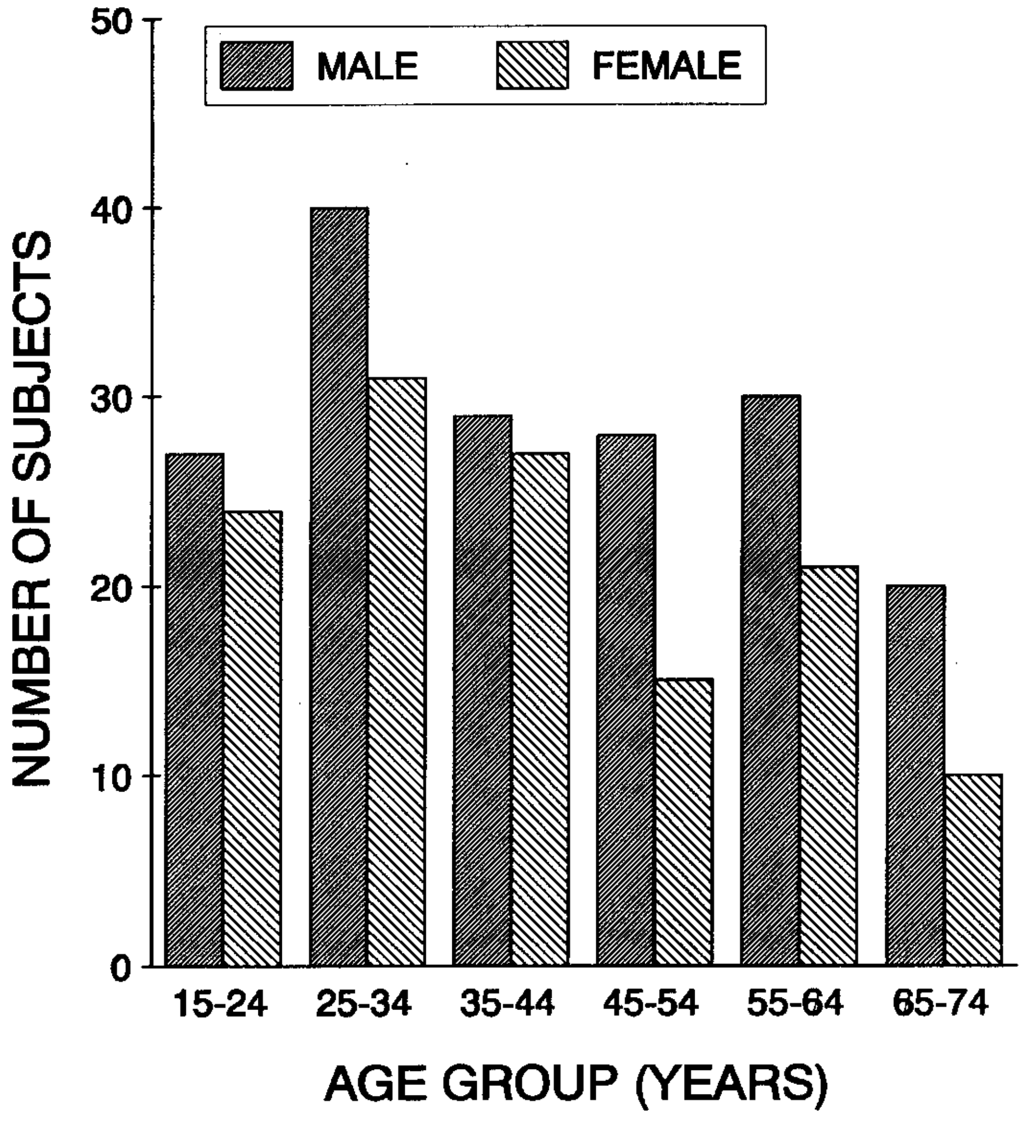

Figure 3. The distribution of subjects across age-groups. Note that women and men were approximately equally represented in each group.

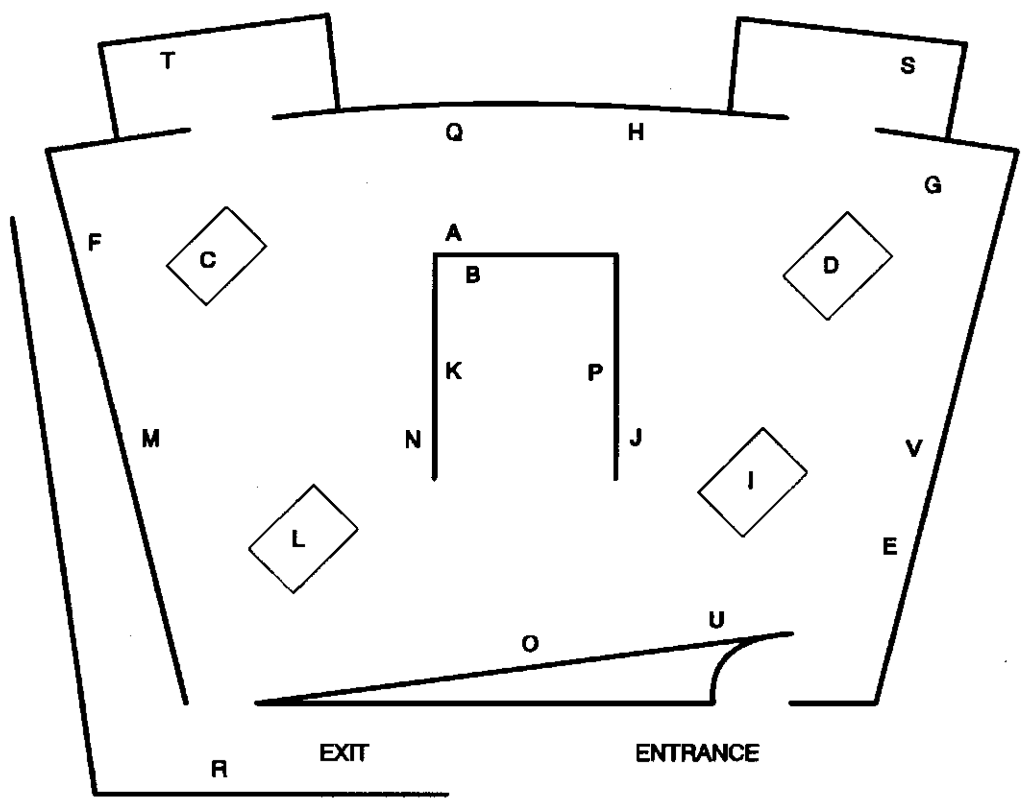

Figure 4. The floor plan of the memory exhibit. Subjects were given this plan without the labels. The labels indicate the locations of the items that subjects were required to recall. There were four types of materials: paintings (items E, V, G, S, H, Q, T, F, M, O, U, R), tables (items I, D, C, L), text panels (items J, A, N), and panels of photographs (items P, B, K).

I did not like it, I did not like or dislike it, I liked it somewhat, I liked it a lot, It was excellent.

Procedure. All subjects were tested individually. They participated in one of two conditions: intentional and incidental. In the intentional condition, visitors to the exhibit were asked to participate in the study on memory before they entered the exhibit room. If they gave their consent, the experimenter told them: "...I would like you to pay attention to what you will see in the exhibit and how the displayed items are arranged because I will ask you about it later. I will give you a memory test". In the incidental condition, visitors were asked to participate in the memory study only after they had left the exhibit room; therefore, they did not learn about the upcoming memory test until that time. Approximately 90% of visitors asked to participate in the study gave their consent, both in the intentional and incidental condition.

After exploring the exhibit, all subjects were asked to estimate how much time they spent in the exhibit room, and to indicate how much they liked the exhibit by choosing one of the statements on the liking scale card. Their gender and age was also recorded.

Spatial memory performance was tested next. Subjects were given the floor plan and one of the photograph booklets. They were asked to indicate the locations of the items on the floor plan. To indicate items' locations, subjects used the letter-labels displayed on the photographs; they wrote these labels on the floor plan. Subjects were asked to locate as many items as they could, but they were not required to locate all items. They were allowed to change their answers as often as they wished, and to take as much time completing the task as they needed. To ensure that no subject had repeated exposure to the exhibit, all were asked if it was their first visit to the exhibit.

Results

The results are organized in three parts. The first part focuses on age effects, the second part on item effects, and the third part on effects of other variables such as time spent in the exhibit on spatial memory test performance. A preliminary analysis showed that there were no effects due to the incidental vs. intentional manipulation, or to the black-and-white vs. color photograph set, and thus, the data were collapsed across these variables. The level of significance was set to $\alpha < 0.05$ for all statistical tests unless stated otherwise.

Age effects. The critical dependent measure was the number of items correctly located by each age-group. An item was scored as correctly located if its indicated location was on the correct structure, i.e. on the correct section of the wall, the right panel, or the right table (see p. 39 for another scoring method). Previous work has shown that this scoring procedure correlates highly with methods that measure whether or not an indicated location is within a certain distance of the actual one (Sharps & Gollin, 1986).

The mean number of items correctly located by subjects in each age group is shown in Figure 5. The figure shows that performance remained constant until the 6^{th} decade when it declined sharply.

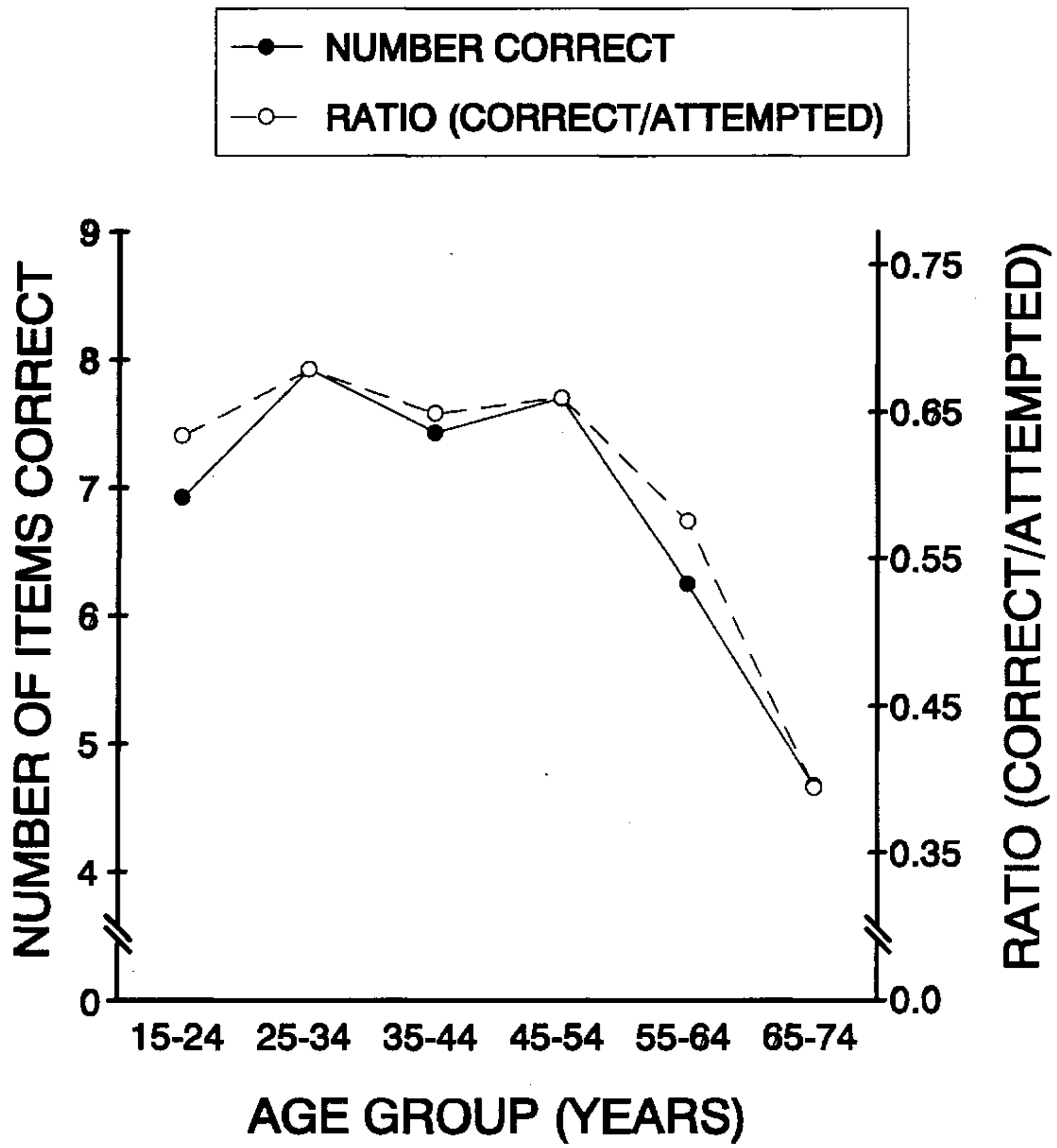

Figure 5. Overall spatial memory test performance by age-group. Performance did not decline until the 6th decade. This is indicated by the number of correctly located items and by the proportion of items correct out of those that subjects indicated on the exhibit plan. The latter measure of performance controls for possible undesirable effects due to age-related changes in item recognition. This result confirms laboratory findings that older people perform more poorly than young people.

A one-way ANOVA with age group as between subject factor performed on these data showed a significant effect of age, $F(5, 296) = 6.34$, $MSe = 8.96$. The Scheffe post hoc multiple contrasts method (Marascuilo & Serlin, 1988) was used to test whether performance was the same for the first four age groups, and decreased linearly thereafter using the following contrast coefficients: 1, 1, 1, 1, -1, -3. This trend was significant, $F(5, 296) = 28.83$.

For the spatial memory test, subjects were given the booklet of item-photographs and required to indicate the location of as many items as they could on the exhibit plan. Thus, older subjects may have performed more poorly than young adults on this test of spatial memory because they were able to recognize fewer items as opposed to recollecting fewer locations. To examine this possibility, a new score was computed for each subject by dividing a number of items that were correctly located by a number of items that each subject attempted to locate by indicating their locations on the exhibit map. This measure controls for possible undesirable effects due to age-related changes in item recognition. The analysis of these data confirmed the age-related pattern in performance described above; performance remained constant until the 6^{th} decade and then declined sharply (see Figure 5). An one-way ANOVA with age group as between subject factor performed on these data showed that the effect of age was significant, $F(5, 296) = 8.90$, $MSe = .019$. Scheffe post hoc multiple contrast method showed that the age-related trend as in the last analysis was significant, $F(5, 296) = 39.26$.

The scoring procedure counted an item as correctly placed if its indicated location was on the correct structure. Thus, the spatial memory test score of subjects who correctly placed two items on the same structure but in the wrong relative positions was not affected. It is possible that a scoring procedure sensitive to the objects' relative placement would reveal an age-related decline in performance earlier than in the 6^{th} decade. To examine this possibility, two paintings that were displayed next to each other on the same structure (item E and V in Figure 4, page 35) were selected for additional analysis. Subjects who indicated the locations of both paintings on the correct structure were classified according to whether or not they indicated their locations in a correct relative position. The proportions of subjects in each age group that correctly indicated the painting's relative positions is shown in Table 3. There is no evidence of an age-related decline on this measure of spatial memory performance. Loglinear analysis for frequency data confirmed that there are no differences in the proportions of subjects who correctly indicated the paintings' relative position, Likelihood ratio $\chi^2(5, \underline{N} = 80) = 3.28$, n.s.

The data were also analyzed for each type of material separately. Figure 6 shows the proportions of items correctly located by each type of material, by age group. The pattern of performance is similar across the materials, and performance declines for only the last two age groups--for subjects over 55 years of age. Due to low levels of performance, paintings and photographs were combined into one category called

Table 3

Experiment 1. The proportion of subjects in each age-group who located item E and item V in their correct relative position.

	Age-group (years)					
	15-24	25-34	35-44	45-54	55-64	65-74
proportion	.94	.85	.87	.90	.71	1.00
n^a	18	26	15	10	7	4

Note. [a]Number of subjects in each age-group who indicated locations of items E and V on the correct structure.

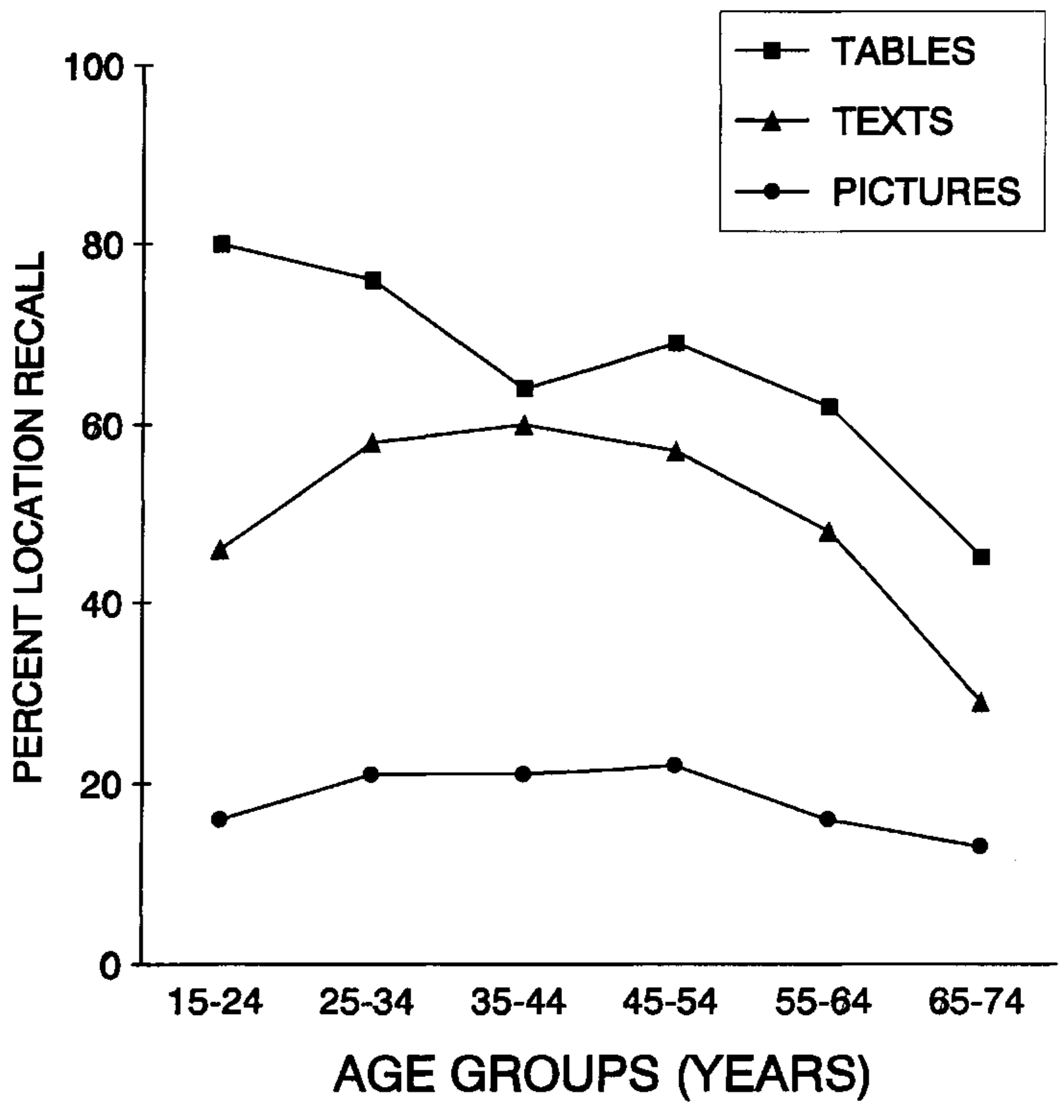

Figure 6. Spatial memory test performance by type of material and age-group. The pattern of performance was similar across materials, and only the oldest group showed a decline. Photos and paintings are plotted together in the figure; performance on these items taken separately is too close to zero to register significant age-related changes.

Pictures. One-way ANOVAs on these data revealed significant effects of age for tables, $F(5, 296) = 6.74$, $MSe = 0.090$, for texts, $F(5, 296) = 3.91$, $MSe = 0.126$, and for pictures, $F(5, 296) = 3.36$, $MSe = 0.017$. The same trend analysis as performed on the overall data confirmed that performance remained constant across the first four age-groups and declined for the last two age-groups. The results were significant for tables, $F(5, 296) = 19.06$, for texts, $F(5, 296) = 16.28$, and for pictures, $F(5, 296) = 11.47$.

Item effects. In studies that present subjects with target items in a sequential order, a usual finding is that early items are remembered very well, middle items most poorly, and if testing immediately follows the study period, the last few items are also very well remembered. To determine whether serial position effects occurred in this study, the paintings were numbered by their serial positions starting at the entrance and going through the exhibit in the same way as did most subjects, and the proportion of subjects who recollected the location of each painting was computed.

The Figure 7 shows this proportion for each individual painting by serial position. The location of the first painting (item E in Figure 4, page 35) was recollected best; and performance decreased with the painting's serial position. The location of the only abstract and thus distinctive painting (item R in Figure 4, see position 12 in Figure 7) was very well recollected. In contrast, the locations of the two paintings in the alcoves (items S, T, in Figure 4, see positions 4, 7, in Figure 7) were recollected

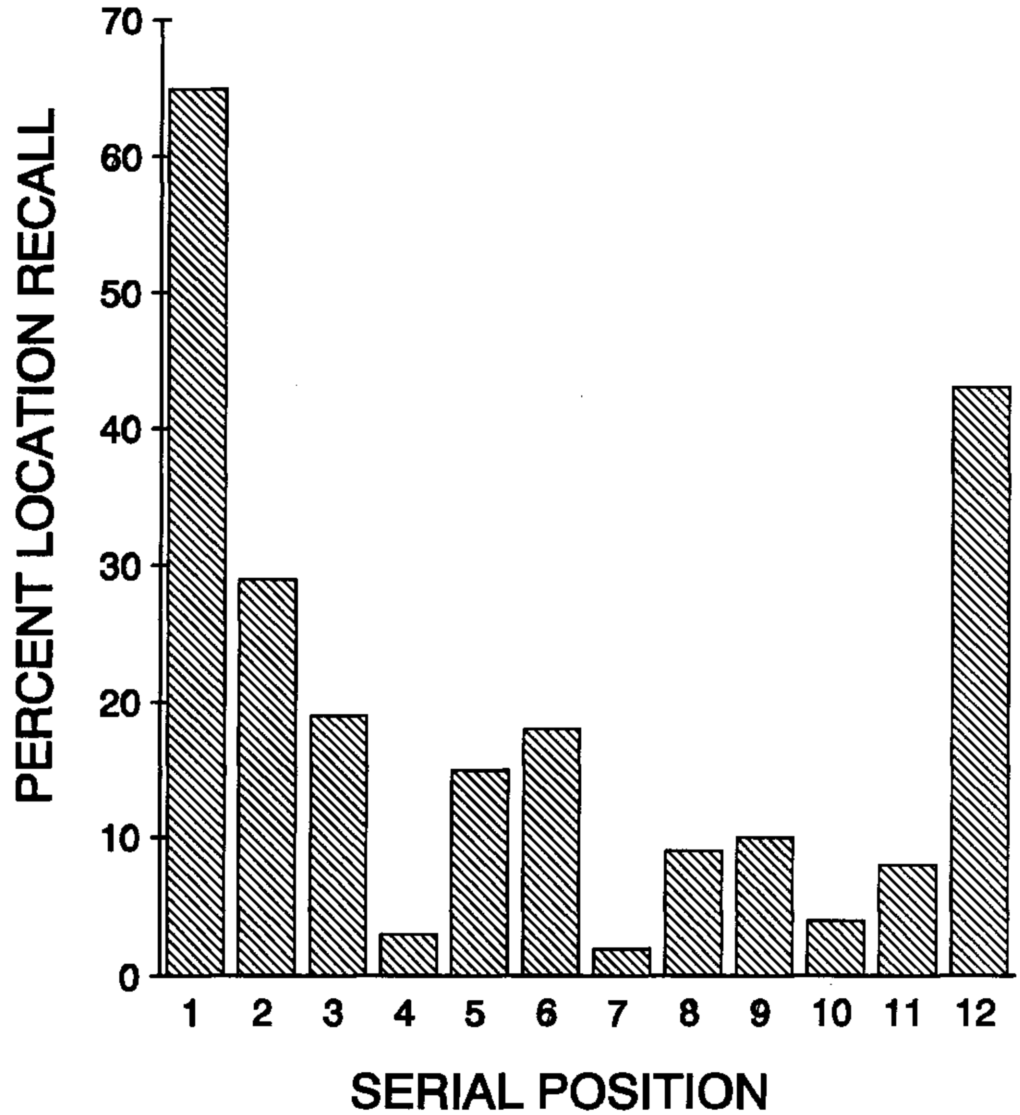

Figure 7. Spatial memory test performance by serial position of painting. The painting were numbered by their serial positions starting at the entrance and going through the exhibit in the same way as most subjects. The location of the first painting was recalled best, and recall rate decreased with serial position. The last painting, the only abstract and thus distinctive one (see photograph in Appendix B), was also very well recalled.

very poorly. Cochran's Q test and the analog of Scheffe post hoc multiple comparison procedure for repeated measures designs with dichotomous data (Marascuilo & Serlin, 1988) were used to test these observations for statistical significance. The statistics of the post hoc multiple comparison test has approximately χ^2 distribution. Cochran's Q test showed that differences in the proportion of subjects recollecting locations of the different paintings were significant, $\underline{Q}(11, \underline{N} = 302) = 800.23$. The results of Scheffe post hoc multiple comparisons are summarized in Table 4. To control for Type I errors, the significance level for these comparisons was set at $\underline{\alpha} < .005$. The first painting (item E in Figure 4) was recollected by a larger proportion of subjects than the 2nd and 3rd paintings (items V and G in Figure 4) combined, $\chi^2(11, \underline{N} = 302) = 231.64$, and in turn, these were recollected by a larger proportion of subjects than the middle six paintings (items S, H, Q, T, F, M in Figure 4, see positions 4, 5, 6, 7, 8, 9 in Figure 7) combined, $\chi^2(11, \underline{N} = 302) = 64.80$. First painting (item E in Figure 4) was also recollected by a larger proportion of subjects than the distinctive painting (item R in Figure 4, see position 12 in Figure 7), $\chi^2(11, \underline{N} = 302) = 51.98$. The distinctive painting was recollected by a larger proportion of subjects than the middle six paintings (items S, H, Q, F, M in Figure 4, see positions 4, 5, 6, 7, 8, 9 in Figure 7), $\chi^2(11, \underline{N} = 302) = 196.56$. Finally, two paintings in alcoves (items S, T in Figure 4, see positions 4, 7 in Figure 7) were recollected by a smaller proportion of subjects than those immediately following these two paintings (item H, Q,

Table 4

Experiment 1. Scheffe multiple contrast comparisons on the proportions of subjects recalling paintings' locations.

Contrast (item numbers)	$\chi^2(11, N = 302)$
1 vs. 12	51.98*
2 vs. 3	12.39
1 vs. 2, 3	231.64*
2, 3 vs. 4, 5, 6, 7, 8, 9	64.80*
12 vs. 4, 5, 6, 7, 8, 9	196.56*
4, 7 vs 5, 6, 8, 9	30.69*

* $p < .005$.

F, M, in Figure 4, see positions 5, 6, 8, 9 in Figure 7), $\chi^2(11, \underline{N} = 302) = 30.69$.

The abstract painting is in the last serial position. Thus, it could be argued that the excellent recollection of this painting's location is due to a recency effect rather then due to distinctiveness. However, there are two reasons why this hypothesis is not plausible. First, the location test for the abstract painting followed the study phase after the delay of several minutes, and after completion of several intervening tasks such as estimation of the time spent in the exhibit, rating of the liking of the exhibit, and testing for the locations of several other target items. The recency effect is known to disappear both after delays as short as 15 seconds or after intervening tasks that prevent rehearsal. Thus, the excellent recollection of the abstract painting's location is not likely to be due to the recency effect.

A second reason why the recency effect is not likely to be responsible for an excellent recollection of the abstract painting's location is that a location of another, nondistinctive painting (item U in Figure 4, see position 11, in Figure 7) was recollected poorly regardless of whether or not subjects saw this painting last. The experimenter recruited subjects for the incidental condition at the exit, and thus, one of the last paintings they saw was the abstract painting. In contrast, a large number of subjects recruited for the intentional condition left the exhibit through the entrance seeing the non-distinctive painting last. If the recency effect was responsible for the excellent recollection of the abstract painting's location

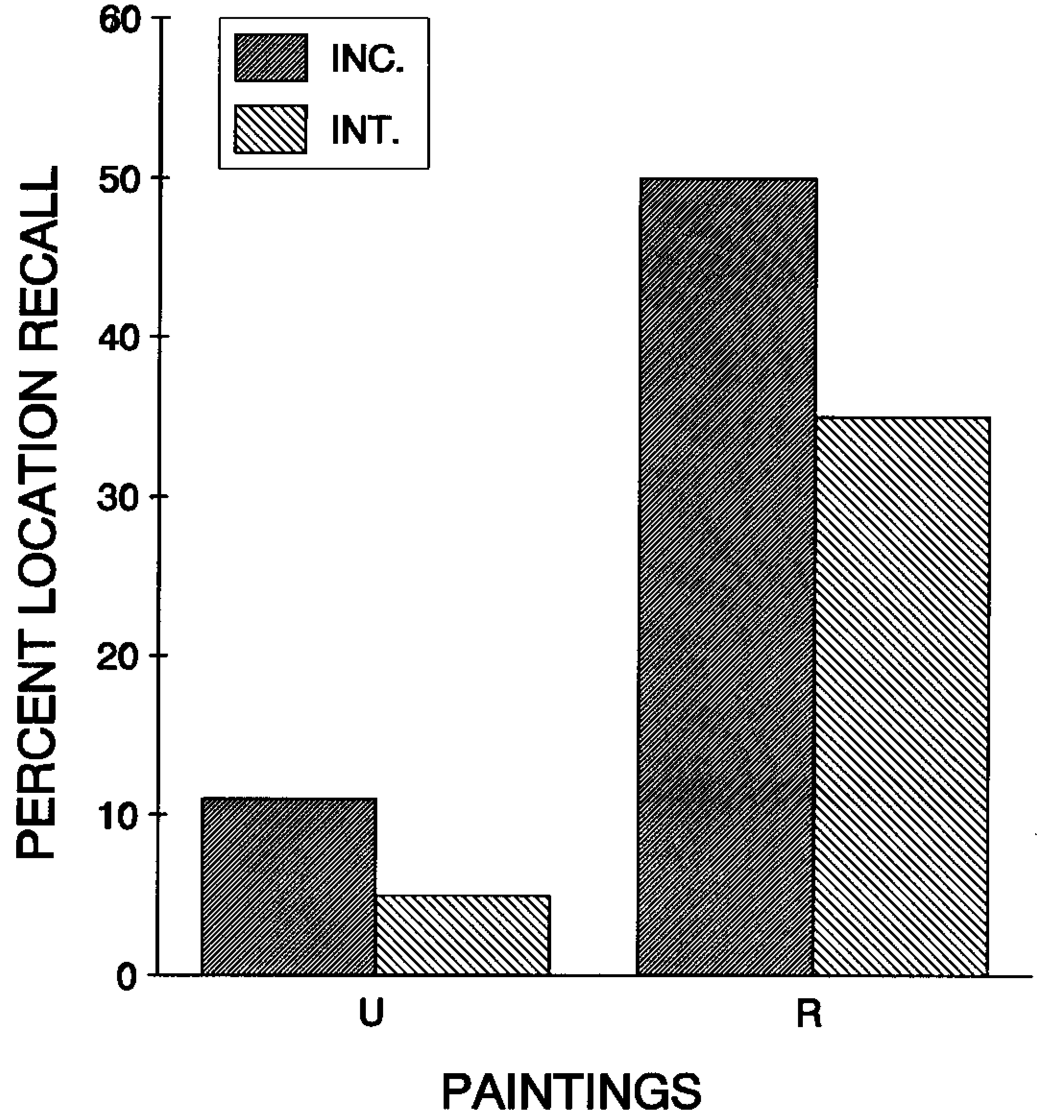

Figure 8. Spatial memory test performance for the non-distinctive painting U and the distinctive, abstract painting R by study condition. Subjects in the incidental condition saw the distinctive painting R last, whereas most subjects in the intentional condition saw the non-distinctive painting U last. Regardless of which painting was seen the last, the location of the distinctive painting R was recalled by greater percentage of subjects than the location of the non-distinctive painting U.

then the location of the non-distinctive painting should be recollected better in the intentional rather then in the incidental condition. Figure 8 shows the proportion of subjects in each condition that correctly located the distinctive and non-distinctive paintings. Contrary to what the recency effect hypothesis predicts, the location of the non-distinctive painting was recalled by a smaller proportion of subjects in the intentional vs. incidental condition, $\chi^2(1, \underline{N} = 302) = 4.52$. Even though performance on the abstract distinctive painting also decreased in the intentional vs. incidental condition, $\chi^2(1, \underline{N} = 302) = 7.15$, the abstract painting was still recalled by a larger proportion of subjects than the non-distinctive painting, $\chi^2(1, \underline{N} = 151) = 38.94$.

Multiple regression analysis. I also conducted a series of multiple regression (MR) analyses to find out whether other variables such as liking of the exhibit, or time spent at the exhibit predicted performance on the spatial memory test.

Two simultaneous multiple regression analyses were performed. The first MR analysis included as predictors the following independent variables and interactions: gender (female vs. male), age (subjects' age), liking (1 = not at all, 5 = extremely), time (self-reported time spent at the exhibit), intent (intentional vs. incidental manipulation), color set (color vs. black-and-white photographs), age by intent, and age by colorset interactions. The second MR analysis included only variables that predicted performance on the spatial memory test in the first model: age, gender, liking, and time. Table 5 shows the standardized regression

Table 5

Experiment 1. Standardized regression coefficients for variables that predict the number of items correctly located on spatial memory test.

Predictor	Full model	Reduced model
Age	-.279***	-.276***
Colorset	-.052	---
Gender	.166**	.166**
Intent	.091	---
Liking	.146*	.147**
Time	.333**	.324**
Age x Intent	-.042	---
Age x Colorset	.116	---
R^2	.213	.205
adjusted R^2	.191	.195
F	9.89***	19.17***
MSe	7.89	7.86

* $p < .05$. ** $p < .01$ *** $p < .001$. $N = 302$.

coefficients that predict the spatial memory test performance. The predictors included in this second, more parsimonious, model accounted for 20.5% of variance in the spatial memory test scores.

The simultaneous MR analyses showed that the number of items correctly located is predicted not only by age, but also by gender, time, and liking. In order to see whether or not these latter variables were responsible for the age-related trend in performance reported in previous analyses, an additional hierarchical MR analysis was performed. In this analysis, time, liking, and gender were entered on the first step, age on the second step, and a new variable, age-squared on the third step to test for a curvilinear trend in the data. The result are reported in Table 6; they show that, even after controlling for the effects due to time, liking, and gender, spatial memory test performance was predicted by subjects' age, and more importantly, that performance was best predicted by a non-linear function. Inclusion of the age-squared variable into the regression analysis significantly improved prediction of spatial memory test performance. The trend analysis of the residuals after the first step, that is after controlling for the effects of time, liking, and gender on spatial memory test performance, confirmed that spatial memory test performance declined only for subjects older than 55 years of age, $F(5, 296) = 36.21$.

Finally, the regression analyses also showed that the intentional/incidental manipulation in Experiment 1 did not influence spatial memory test performance since the variables representing

Table 6

Experiment 1. The result of hierarchical multiple regression analysis testing linear and quadratic age-trends in spatial memory test performance after controlling for effects due to gender, liking, and time spent in the exhibit.

Step	Predictor(s)	R^2	ΔR^2	F change	F full model
1	gender, time, liking	.136	.136	15.62*	15.62*
2	age	.205	.069	25.88*	19.17*
3	age-squared	.246	.041	15.90*	19.28*

* $p < .001$. $N = 302$.

the intentional/incidental manipulation and its interaction with age did not predict the performance. Thus, neither old nor young adults benefited from being informed about an upcoming test.

Discussion

Experiment 1 generalized previous laboratory findings of age-related decline in spatial memory performance to a real-life setting. The results showed that the spatial memory test performance of older people was inferior to that of younger people even in a real-life situation. More importantly, Experiment 1 extended laboratory findings by showing that spatial memory does not decline gradually with age, but remains unchanged until about 55 years of age, when it declines sharply. Other findings that emerged from Experiment 1 were that (1) an intentional/incidental manipulation did not affect spatial memory test performance, (2) the locations of distinctive items were easier to recollect than locations of the non-distinctive items, and, (3) spatial memory test performance was predicted not only by age but also by time spent in the exhibit, subjects' gender, and liking of the exhibit.

The finding that older adults performed more poorly than younger adults is consistent with the results of several previous studies that modeled real-life situations and found that spatial memory performance declined with age (e.g., Park et al., 1990; Read, 1987; Sharps, 1991, West, 1992), and they lend little support to the claims that no age-related changes in spatial memory performance are found in real-life situations

(Waddell & Rogoff, 1981; Sharps & Gollin, 1987), or that processing of spatial information is not influenced by aging (Hasher & Zacks, 1979).

Perhaps the most important finding of this experiment is that spatial memory test performance remained unchanged until the 6th decade. This finding suggests that the gradual age-related decline in performance obtained on some psychometric tests of spatial memory (Moore, Richards, & Hoood, 1984) or on more typical laboratory tasks (Salthouse, 1982; Salthouse et al., 1988a) may not generalize to real-life situations. The reason for these discrepant findings is not clear. One possibility is that age-related changes in performance on spatial memory tasks used in the psychometric and in traditional laboratory test situations are mediated by age-differences in the degree of familiarity with such abstract tasks rather than reflecting changes in processing of spatial information (Kirasic & Allen, 1985; Labouvie-Vief, 1977). The familiarity with psychometric or typical laboratory tasks may decrease linearly with the individual's time-distance from the educational system, or with the individual's membership in older age-cohorts. For example, remembering the locations of 7 letters in 5 x 5 matrix--a typical psychometric or laboratory spatial memory task--may be a relatively familiar task to young adults who are required to perform similar abstract tasks in various educational situations, whereas it is not likely to be familiar to older adults who do not usually encounter such tasks in everyday life. In contrast to psychometric and laboratory tasks, age-related changes in performance on the spatial memory task used in the present experiment is not likely to reflect age-differences in task-familiarity because the task is very similar to those encountered by people of all ages during their daily activities. Based on such considerations, I believe that the age -function obtained in the present experiment reflects age-related changes in processing of spatial information rather than being due to a difference in task-familiarity.

One possibility is that the age-related decline in spatial memory performance occurring after the 6^{th} decade of life may be associated with a major life event--retirement (Baltes & Labouvie-Vief, 1973; Labouvie-Vief & Chandler, 1978). Older adults who are approaching retirement age or who are already retired may prefer modes of cognition that are more appropriate to their life-style than those of younger adults. Older adults may focus on meaning or aesthetic evaluation of presented stimuli, whereas younger adults may focus on descriptive aspects of presented stimuli (e.g., color, size, spatial position).

The observed non-gradual age-decline in spatial memory test performance goes against the resource reduction theories of cognitive aging because they assume that age-related declines are linear, tied to linear changes in an underlying cognitive mechanism (Salthouse, 1982, 1988, Salthouse et al., 1988a).

It can be argued that the non-gradual, age-related decline in spatial memory test performance reflects changes in item recognition rather than in spatial memory. For the spatial memory test, subjects were given a booklet of item-photographs and asked to indicate items locations on the exhibit map. Thus, they indicated locations of only those items they could recognize. To see if age-related changes in item-recognition were responsible for the age-related decline in test performance, an analysis was performed on the ratio of items correctly located to those that subjects attempted to locate. The ratio measures spatial memory test performance while controlling for undesirable age-related changes in item recognition. The analysis of these data confirmed the age-related pattern in performance described above; performance remained constant until the 6th decade and then decline sharply.

In Experiment 1, the incidental/intentional manipulation did not affect the performance; neither older, nor young people gained any advantage from being informed about the upcoming test. This finding is contrary to the prediction made on the basis of the results of previous research. The reason for a failure to find the effect of intentional/incidental manipulation is not clear, but one possibility is that this manipulation in the present experiment was too weak. In the intentional condition, subjects were only asked to pay attention to what they see in the exhibit and how the items were arranged. They were not specifically told to remember location of each item since there were limits on what a visitor to the exhibit could reasonably be asked to do and still participate in the study.

The results of Experiment 1 showed that recall of an item's spatial location appears to be influenced by the item's distinctiveness. The abstract painting, only one of its kind in the whole exhibit, was very well recalled. This finding is consistent with the results of several previous studies that showed that the locations of distinctive items were remembered better than those of non-distinctive items (Bruce & Herman, 1986; Kearins, 1981). Distinctiveness may increase the extent to which an item and its spatial context are processed, therefore increasing the likelihood of recollecting its spatial location on a subsequent test. Furthermore, distinctiveness may also make an item easier to identify, or to label, thereby making it easier to associate the item with a particular location (Kearins, 1981).

The results of multiple-regression analyses showed that spatial memory test performance was predicted by subjects' estimate of time spent in the exhibit, subjects' gender, and by degree of liking the exhibit. Subjects recollected more locations when they spent more time in the exhibit, and when they liked the exhibit. Male subjects remembered more locations than female subjects. However, these predictors accounted for only small proportion of variance in spatial memory test performance, 13.6%. Perhaps more importantly, the results showed that statistically controlling for the effect of the above predictors did not change the pattern of age-related changes in spatial memory test performance discussed above.

Finally, the findings of Experiment 1 have to be interpreted with caution for several reasons. The first is that the experiment was a field study, conducted in a real-life setting, and as a result, there was no control over which items subjects actually saw, or how much attention they paid to each of them. The second is that the experiment employed a cross-sectional design to examine age-related changes in spatial memory performance and thus, age-related changes in performance were measured only indirectly. The results may be confounded by other, undetected differences between subjects of different age-groups that are not directly associated with age, for example, differences in health, education, or employment status. The design of Experiment 1 did not allow the elimination of any of these variables as possible confounds because the only information collected about subjects was their age and gender.

Chapter four

EXPERIMENT TWO

Introduction

This experiment had two main goals. The first was to validate the findings from Experiment 1 under more controlled conditions while still keeping to a real-life situation. The second was to examine whether age-related differences in episodic spatial memory are similar across two different tests. In addition, Experiment 2 examined the relationship between subjects' performance on these different tests and on several standard memory tests.

Experiment 2 required subjects to play the role of a secretary. An office was set up and subjects were asked to carry out a series of tasks that a secretary might do on a typical day, such as filing mail. Spatial memory performance was assessed by asking subjects to recollect the locations of items they used to complete the secretarial tasks. Two different tests were used. On the relocation test, subjects were asked to relocate items in the office where they had appeared during study, whereas on the map test, they were asked to indicate the locations of the same items on a floor plan of the office.

Method

Subjects. The subjects were 80 student volunteers who participated for course credit ($\underline{M}$ = 20.9 years, range 17 to 30 years) and

32 older volunteers (M = 71.2 years, range 65 to 85 years) who were recruited through newspaper advertisements. Sixteen of the young subjects (M = 20.1 years, range 17 to 28 years) were tested in a baseline condition, and 64 for the critical experimental conditions (M = 21.2 years, range 18 to 30 years). Figure 9 shows the number of men and women in each experimental condition. All subjects lived in Vancouver, British Columbia.

Design. The experiment used a three factor mixed design with age (young vs. older group) and study trial instruction (intentional vs. incidental) as between-subject factors, and test type (map vs. relocation) as a within-subject factor. A secondary between-subject factor was the order of giving the map and relocation tests; half of the subjects in each instruction condition were given the map test first, whereas the remaining subjects were given the relocation test first. The design of the study is shown by Figure 9.

Setting and materials. An office was set up in a room measuring 3.25 x 4.35 meters. An office desk, three tables, a file cabinet, and two shelving units were placed in the office. An outline of the office and the arrangement of the furniture is shown in Figure 10.

The to-be-remembered targets were forty common items, such as a chair, a phone book, and a plant. They were randomly assigned to two sets of 20: A and B. A complete list of each set is in Appendix C. Each item was assigned a specific location in the office, and these locations are indicated in Figure 10.

<table>
<tr><th>AGE GROUP</th><th>STUDY INSTRUCTION</th></tr>
<tr><td rowspan="2">YOUNG
(32 men, 32 women)</td><td>INCIDENTAL
(16 men, 16 women)</td></tr>
<tr><td>INTENTIONAL
(16 men, 16 women)</td></tr>
<tr><td rowspan="2">OLD
(9 men, 23 women)</td><td>INCIDENTAL
(5 men, 11 women)</td></tr>
<tr><td>INTENTIONAL
(4 men, 12 women)</td></tr>
</table>

Figure 9. The design of the office study. Age-group (young vs. old) and study instruction (incidental vs. intentional) were between-subjects factors. Test type (map vs. relocation) was a within-subject factor.

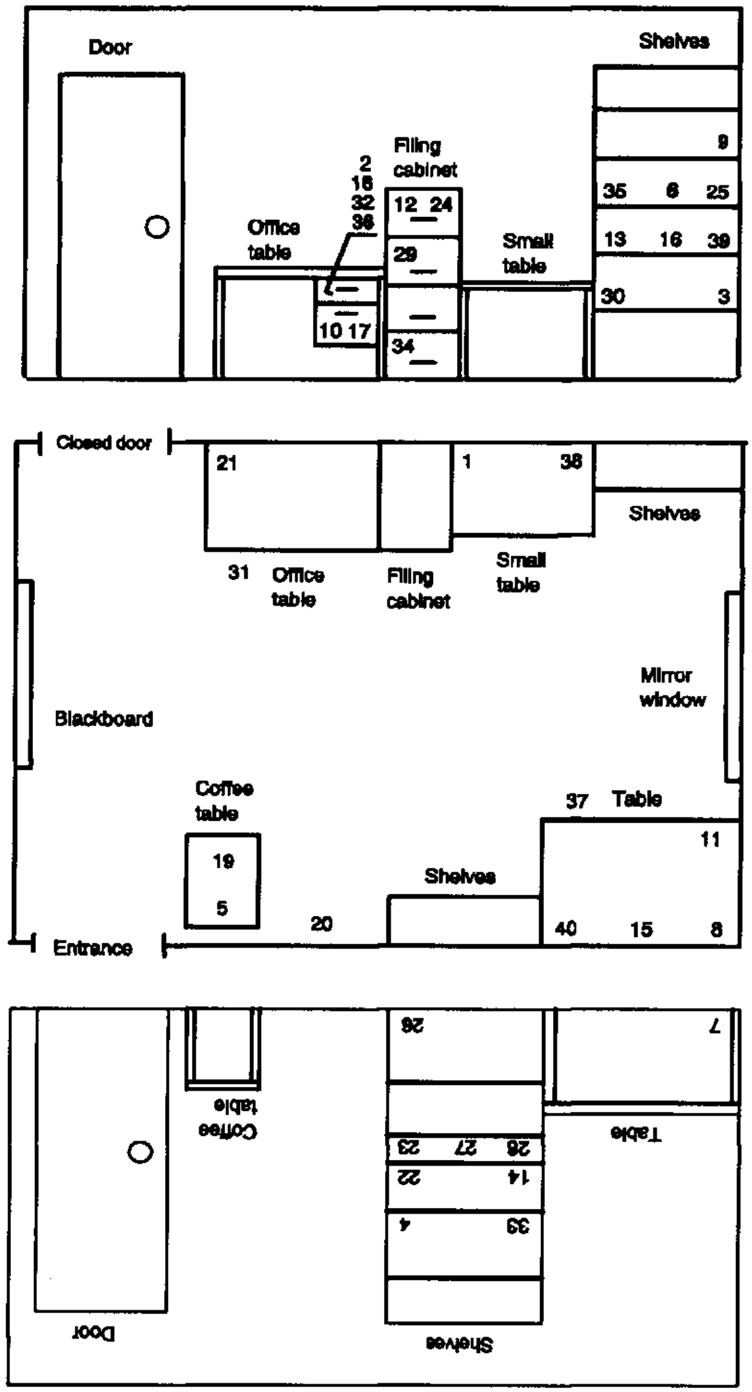

Figure 10. The floor plan of the exhibit. Subjects were given this plan without the numbers. The numbers indicate the locations of items that subjects had to recall.

A map of the office (see Figure 10), printed on an 28 x 43 cm sheet of paper, as well as a color photograph of each target item was prepared. All photographs were 10 x 15 cm in size. A small label with an identification number was attached to each photograph. Examples appear in Appendix D.

Procedure. Each subject was tested individually in one session lasting approximately 1.5 hrs. The session had three phases: instruction, study, and test. All subjects were told that the experiment examined people's ability to cope with the demands of a new environment.

In the first phase of the experiment, the subjects were told that they would be required to carry out a series of tasks, described in written instructions, that a secretary might do in a typical day, and that later they would be given a memory test of an unspecified nature. The experimenter told subjects:

> "...follow the instructions to the best of your abilities, one at a time, and pay close attention to what you are doing because when you are finished with the last task, I will give you a memory test."

In the incidental condition, the experimenter did not inform subjects about the specific nature of the memory test, whereas in the intentional condition, the experimenter qualified the nature of the memory test. Hence, in the intentional condition, the experimenter continued with the following instructions:

"...As a secretary you need to remember where you put things and where you can find them. When you are finished, I will ask you to tell me where the objects which you used belong."

The complete instructions are in Appendix E.

Following these general instructions, subjects were taken to the office and given written instructions that required them to carry out a series of secretarial tasks such as filing mail (see Appendix F for complete instructions). Subjects were required to individually use each of the 40 TBR targets to complete the secretarial tasks. A short excerpt from the instructions illustrates the tasks that subjects were asked to carry out. The instructions explained, for example, that:

"...there is also some mail on your desk. Put the mail where it belongs:

...the newspaper called "UBYSSEY" goes on the coffee table next to the entrance door. Place it on the side which is closer to the wall,

...Your boss left several things on your desk. Your are asked to put them where they belong.

...the book 'Lisp' goes in the book case with the dark shelves. Place it to the far right on the second shelf from the top,

...the file folder labeled 'Documentation'. This file folder goes into the top drawer of the filing cabinet,..."

Subjects were asked to carry out the tasks one at a time, and were allowed as much time as they needed to complete them. Furthermore, all subjects received the same instructions in exactly the same order. When subjects finished the secretarial tasks, they left the office and immediately began the test phase.

In this phase, subjects first received the paired associates test, followed by the digit forward and digit backward subtests from the Wechsler Memory Scale (Wechsler, 1945; Lezak,1983). Subjects also completed Baddeley's (1990) Everyday Memory Questionnaire (EMQ). While they were completing the EMQ, the experimenter checked the placements of all items in the office to ensure that subjects had followed the study instructions.

Following the EMQ, about 15 min after the study phase, subjects were given two spatial memory tests: the map test and the relocation test. For the map test, subjects were given a map of the office and a shuffled deck of photographs of 20 of the TBR targets. The experimenter explained the map to the subjects, pointing out that the map consisted of three sections: a floor view, and two wall views (see Figure 10). Subjects were asked to indicate on this map where in the office the TBR targets from the photographs belonged. They were asked where the targets appeared or, for items announced as mail and supplies, where they were asked to put them during the study trial. The experimenter explained:

> "... I would like you to indicate on this map where in the office these items belong, that is, to indicate the locations where they appeared, or where you put them while completing the secretarial

tasks. Please be as accurate as possible when indicating the locations of the items and indicate their exact locations."

Subjects were asked to indicate each location in the most informative way. For example, if an item's study location had been on top of a piece of furniture, then the subject indicated its location on the floor view section of the map. If, however, an item's study location was elsewhere, for example on a shelf, then they indicated its location on one of the wall view sections of the map. Subjects were allowed to go through the deck of photographs in any order they wished and they were allowed to change their mind about the correct study locations of items. Subjects were not required to place all TBR items on the map.

For the relocation test, the experimenter first placed the TBR targets haphazardly on the office desk. Subjects were then taken into the office and asked to place the items where they belonged. They were asked where the targets appeared or, for items announced as mail and supplies, where they put them during the study. They were instructed to be as accurate as possible when relocating the items. The experimenter explained:

"... I would like you to place all of the items in the locations where they belong, that is, in the locations where they appeared, or where you put them while completing the secretarial tasks. Please be as accurate as possible when placing the items, and put them in their exact locations."

Because there were two spatial memory tests and each subject completed both, they were given the tests in one of the two orders, either the map test followed by the relocation test or the relocation test followed by the map test. In each condition, an equal number of subjects received the tests in each order. On the first test, subjects were asked to recollect the locations of 20 TBR items from either set A or set B (each set is a random half of the TBR items), whereas on the second test, they were required to recollect the locations of all items. The number of subjects who received set A or set B respectively on the first test was counterbalanced in each experimental condition and across the different test orders. The purpose of this counterbalancing procedure was to ensure that the performance on at least one of the item sets on the second test was free of practice effects (caused by completing of the first test). Thus, for example, subjects' performance on set B on the second test should be free of effects due to the previous experience with recalling the locations of items in set A on the first test.

Following the spatial memory tests, subjects were given a map manipulation check in order to see whether or not they understood the map of the office. For this purpose, subjects were taken into the office, and given the office map along with the photographs of the first 10 items from the set which they received on the relocation test. These items were still in the locations where the subjects had initially placed them on the relocation test. Subjects were asked to transcribe the locations of the items pictured in the photographs by writing the photograph labels on the map. They were advised not to use their memory for this task but rather to look for each item first, and then to indicate its location on the map. Following the manipulation check, the experimenter collected subject data including age, gender, and number of years in formal education.

Subjects might place some items correctly by chance alone or by knowing where such items are usually kept. Hence, the knowledge of this baseline performance was necessary to determine whether spatial memory test performance was higher than baseline in the experimental conditions. Sixteen young subjects were used to find this baseline level for both the map test and the relocation test. Subjects were taken to the office and told that it was the secretary's office. The experimenter pointed to and named all the pieces of furniture in the office, and showed them the items lying haphazardly on the desk. One half of the subjects were asked to put the items where they thought they belonged or were usually kept. The other half of the subjects were led to the adjacent room, given the office map along with the photographs of all of the items, and asked to indicate on the map where they thought the items belonged or were usually kept. The proportion of correctly placed or indicated items yielded an index of baseline performance for the relocation test and the map test, respectively.

Results

The results are organized in four parts. The first part presents the results of preliminary analyses of possible order effects, findings concerning the validity of the map test, and an indication of baseline, or chance performance. The second part focuses on analyses of overall performance. The third part reports the results of correlational analyses that examined the relationships among performance on the spatial memory tests and performance on several standard memory tests. Finally, the last part presents the results of item analyses.

Preliminary analysis. The main goals of the preliminary analysis was to examine the data for possible order effects, and to find out what was the baseline performance on the relocation test and the map test, respectively.

The main dependent measure was the proportion of items correctly located on each spatial memory test computed separately for set A and set B. An item was considered correctly located when its indicated location was in the correct part of a structure. The details of the scoring procedure are in Appendix G. The significance level for all statistical tests was set at $\alpha = .05$ unless stated otherwise.

Table 7 shows the proportions of items correctly located as a function of test order, test type, and item set. Inspection of the performance levels suggests that there may be possible order effects but only when the first and second test involved the same set of items. The performance on the map test with set B appeared to be higher when this test was second and preceded by the relocation test with the same set, $M = .63$, than when this test was first, $M = .56$. While this difference was not significant, the effect size, $ES = .38$, suggests that the effect of practice was large enough to bias the results of critical analysis. For this reason,

Table 7

Experiment 2. Proportion of items correctly located as a function of test order, test type, and item set.

	First test	Second test: Same set	Second test: Different set
	Map (A)	Rel (A)	Rel (B)
M	.72	.80	.68
SD	.22	.14	.16
	Map (B)	Rel (B)	Rel (A)
M	.56	.69	.79
SD	.17	.18	.15
	Rel (A)	Map (A)	Map (B)
M	.81	.70	.58
SD	.13	.21	.20
	Rel (B)	Map (B)	Map (A)
M	.67	.63	.70
SD	.15	.20	.21

Note. Subjects always received only one set of items on the first test. However, they always received both sets on the second test. Map (A) stands for the map test and set A combination, whereas Map (B) stands for the map test and set B combination. Similarly, Rel (A) stands for the relocation test with set A, and Rel (B) stands for the relocation test with set B.

all of the following analyses were carried out only on items that appeared for the first time on the second test.

Inspection of overall performance on set A and set B shows that performance on items in set A was higher than on those in set B, $M = .77$ vs. $M = .62$, $t(94) = 4.37$. A possible explanation why some items were easier to recollect than others is discussed in the section on item analysis.

Subjects are likely to place some items correctly by chance and by knowing where the items are usually kept in a typical office. This baseline performance was obtained as described in the procedure section. The mean baseline performance was .14 for both set A and B on the map test, $SD = .05$ and .08, respectively, and .13 for set A and .11 for set B on the relocation test, $SD = .08$ and .06, respectively. These proportions did not differ from one another.

Overall performance analysis. The main purpose of the analyses described in this section was to examine the data with respect to the critical questions that motivated my research. Does spatial memory test performance decline with age? Do older adults benefit more than young adults when informed about an upcoming spatial memory test? Do both age groups benefit more when testing involves relocating items in a real-life setting as opposed to indicating item-locations on an abstract map, and if so, is this advantage greater for older than for young adults?

The results (see Figure 11) showed that older people performed more poorly than young people in all experimental conditions. The intentional/incidental manipulation had a large effect on the performance of older adults but it had only a minimal effect on the performance of the young adults. Furthermore, both young and older subjects performed higher on the relocation test than on the map test. However, in comparison to young adults, older adults' performance on the relocation test was facilitated to a greater extent. The analyses supporting these conclusions are described in the following paragraphs.

Figure 11 shows the overall performance by age-group, intent condition, and type of test. The mean levels of performance were higher than baseline levels in all conditions, indicating that the performance levels were free of floor effects. Using the Welch-Aspin correction for unequal variances the smallest t-value was obtained when the map performance of older adults in the incidental condition was compared to the baseline, $t(16) = 5.07$.

Planned comparisons were conducted to see if older adults performed more poorly than young adults in all experimental conditions as suggested by the results of the previous laboratory research. The comparisons showed that, when compared to young adults, older people performed more poorly on the relocation test in the intentional condition, $t(46) = 2.57$, and in the incidental condition, $t(46) = 3.24$. The same age-difference in performance occurred on the map test, where the older subjects scored lower than the young in the intentional condition, $t(46) = 2.45$, and in the incidental condition, $t(46) = 5.13$.

A repeated measures analysis of variance with age group (young vs. older adults) and study instructions (incidental vs. intentional) as

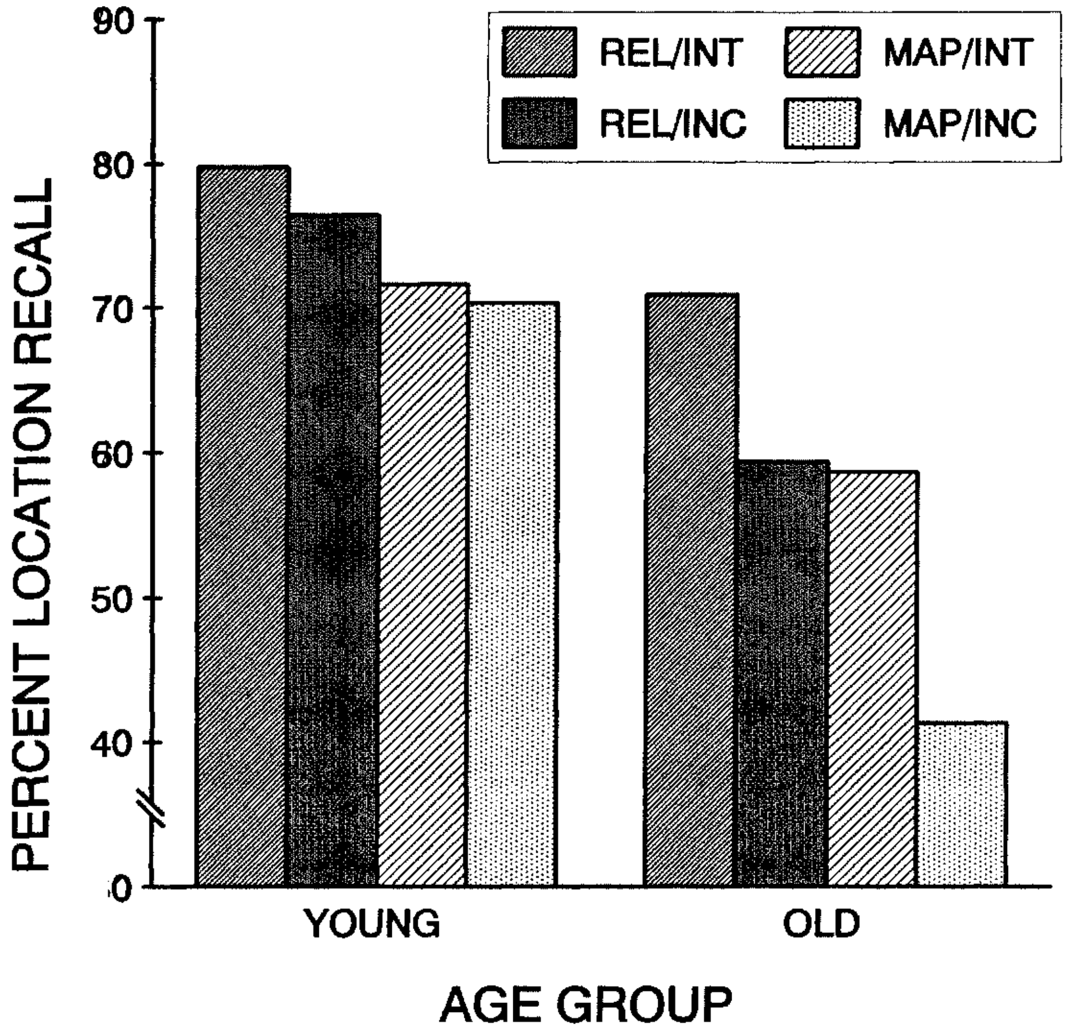

Figure 11. Spatial memory test performance by age-group, study instruction, and type of test. The older adults placed fewer items correctly than young adults, performance was lower on the map than on the relocation test, and performance in the incidental condition was lower than in the intentional condition. These findings are further qualified by two interactions: (1) the older adults improved more than the young adults when they were informed about the upcoming spatial memory test, and (2) the effect due to age-group was larger on the map than on the relocation test.

between subject factors, and test type (map vs. relocation) as a within subject factor showed that all three independent variables had a significant influence on spatial memory test performance. The older adults placed fewer items correctly than the young adults, $F(1, 92)$ = 34.63, MSe = 354.01, overall performance in the incidental condition was lower than in the intentional condition, $F(1, 92)$ = 8.50, MSe =354.01, and overall performance was lower on the map test than on the relocation test, $F(1, 92)$ = 30.43, MSe = 174.20. The main effects are further qualified by two interactions: (1) the older adults improved more than the young adults when they were informed about the upcoming memory test, $F(1, 92)$ = 4.45, MSe = 354.01, and (2) the effect due to age-group was larger on the map test than on the relocation test; older adults performed especially poorly on the map as opposed to the relocation test, $F(1, 92)$ = 3.96, MSe = 174.20.

Follow up simple effects analyses were conducted to see if the intentional/incidental manipulation and the type of test had significant effects on performance of both older and young adults. These analyses showed that performance of older adults was higher in the intentional versus incidental condition, $F(1, 92)$ = 9.47, MSe = 354.01, but performance of young adults was the same in these two conditions, $F(1, 92)$ = .487, MSe = 354.01, n. s.. The analyses also showed that both older and young adults performed better on the relocation than on the map test, $F(1, 92)$ = 9.43, MSe = 174.20, and $F(1, 92)$ = 21.13, MSe = 174.20, respectively.

In order to examine whether the main findings from this study are due to a few items which are remembered better or worse by older versus young adults, further analyses were conducted to determine what proportion of items contributed to each main effect. Sign tests applied across all 40 TBR items showed that young adults performed better than older adults on 37 (of 40 items), equally well on 1 item, and more poorly on the remaining 2 items, $z = 5.38$. Subjects in the intentional condition performed better than those in the incidental condition on 31 items, equally well on 1 item, and more poorly on the remaining 8 items, $z = 3.48$. Finally, all subjects performed better on the relocation test than on the map test on 33 items, equally well on 1 item, and more poorly on the remaining 6 items, $z = 4.11$. In combination, these finding indicate that the outcomes of Experiment 2 is not limited performance difference on only a few items.

The test instructions did not require or force subjects to relocate or to indicate the locations of all targets. A failure to relocate, or to indicate the locations of a target item could occur for two reasons: because a subject could not recall the item's location or he or she could not remember that item in the first place. Thus, it could be argued that older subjects performed more poorly than young adults on the spatial memory tests not because of their impaired spatial memory abilities, but because they failed to recognize target items in the first place. It is, therefore, important to examine if older adults failed to relocate, or to indicate locations of more target items than young adults, and if they did, whether the percentage of omitted items varied with the experimental condition. A finding that the percentage of omitted items by older adults was the same in all experimental conditions would be consistent with the interpretation that older adults failed to recognize these items in the first place. The results showed that, young adults omitted on average 0.58% of the test items in each of the experimental conditions. In contrast, older adults omitted 2.18% and 3.75% of items on the relocation test, in the intentional and incidental condition, respectively, and 3.19% and 9.37% of the test item on the map test, in the intentional and incidental conditions, respectively. Statistical analysis of these data were not meaningful because of the floor effects. However, the variation of these data across the experimental conditions, which is inverse to that found in the spatial memory test performance data, appears to be more consistent with the interpretation that older adults had difficulty recollecting locations as opposed to being unable to recognize target items. Furthermore, none of the subjects suggested that he or she could not recognize any of the target items.

There was an interaction between age and test type: Older adults improved more than young adults when spatial memory was tested by the relocation as opposed to the map test. There are two possible reasons for this interaction. First, the concrete relocation test helped performance of older adults more than that of young adults. Second, the abstract map test interfered with performance of older as opposed to young adults. The map manipulation check was designed to examine the reason for the interaction by assessing subjects ability to translate the real-life locations onto the abstract map of the office. Subjects were taken to the office, given the photographs of 10 items that were still at the locations where they had placed them during the preceding relocation test, and asked to indicate their current locations on the map. However, observation of older subjects during this task showed that, contrary to the instructions, they spontaneously relied on their memory of the relocation test to indicate the locations of the items selected for this check. They did not turn to see where the items were but indicated their locations on the map. The analysis of the map manipulation check data showed that young adults correctly indicated locations of 97.5% of items, SD = 5.05, in both the intentional and incidental conditions, whereas older adults correctly indicated 91.2% items, SD = 10.88, in the intentional condition and only 83.8% of items, SD = 18.57, in the incidental condition. No statistical analyses of these data could be performed because of performance ceiling effects. However, the finding that the older adults' performance depended on the experimental condition support the idea that they were relying on their memory rather than following the instructions to indicate current item-locations. It follows that these data cannot be used to determine whether older adults' memory performance was facilitated more than that of young adults by the familiar concrete nature of the relocation test or whether they had difficulty with the abstract map test.

Correlational analyses. The correlational analyses were designed to examine, across all subjects and within each age group, the relationships between performance on the spatial memory tests and performance on the standard memory tests. A single measure of spatial memory performance was computed for each person by averaging performance on the two spatial memory test. The averaged levels of performance on the spatial memory tests and on the other tests used to assess memory functions are shown in Table 8. The tabled means show that young adults performed better on the spatial memory test, $t(94) = 5.65$, and on the paired associates test than did the older adults, $t(94) = 4.91$. However, the performance of older and young adults did not differ on the digit span forward, $t(94) = .93$, or on the digit span backward tests, $t(94) = 1.48$.

The correlations among performance on the spatial memory test and performance on other, standard memory tests are shown in Table 9. There are three entries for each pair of tests. The first of these is the correlation between the two tests across all 96 subjects. The second and third entries are correlations computed separately for young and older adults. When correlations across all subjects are considered, performance on the spatial memory test is related to performance on only two of the standard memory tests: paired associates and digit span backward. Neither performance on the forward digit span nor scores obtained on the EMQ were related to performance on the spatial memory test.

An important finding that emerged from the correlational analyses is that age-related changes in the spatial memory test performance are

Table 8

Experiment 2. Mean levels of performance on the spatial memory and standard memory tests by age-group.

	Young (n = 64)		Older (n = 32)		
Memory test	M	SD	M	SD	t-value
Spatial (%)	74.50	11.56	57.55	17.62	5.65**
Digit span forward	8.67	2.34	8.22	2.07	.93
Digit span backward	7.48	1.85	6.88	2.01	1.48
Paired associates	34.13	5.49	27.75	6.91	4.91**
EMQ	82.30	26.99	69.19	24.15	2.32*

*$p < .05$, **$p < .001$.

Table 9

Experiment 2. Correlations among the performance on the standard memory tests, performance on the spatial memory test, and subjects' age.

Memory test	Subject -group	Digit span forward	Digit span backward	Paired associates	Spatial memory[a]		Age
Digit span forward	all		.44*	.13	.19	(.21)	-.12
	young		.33*	.12	.07		
	older		.66*	.07	.32	(.37)	
Digit span backward	all			.24	.31*	(.35*)	-.17
	young			.26	.22		
	older			.10	.34	(.47*)	
Paired associates	all				.51*	(.50*)	-.48*
	young				.15		
	older				.59*	(.53*)	
Spatial memory test	all						-.54*
	young						
	older						
EMQ	all	.36*	.21	.03	.06	(.06)	-.22
	young	.42*	.13	.06	.06	(.06)	
	older	.19	.29	-.36	-.27	(-.17)	

Note. *$p < .01$. The first entry in each cell is based on all 96 subjects. The second and third entries are for young (n = 64) and older adults (n = 32), respectively. [a]Numbers in parenthesis are partial correlations after statistically controlling for the effects due to the intentional/incidental manipulation. As can be seen from the tabled values, the pattern of correlations did not change.

not accounted for by performance on the digit span backward test. This is surprising in a view of resource reduction theories of cognitive aging (Salthouse, 1988; Salthouse, Kausler, & Saults, 1988b; for review see Light, 1991) which claim that age-related changes in performance on cognitive tasks are mediated by the reduced capacity of the processing resources. Thus, if the index of resource capacity is obtained and if the variability in the performance that can be explained by this index is partialled out, any existing relationship between performance on a given cognitive task and age should be eliminated (Salthouse et al., 1988b). Assuming that the performance on the digit span backward test is a valid measure of the processing resources (see Salthouse, 1988; Light, 1991), the correlation between the spatial memory test performance and age is expected to disappear when the performance on the digit span backward test is partialled out. However, the results show that the correlation between performance on the spatial memory test and age, $r = -.54$, did not decrease when performance on the digit span backward was partialled out, $r_{partial} = -.52$. This finding suggests that performance on the digit span backward test is not a valid index of the available capacity of processing resources, or that the available capacity of processing resources does not mediate age-related changes in performance obtained in this experiment.

The automaticity view (Hasher & Zacks, 1979) claims that processing of spatial information is genetically prepared, and thus depends on processes or structures entirely distinct from those used for processing of other information such as learning of verbal associations. By this view, the performance on the spatial memory tests should not be related to the performance on the paired-associate test. However, contrary to the automaticity view, the obtained correlations suggest that performance on the two tests is mediated by at least some of the same processes. This conclusion emerges from the finding that performance on the spatial memory test and on the paired associates test are moderately correlated, $r = .51$. However, the correlations computed separately for young and older adults show that performance on these two tests is correlated for older adults, $r = .59$, but not for young adults, $r = .15$, perhaps because their performance was high on both tests. The relationship between the performance on the two tests is shown in Figure 12. The difference between the correlation coefficients obtained for young and older adults is significant, $z = 2.61$. This pattern of correlations is consistent with Craik's (1983) proposal that when compared to young adults, older adults have difficulty initiating and guiding the processing of relevant information. An intuitive analysis of the processing requirements of the two tests suggests that the performance on both tests depends, to a large extent, on subject initiated processing. Thus, if we allow that some, but not all, older adults experience difficulty initiating and guiding the processing of target information, the performance on the two tests would be correlated for older but not for young adults, who presumably have no such difficulty initiating and guiding processing.

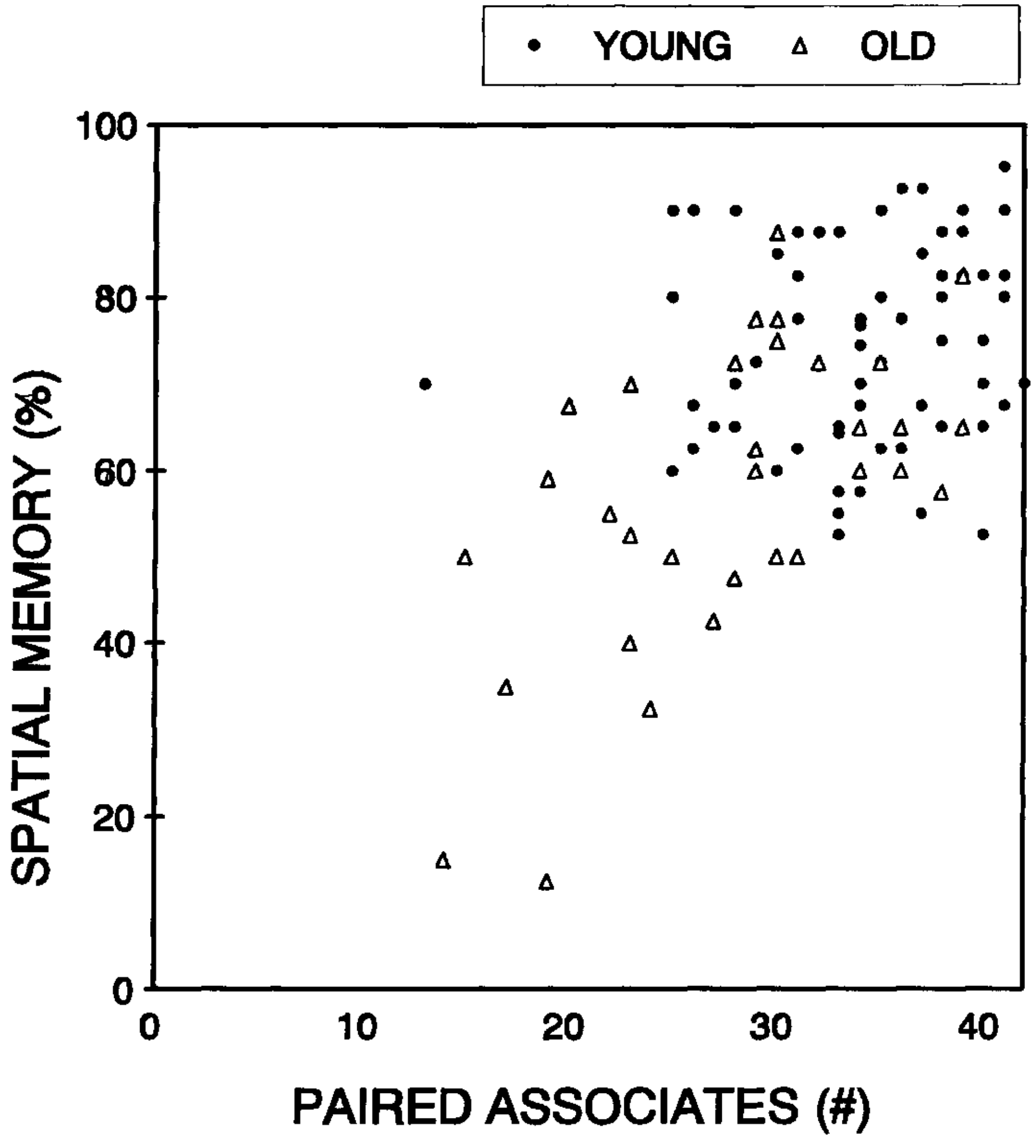

Figure 12. Relationship between performance on the spatial memory test and performance on the paired associate test. Figure shows that the performance on the spatial memory test was related to the performance on the paired associate test for older adults only. There is no apparent relationship between performance on the two tests for young adults who scored high on both tests. Their scores appear in an upper right quadrant of the scatterplot.

Item analysis. Figure 17 shows the proportion of subjects recalling the locations of each item, as well as baseline performance on each item. Test performance was correlated with baseline performance, $r = .36$, suggesting that location recall on some items may be, in part, mediated by the subjects' knowledge of where these items ordinarily belong. Inspection of Figure 17 shows that test performance was very high for some items, specifically, those items in the top desk drawer (pencils, item 2, Scotch tape, item 18, staples, item 32, and business card file, item 36). This may reflect prior knowledge of where these items usually belong since baseline performance on these items was also high. Spatial memory test performance was also high for several other items: the artificial plant (item 19), the newspaper (item 5), and the pen holder (item 21). But the high performance on these items cannot be attributed to prior knowledge, since baseline performance on them was low. Instead, high performance on these items may be due to their distinctiveness or due to their distinctive locations.

The most poorly recalled locations were those of items that belonged on the shelves (items 6, 13, 21, 28, 35). To determine whether the locations of items on the shelves were relatively more difficult to remember, performance on these items was compared to performance on other items that showed low baselines, including items on the desk, tables, and floor. The results showed that performance on the items on the shelves, $M = .56$, $SD = .16$, was lower than performance on the items located on the other furniture and on the floor, $M = .77$, $SD = .13$, $t(28) =$

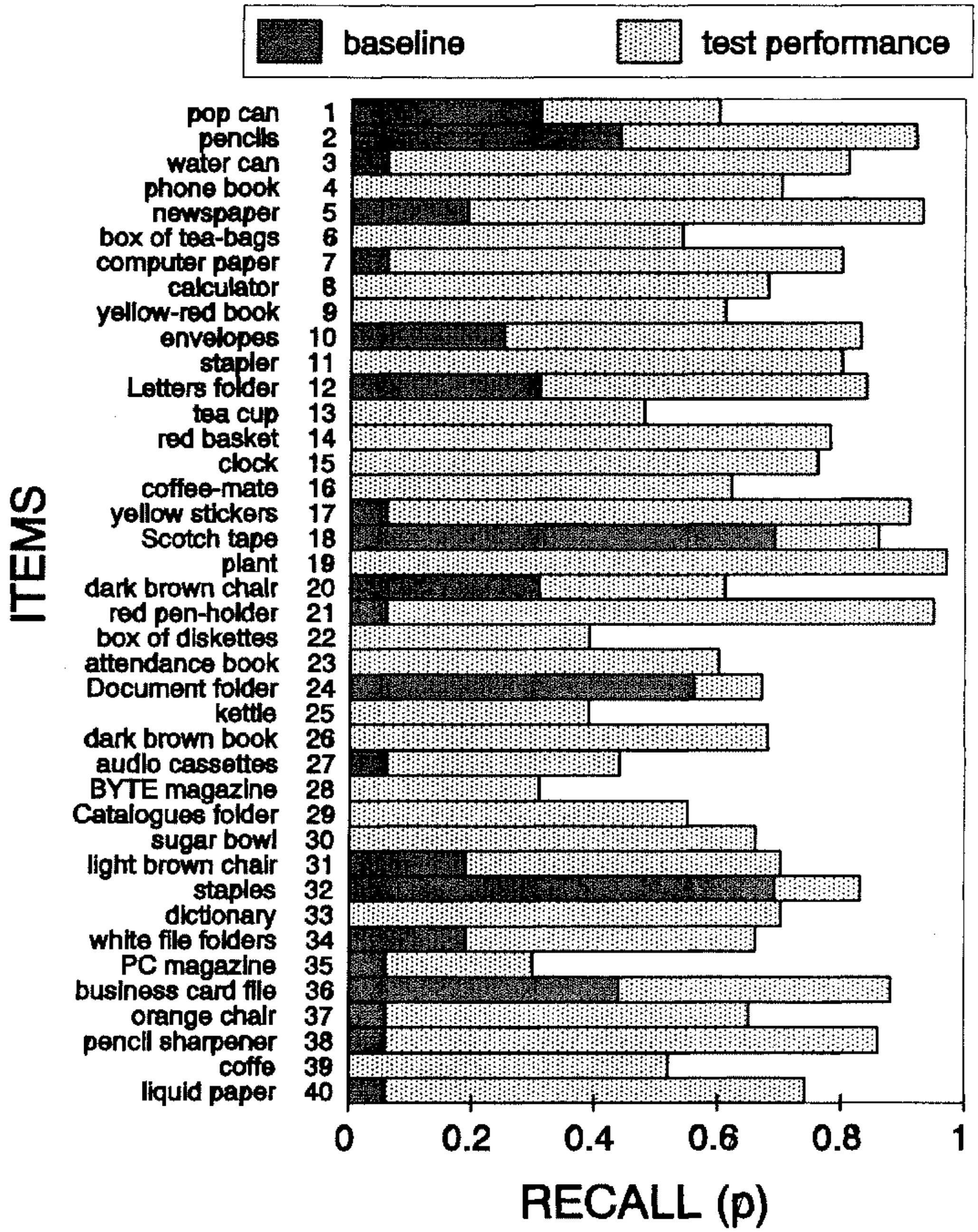

Figure 13. Spatial memory test and baseline performance by target item. The figure shows that performance on some items (e.g., pencils, item 2) was mediated by subjects knowledge where these items are usually kept. It also suggests that item's distinctiveness may also influence the performance. A location of an artificial plant (item 19), only such item in the office, was very well recalled.

3.99. Thus, it appears that subjects had more difficulty with remembering the locations of items on the shelves, perhaps due to the relatively low distinctiveness of shelf locations. A difference in distinctive locations may also explain why performance on set A was higher than on set B, because set A included 7 items on the shelves whereas set B contained 10 such items.

Discussion

The results of Experiment 2 replicate and generalize the findings of age-related changes in spatial memory test performance from Experiment 1. Older adults performed more poorly than young adults even in a controlled, laboratory situation. Experiment 2 extended the above finding by showing that (1) older but not young adults improved when they were informed about an upcoming spatial memory test, and (2) both older and young adults performed better on the relocation than on the map test, but this benefit was greater for older adults. Two additional findings emerged from the correlational analyses. First, age-effects in performance on the spatial memory test and on the paired associates test were not accounted for by performance on the digit span backward test, one of the suggested measures of the available capacity of processing resources. Second, performance on the spatial memory test was correlated, at least for older adults, with performance on the paired associates test.

Two of the above findings are of critical importance. The first is that the performance of older but not young adults improved when they were informed about the upcoming spatial memory test. This indicates that the performance of older adults is more dependent on study instructions, and it suggests that when left to their own initiative, older adults are less likely to process spatial information than young adults. But the finding also show that older adults are capable of such processing when given appropriate instructions. This is consistent with the idea that age-related changes in spatial memory test performance are mediated, to a large extent, by changes in the subject-initiated, strategic processing (Labouvie-Vief, 1977).

The second critical finding is that while both older and young adults performed better on the relocation than on the map test, performance of older adults improved more than that of young adults. Thus, the age-effects were minimized when spatial memory was tested by means of a concrete, familiar test that involved relocating targets in an office, as opposed to indicating their locations on a map. An intuitive comparison of the two tests suggests that on the relocation test remembering may be initiated and guided by the familiar aspects of the environment such as the size or color of items and their context, whereas on the map test, remembering must be initiated and guided by the subjects' strategies because the map tests offers only a few cues that may elicit remembering. The relocation test seems to provide more environmental support to initiate and guide remembering than the map test, and thereby facilitates spatial memory performance.

The finding that the advatage due to the relocation test was larger for older than for young adults suggests that the older adults' spatial memory test performance may depend more on the environmental support provided by the relocation test. This is consistent with Craik's (1983) proposal that older adults are less likely to engage in self-initiated processing, and are more dependent on environmental support to initiate and guide remembering.

It is important to note that the age-effects in spatial memory test performance varied substantially across experimental manipulations. Whereas older adults performed more poorly than young adults in all experimental conditions, age-effects in the spatial memory test performance were small when subjects were informed about the upcoming spatial memory test and when testing involved relocating target items in a real-life setting. Older adults performed at 88.9% of young adults performance. In contrast, age-effects were large when subjects were not informed about the test and testing involved indicating target locations on the map. Older adults performed only at 58.7% of young adults' performance. This combination of findings suggests that age-related changes in spatial memory test performance are mediated, to a large extent, by changes in processing strategies and familiarity with the study and test tasks and their context rather than irreversible degradation in the underlying cognitive "hardware" (Labouvie-Vief, 1977).

The results of the correlational analyses showed that age-related changes in spatial memory test performance were not accounted for by the performance on the digit span backward test. The resource reduction views (e.g., Craik, 1983; Salthouse, 1988; Salthouse, 1988b) claim that age-related declines in performance on cognitive task are mediated by an age-related decrease in the available capacity of the processing resources. It follows that when a valid index of the available capacity of processing resources is partialled out from the performance on a spatial memory test, the correlation between test performance and age should decrease. It has been suggested that one such index is the performance on the digit span backwards. The fact that there was only a minimal change in correlation between age and the performance on the spatial memory test when the variability due to the performance on the digit span backward was partialled out suggests that either the performance on the digit span backward is not a valid measure of processing resources or that the reduction in the available processing resources does not mediate the observed age-related decline on spatial memory tests.

Finally, the finding that performance on the spatial memory test is correlated with performance on the paired associates test is not consistent with the automaticity view (Hasher & Zacks, 1979). According to the automaticity view--special case of the resource reduction views--processing of spatial information is genetically prepared, and thus does not depend on the available capacity of processing resources that diminishes with aging. In contrast, learning of verbal associations demands the processing resources. By this view, the performance on the spatial memory tests and the paired associates test should not be correlated.

The finding suggests that at least for older adults, performance on these two types of memory tasks is dependent, in part, on the similar or same processes. Hulicka and Grossman (1967) had shown that performance on the paired associates test is largely dependent on subject-initiated processing. An intuitive analysis of the requirements of the spatial memory test also suggests that the performance on this test depends to a large degree on subject initiated processing. Thus, consistent with Craik's (1983) ideas, older adults who perform poorly on one test also perform poorly on the other test and, as a result, the performance on the two tests is correlated. No correlation between performance on the spatial memory test and paired associates test was observed for young adults, perhaps because their performance was too high on both tests.

Chapter five

GENERAL DISCUSSION

The goal of this thesis was to gain more insight into how spatial memory changes across the adult-life span. Towards this general goal, my research investigated the following specific questions. Do age-related changes in spatial memory performance occur in real-life situations? If there are age-related changes in spatial memory do they increase linearly with age? Do older versus young adults benefit more from being informed about an upcoming spatial memory test? Do age-related changes in performance vary across different types of spatial memory test?

The first section of this chapter presents a brief overview of my research and it reviews the main findings that emerged. The second section discusses their theoretical implications. Finally, the third section outlines some limitations of my research.

Summary of main findings

I conducted two experiments. The first was carried out in a real-life setting--as part of an exhibit on memory. Subjects were visitors to the exhibit, and were from a wide age range, from 15 to 74 years. To obtain an index of their spatial memory performance, they were asked to indicate the locations of displayed items on a floor map of the exhibit.

The second experiment was carried out in a laboratory, under more controlled conditions. In order to keep the study and test tasks as similar as possible to a real-life situation, an office was set up, and subjects were asked to play the role of a secretary. The subjects were a group of young, university students, and a group of adults, 65 years of age and older. To measure spatial memory performance, subjects were required to recollect the items they had used to complete a series of secretarial tasks, either by indicating their locations on a map of the office (the map test), or by relocating them in the office (the relocation test).

The results showed that spatial memory test performance declines with age, even in real-life situations. In Experiment 1, adults older than 55 years of age correctly indicated the locations of fewer displayed items than younger adults (see Figure 5, page 38). Similarly, in Experiment 2, older adults recollected fewer item-locations than young adults, in each of the experimental conditions (see Figure 11, page 73). These results generalize and extend the findings from previous laboratory research (e.g., Light & Zelinski, 1983; Naveh-Benjamin, 1987; Park et al., 1983) to real-life situations.

However, perhaps the most important, new finding from my work concerns the pattern of age-related performance decline in Experiment 1. The results showed that spatial memory performance remained constant until about 60 years of age and than declined sharply. This finding contrasts with the gradual age-related decline found in previous psychometric studies of spatial memory (e.g., Moore et al., 1984; Salthouse et al., 1988a) thereby suggesting that the findings from the psychometric studies do not generalize to real-life situations. The pattern of spatial memory decline, shown in Figure 5, page 38, is correlated with a major life event/change--retirement and this may give clues about its cause (see Baltes & Labouvie-Vief, 1973; Labouvie-Vief & Chandler, 1978).

The next two important findings emerged from Experiment 2. The first concerns study instructions or knowing that spatial memory will be tested. The results, shown in Figure 11, page 73, reveal that older adults improved when they were informed about the upcoming test whereas the performance of young adults did not improve. In other words, age-related differences in performance were minimized when the subjects were informed about an upcoming spatial memory test.

The second finding from Experiment 2 concerns the way in which spatial memory performance was tested. The results, shown in Figure 11, page 73, indicate that both age-groups performed better on the relocation than the map test, but the performance increase was larger for older than young adults. Thus, age-related differences were minimized when spatial memory testing involved relocating items in a familiar, concrete setting (the relocation test) as opposed to when it required indicating item locations on an abstract map.

Finally, an exploratory post hoc data analysis showed that, both in Experiment 1 and 2, the locations of distinctive items were easier to recollect than the locations of other, non-distinctive items, and this was true for both young and older adults. This finding is consistent with the results of several previous studies (e.g., Bruce & Herman, 1986; Kearins, 1981).

Theoretical implications of my research

What are the main theoretical implications of these findings? In this section, I will relate the findings to the automaticity view (Hasher & Zacks, 1979) that motivated most of the previous research on spatial memory and aging, as well as to the modified version of the TAP view (cf., Morris et al., 1977) of memory and aging (Craik, 1983, 1991; Graf, 1990, 1991) that guided my research.

Why does spatial memory performance change around 60 years of age? The results of Experiment 1 showed that spatial memory test performance did not decline gradually across adulthood, but it remained stable until about 60 years of age and then declined gradually. This suggests that the linear decline starting at about 20 years of age obtained previously on psychometric or traditional laboratory tests of spatial memory (e.g., Moore et al., 1984; Salthouse et al., 1988a) does not generalize to real-life situations.

One possible reason for the discrepant findings is that the pattern of decline obtained on psychometric and laboratory tests is mediated by older adults' decreasing familiarity with the spatial memory tasks employed in previous studies. In contrast, the pattern of decline observed in Experiment 1 is not likely to reflect age-related differences in familiarity with the spatial memory task used in Experiment 1 since it is similar to those encountered in real-life situations by adults of all ages. In light of these considerations, I believe that the pattern of age-related decline obtained in Experiment 1 is mediated by changes in how spatial information is processed rather than resulting from differences in familiarity.

The observed pattern of decline has important implications for extant theoretical views, especially the automaticity (Hasher & Zacks, 1979) and other resource views (e.g., Salthouse, 1988; Craik, 1983). Each of these views assume that performance on cognitive tasks is dependent on the available capacity of processing resources that diminishes gradually across adulthood. This is because the capacity of processing resources is given by its biological antecedents such as neuronal loss. The automaticity view, which is a special case of the resource view also claims that, because of its fundamental nature, and its relevance to biological survival, processing of spatial information operates independently of the processing resources by being genetically prepared (Hasher & Zacks, 1979). From this assumption, it follows that the resource views predict that spatial memory test performance should declines gradually across the adulthood, and the automaticity view claims that no decline in performance should occur at all. Evidently, the pattern of decline observed in Experiment 1 goes against both of these views.

The reason why spatial memory test performance declined only for subjects older than about 60 years of age remains unclear. One possible explanation arises from the fact that this decline is associated with a major life-event/change--retirement. It has been pointed out (e.g., Baltes

& Labouvie-Vief, 1973; Labouvie-Vief, 1977) that retirement brings about changes in social and environmental opportunities and demands, and that these changes may lead older adults to adopt different modes of processing presented information. For example, older adults may focus on processing meaning or aesthetic aspects of presented stimuli whereas younger adults may focus more on descriptive aspects such as color, size, and spatial location of each stimulus. By this view, age-related changes in spatial memory performance reflect, at least in part, qualitative rather then quantitative changes in processing of presented information (for the recent evidence supporting this view see Schmidt and Graf, 1992).

It is also possible that the post-60 years decline in spatial memory performance is mediated, in part, by age-related changes in vision. The visual accuity, the size of the visual field, and other vision abilities decline after about 60 years of age (Fozard, 1990; Fozard, Wolf, Bell, McFarland, & Podolsky, 1977; Haas, Flammer, & Schneider, 1986). These changes in vision could influence the ability of older adults to encode spatial information by restricting the amount of information available to them. However, the age-related changes in vision cannot account for other findings from my research that are discussed in the following paragraphs.

Why do intentional study instructions benefit older but not young adults? The results of Experiment 2 showed that intentional study instructions improved spatial memory test performance of older but not young adults. The finding that the intentional manipulation affected performance of any subject group is contrary to a strong version of the automaticity view (Hasher & Zacks, 1979). As I have pointed out above, the automaticity view claims that processing of spatial information operates independently of the available processing resources, because it is genetically prepared. Because of its nature, automatic processing cannot be outperformed by strategic processing which is always limited by the available resources. Thus, by the automaticity view, intentional study instructions should not result in improved processing and remembering of spatial information. However, contrary to this view, the performance of older adults did improve when they were informed about the upcoming spatial memory test.

The findings from the intentional/incidental conditions suggest that older adults are dependent on intentional instructions to initiate/guide processing of spatial information. The finding indicates that older adults are not as likely as young adults to process spatial information when left to their own devices but they are capable of such processing. This is consistent with the idea that age-related changes in spatial memory performance are mediated, to a large extent, by changes in subject-initiated, strategic processing (Labouvie-Vief, 1977).

Why does spatial memory test performance depend on a type of test? The results showed that both older and young adults performed better on the relocation test than on the map test, and even more importantly, that the improvement in performance was larger for older than for young adults. An intuitive analysis suggests that on the relocation test, the processes involved in remembering may be initiated and guided by the familiar aspects of the environment such as the size or color of items and their context. In contrast, on the map test, the processes required for effective remembering must be initiated and guided by the subjects' strategies because the map test lacks many cues that may elicit remembering. In short, it appears that the relocation test provides more environmental support to initiate and guide remembering than the map test, and thereby facilitates spatial memory performance

The findings and the above analysis suggest that performance of older versus young adults is more dependent on environmental support such as that provided by the relocation test. This is consistent with Craik's (1983) proposal that older adults are less likely to engage in self-initiated processing, and are more dependent on environmental support to initiate and guide the processes required for effective remembering.

This interpretation has to be viewed with caution, however. An alternative possibility is that the effect of test type may have been larger for older adults because they had more difficulties with translating the items' real-life locations onto the highly abstract map of the office. In other words, older adults may have remembered the locations of more items than is indicated by their performance on the map test, but they were unable to indicate these locations correctly.

Why were the locations of distinctive items recollected better than those of other, non-distinctive items? Exploratory analyses indicate that the locations of distinctive items were easier to recollect than those of non-distinctive items for both young and older adults. It is possible that distinctive items invite more extensive processing of both their unique features and their relations to other items in the exhibit (see Eysenck, 1979; Hunt & Einstein, 1981), and thereby increase the likelihood of recollecting their spatial locations. In addition, distinctive items may also be easier to label or identify, thereby making it easier to associate the items with particular locations (Bruce & Herman, 1986; Kearins, 1981).

Global implications of my research. The global implications of my research concern the automaticity view (Hasher & Zacks, 1979) that has guided most of the previous research on age-related changes in spatial memory, and the modified version of the TAP view (Craik, 1983, 1991; Graf, 1990, 1991) that has guided my research.

The combined findings from my research conflict with the strong version of the automaticity view as proposed by Hasher and Zacks (1979). This view assumes that performance on most cognitive tasks depends on the availability of some type of processing resource(s). The availability of resources is believed to decrease with aging because it is tied to its biological functioning (Salthouse, 1988; Craik, 1991). This view claims that a few fundamental aspects of the stimulus such as its spatial location, are processed independently and without requiring processing resources because such processing--called automatic--is genetically prepared. Because of its nature, automatic processing cannot be improved upon by other, resource dependent processing. By this view, it follows that spatial memory test performance should not be dependent on aging, intentional/incidental manipulation, type of test, or an item's distinctiveness.

The finding from my research might be accommodated by this view if it is assumed that the automaticity is not an all-or-none phenomenon but rather depends on practice, and in turn on tasks, contexts, and subjects' characteristics (e.g.,Logan, 1985, 1988a, 1988b). The difficulty with such a modified view is that it looses its predictive power.

I prefer an extension of the TAP view (cf., Morris et al., 1977) for age-related changes in memory (Craik, 1983, 1991; Graf, 1990, 1991). The TAP view claims that performance on any memory test is facilitated by the degree of overlap between mental operations engaged at study and test (Kolers, 1973). Craik (1983) extended this general idea by proposing that study and test tasks can be arranged on the continuum that reflects the extent to which performance depends on subject-initiated processing and the extent to which it is supported and guided by the environment. The environmental support consists of the cues and instructions that are given to subjects (Graf, 1990, 1991). Craik (1983, 1991) further argued that age reduces the capacity for subject-initiated processing (note, Craik's view is ultimately linked with the resource views of aging), and thus it makes older adults more dependent on environmental support to initiate and guide their memory processes. Consistent with this view, the results of the present research suggest that intentional instructions and familiar, concrete test cues may be more effective in initiating and guiding study and test processing. It follows that it is less dependent on subject-initiated processing, and age-effects are reduced.

The fact that the experimental manipulations had a larger effect on older than young adults indicates that while they can do the type of processing required for effective remembering of spatial information, they are not as likely as young adults to do so when left to their own devices. Thus, the findings from my research support the notion that age-related changes in spatial memory test performance reflect, at least in part, changes in processing strategies and familiarity with the study and test tasks and their context rather than irreversible changes in the underlying cognitive "hardware" (Labouvie-Vief, 1977).

Limitations of my research

One of the major concerns of my research was to examine how spatial memory changes across adulthood in real-life situations. This led me to conduct two experiments: one naturalistic and one in the laboratory. These two designs have their benefits but also some important limitations. For this reason, I will discuss some factors that limit the generality of the conclusions drawn from my research results.

Limitations of Experiment 1. Experiment 1 has several limitations that suggest caution in interpreting its principal result, the finding that spatial memory performance declined only for subjects older than approximately 60 years of age. One reason for caution arises from the naturalistic design of Experiment 1. Subjects, who were visitors to the exhibit explored the exhibit room as they liked and were not required to inspect all displayed items. Thus, there was no control over which items subjects actually saw and how much attention they paid to each item. Although I have attempted to control for the influence of some variables such as time spent in the exhibit and how much they liked/disliked it, the indices used--subject's estimate of time and subject's rating of liking on a Likert-type scale--were rather crude. Even if these measures were accurate, what subjects saw may also depend on whether they visited the exhibit alone or with someone else, as well as on whether the exhibit room was crowded (i.e. distracting) or empty. I have only attempted to limit the influence of these latter variables by excluding from the study visitors that came with children and by suspending the study whenever the exhibit room appeared to be too crowded to allow inspection of each item by all subjects.

Another major reason for interpretive caution comes from the cross-sectional design of Experiment 1. In such designs, age-related changes are measured only indirectly, and thus a pattern of observed age-related changes may be influenced by other variables related to age such as subjects' health, education, or employment status. The fact that little is known about subjects who participated in Experiment 1 makes it impossible to exclude any of these variables as explanations for the observed pattern of age-related decline.

Finally, the results of Experiment 1 have to be generalized with caution because visitors to the memory exhibit that took place in Science World, Vancouver, may not be representative of the population at large.

The main theme of the exhibit was memory, and thus many visitors were presumably interested in learning more about memory. In addition, a large part of the exhibit consisted of paintings, and thus many people who came to visit were likely interested in visual arts. In light of these consideration and the academic nature of the exhibit, it is possible that the visitors to the exhibit differed from the general population in academic, cognitive, or other respects.

Limitations of Experiment 2. The results of Experiment 2 have to be interpreted with caution primarily because of its cross-sectional, two-age-groups-only design. It is possible that the results are influenced by other differences between age-groups that are related to age. I have attempted to eliminate some of these by obtaining more data about the subjects themselves including their number of years in formal education, and their performance on two subtests of the WAIS--the digit span forward and the digit span backward. By means of statistical methods, I was able to rule out differences in education as mediating the results. Furthermore, based on the subjects' performance on the two subtests of WAIS, I believe that older subjects did not suffer from any serious cognitive impairment since all subjects' scores were clearly in the normal range (Lezak, 1983). Nevertheless, other variables related to age may have influenced the results. For example, it is possible that a higher proportion of older than young adults had vision problems.

Another limitation of Experiment 2 is that the two-age-groups-only design does not allow any conclusions about the age when the effects of study instructions and test type on spatial memory test performance first occur. Do such effects first appear around 60 years of age as suggested by Experiment 1? This question needs to be addressed in future experiments.

The method of recruiting the subjects also limits the generality of the results. The majority of older adults were recruited through advertisements in the Vancouver Sun and Province. Subjects were required to secure their own transportation to the testing site. The majority came by car while others came by bus. This subject selection procedure likely biased the sample of older adults towards more socially active and more educated adults. This is supported by the fact that older adults were above average in years of education, thereby indicating that they were not representative of the population at large.

Finally, the finding that older adults improved more than young adults when spatial memory was tested by the relocation as opposed to the map test has to be interpreted with caution because there are at least two possible explanations. One is that older adults' recollection benefit more than that of young adults from the familiar, concrete cues provided by the relocation test. An alternative possibility is that older adults' performance was interfered with by the abstract nature of the map test. In other words, older adults may have remembered TBR items, but had difficulty indicating their locations on the map.

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Appendix A

STUDIES INCLUDED IN THE META-ANALYSIS THAT EXAMINED INFLUENCE OF METHOD OF LOCATING TARGETS ON THE SIZE OF AGE-EFFECT IN SPATIAL MEMORY TEST PERFORMANCE

Matrix method

Naveh-Benjamin (1987), Naveh-Benjamin (1988), Waddell and Rogoff (1981), Puglisi et al. (1985)

Map method

Light and Zelinski (1983), Park et al. (1990), Perlmutter et al. (1981), Sharps (1991), Sharps and Gollin (1987), Thomas (1987), Zelinski and Light (1988)

Real-life method

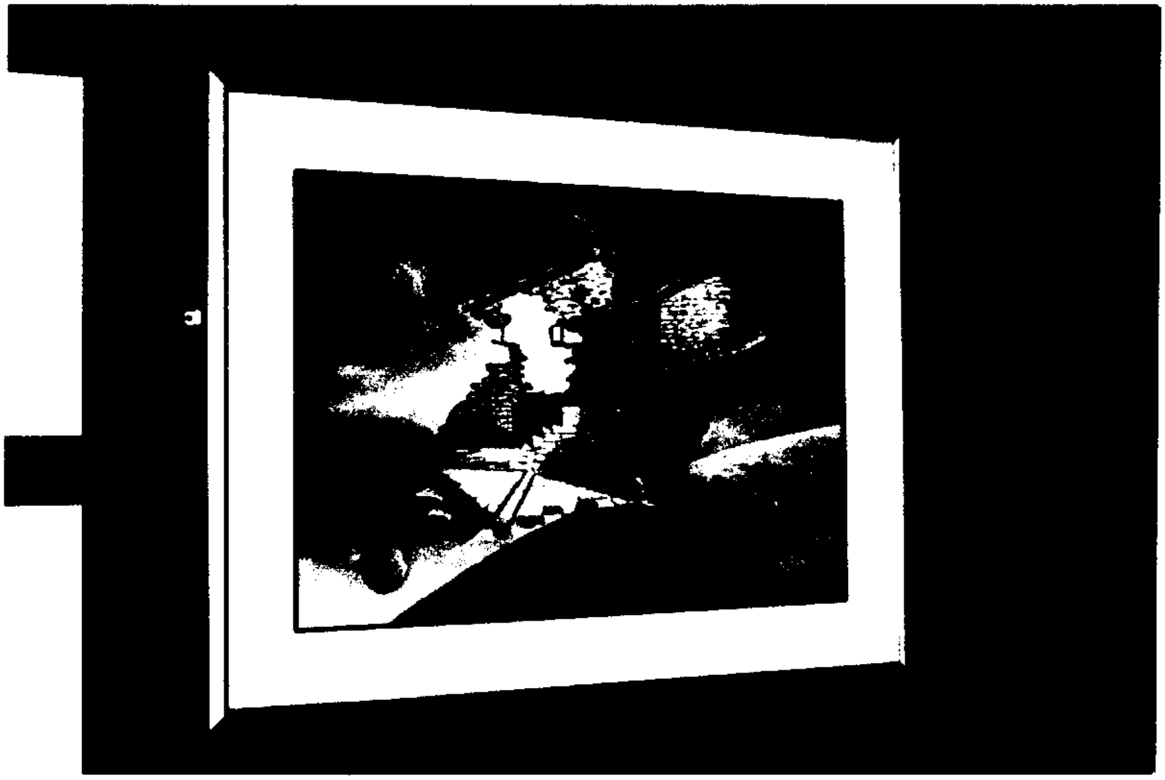
Bruce and Herman (1986), Park et al. (1990), Sharps and Gollin (1987), Sharps and Gollin (1991), Waddell and Rogoff (1981), Waddell and Rogoff (1987)

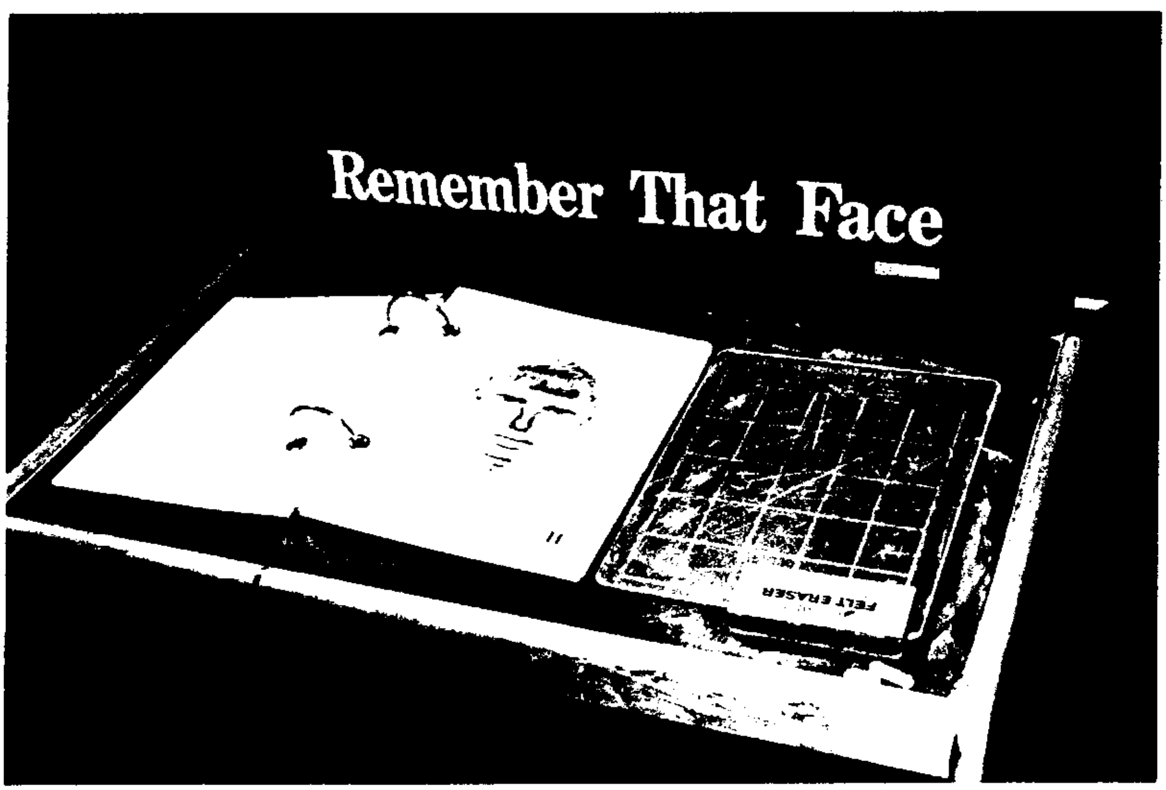
2-/4-Field methods

Ellis et al. (1987), McCormack (1981), Park et al. (1982), Park et al. (1983), Rohling et al. (1991)

Appendix B

EXPERIMENT 1: EXAMPLES OF TARGET ITEMS




Remember That Face
FELT ERASER

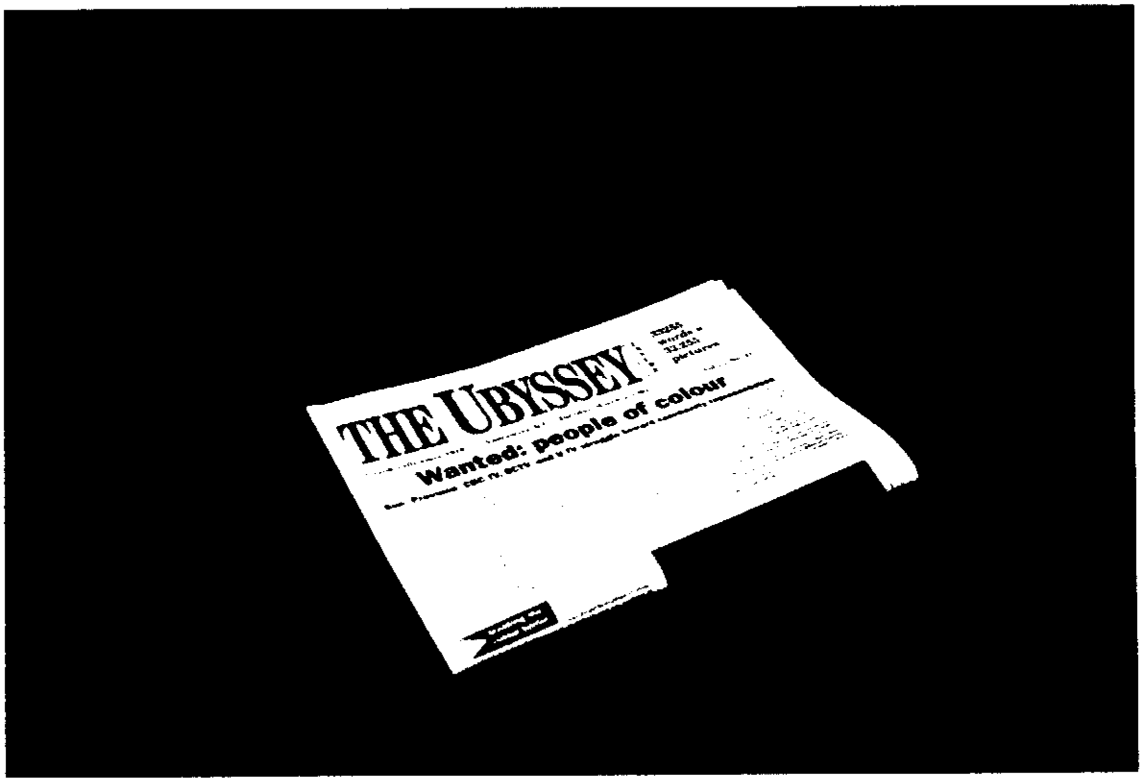
Appendix C

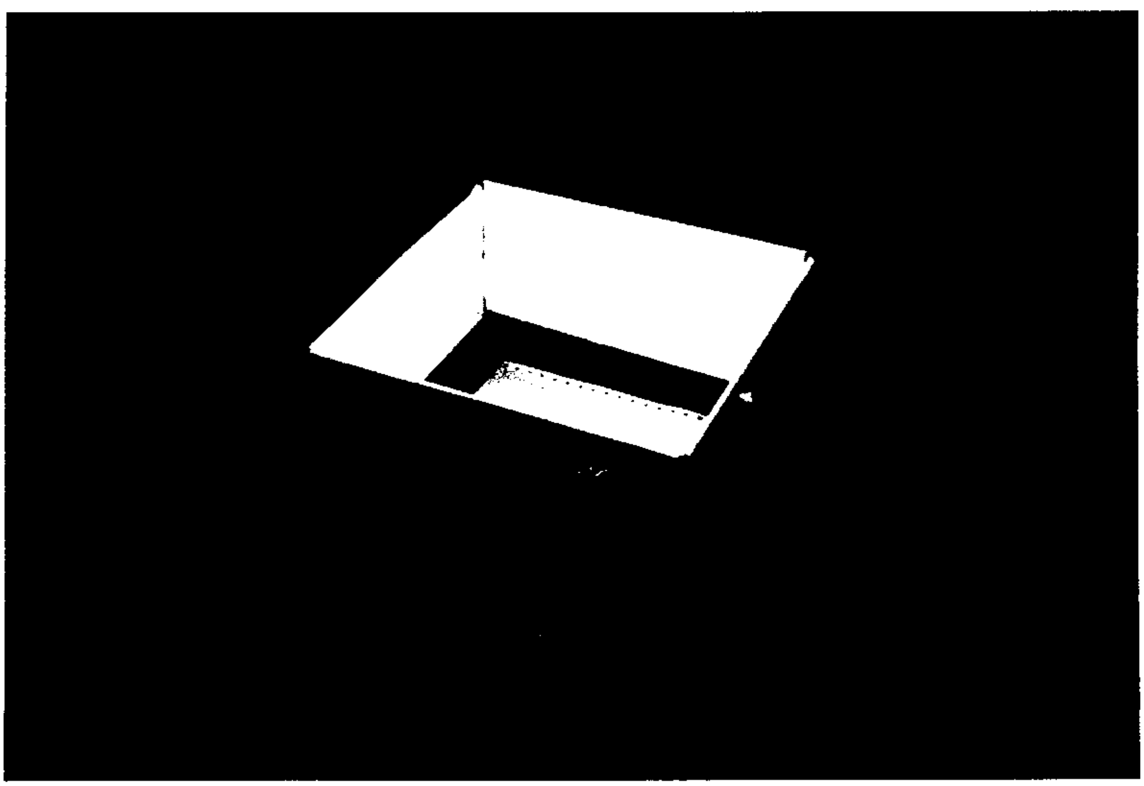
EXPERIMENT 2: TARGET ITEMS BY SET MEMBERSHIP

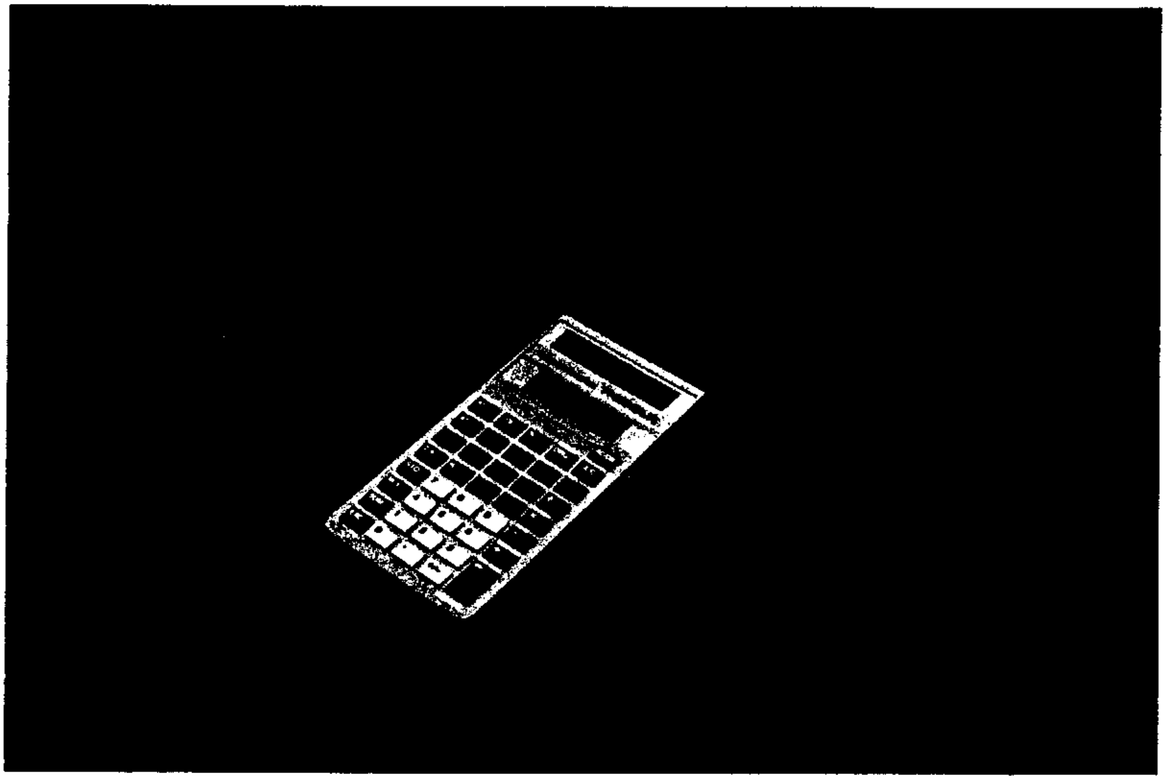
	Set A		Set B
1	pop can (Pepsi)	21	red pen holder
2	pencils	22	diskettes
3	water can	23	attendance book
4	phone book	24	"Documentation" folder
5	newspaper (Ubyssey)	25	kettle
6	box of tea-bags	26	book (Perceptual org.)
7	computer paper	27	audio cassettes
8	calculator	28	BYTE magazine
9	book (Lisp)	29	"Catalogues" folder
10	envelopes	30	sugar bowl
11	stapler	31	light brown chair
12	"Letters" folder	32	staples
13	tea cup	33	dictionary
14	red basket	34	white file folders
15	clock	35	PC magazine
16	coffee mate	36	business card file
17	yellow stickers	37	orange chair
18	Scotch tape	38	pencil sharpener
19	plant	39	coffee
20	brown chair	40	liquid paper

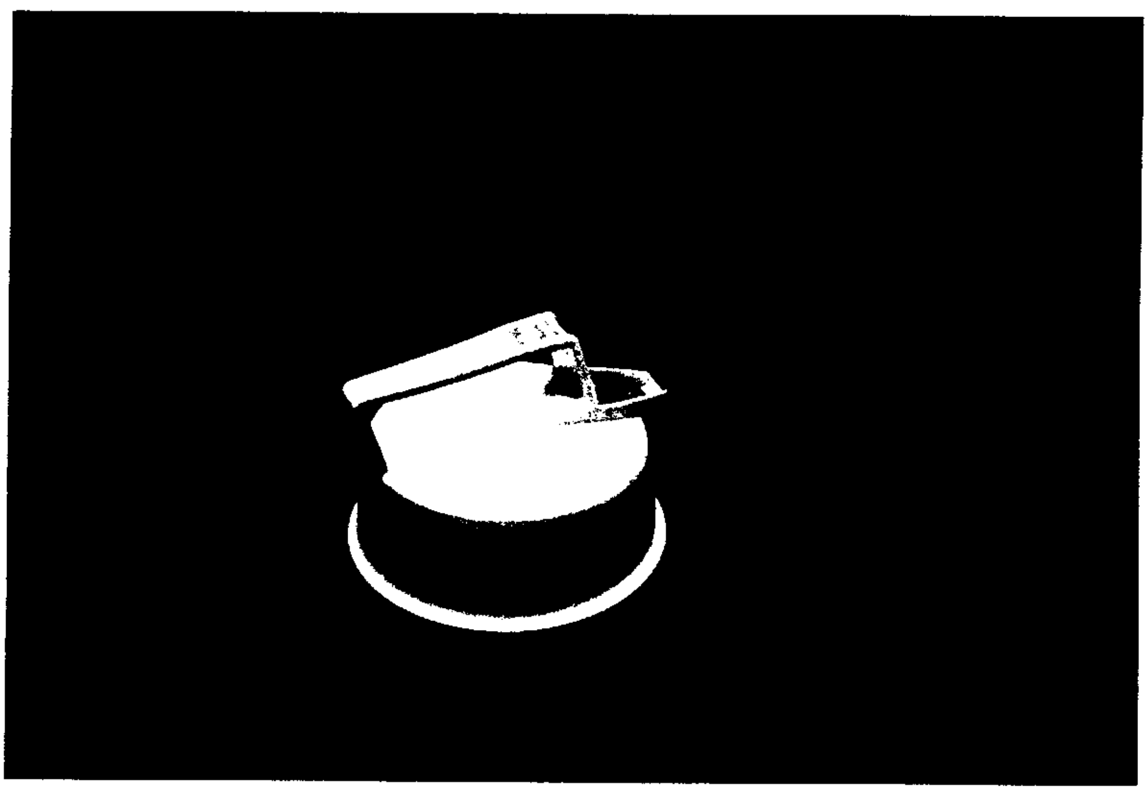
Appendix D

EXPERIMENT 2: EXAMPLES OF TARGET ITEMS


THE UBYSSEY
words =
pictures
Wanted: people of colour







Appendix E

EXPERIMENT 2: INTRODUCTORY INSTRUCTIONS

I am interested in the ability of people to adapt to new environments. For example, how do people cope with the demands of a new job, and how they find their way around a new place after moving to a new home, neighborhood, a city.

In a few minutes, I will take you to a room that is arranged to look like an office, such as an office of secretary in a company dealing with computer supplies. I want you to imagine that you are a secretary who works in that office.

As part of your work, I will ask you to do a series of short tasks of the sort that most secretaries have to do on regular basis, such as making phone calls. The tasks that I want you to carry out are all described on a piece of paper. I will give you these instructions when we go to the office. What I would like you to do is to read and carry out these instructions one at a time. Begin at the top of the list, read the first instruction and do it, then read the second, and so on down the list.

Follow the instructions to the best of your abilities, one at a time, and pay close attention to what you are doing because when you are finished with the last task, I will give you a memory test.

[For the subjects in the INTENTIONAL condition only] As a secretary you need to remember where you put things and where you can find them. When you are finished I will ask you to tell me where the objects which you used belong. I will ask you where the things were or where you put them.

Appendix F

EXPERIMENT 2: INSTRUCTIONS FOR SECRETARIAL TASKS

(1) There is a box with computer paper on the light brown chair. Pick it up and put it under the large desk with no drawers (the one next to the mirror window). It should be placed as close to the wall with the mirror-window as possible.

(2) The chairs were misplaced by a janitor. Please put them where they belong. The orange chair belongs by the desk with no drawers, the dark brown chair should be placed by the wall between the book case with light-colored shelves and the coffee table, and the light-brown chair belongs by the desk with two drawers (your desk).

(3) Make coffee for your imagined boss. Coffee, coffee-mate, sugar, a cup with a spoon, and a kettle with water are in the book case next to the small table. Take the kettle first and plug it into the yellow electricity bar on the small table in order to get water boiling. Make it one spoon of coffee, one spoon of coffee-mate, and one sugar.

(4) There are some office supplies on your desk. Put them where they belong:
Take one of the pencils and sharpen it using the automatic pencil-sharpener. The pencil-sharpener is on the small table next to the black

filing cabinet. After you sharpen the pencil, put it in the top drawer of the your desk.

Put the rest of the supplies where they belong:

-- the other pencil goes into the top drawer of your desk,

-- the Scotch tape goes into the top drawer of your desk,

-- the staples (the small white-blue-red box) go into the top drawer of your desk,

-- the envelopes go to the far left in the bottom (big) drawer of your desk,

-- the box of computer disks (labeled "University disks") should be placed in the book case with the light-colored shelves. Place it to the far right side on the fourth shelf from the bottom (on the same shelf as the red basket),

-- the cassette tapes go in the book case with the light-colored shelves. Place them to the middle on the third shelf from the bottom.

-- the white file folders go into the bottom drawer of the black filing cabinet.

-- the tiny bottle labeled "LIQUID PAPER" goes to the far right and close to the wall on the top of the large desk with no drawers,

-- the tea goes in the book case with the dark-colored shelves. Place it to the middle on the fourth shelf from the bottom,

-- the PEPSI goes on the small table which is between the black filing cabinet and the book case with dark shelves. Place it to the far left and close to the wall.

(5) There is also some mail on your desk. Put the mail where it belongs:
-- the BYTE magazine goes in the book case unit with the light-colored shelves. Place it to the far left on the third shelf from the bottom,
-- the PC magazine goes in the book case with the dark-colored shelves. Place it to the far left on the fourth shelf from the bottom,
-- the newspaper called "UBYSSEY" goes on the coffee table next to the entrance door. Place it on the side which is closer to the wall.
-- the book "Perceptual organization" goes in the book case with the light colored shelves. Place it to the far right on the first bottom shelf.
-- the letter goes in the top drawer of the black filing cabinet. Place it in the green file folder (labeled "LETTERS"),
-- staple the two bills (sheets of paper labeled "BLAISE COMPUTING") together, and put them into the red basket. The stapler is on the desk with no drawers.

(6) Your boss wants you to find two phone numbers.
-- Find the phone number of the "West boat charters". This phone number can be found in the business card file which is in the first drawer of your desk. Write the phone number on the message sticker (the yellow message stickers are on the far right in the bottom drawer of your desk). To write the phone number use one of the pens or pencils in the red pen holder on your desk.

-- Find the phone number of the "Airport Parking V I P" in the Vancouver phone book. The phone book is in the book case with the light colored shelves. Write the number on the message sticker too.
-- Place the message sticker on the message board above your desk to the left.

(7) Your boss wants you to check if spelling of the following word is correct: "ratatouille". Check the spelling even if you are sure that it is correct. To check the spelling, use the dictionary which is in the book case next to the desk with no drawers. If the spelling is not correct, leave the message for your boss on the message board.

(8) Your boss left several things on your desk. You are asked to put them back where they belong.
-- the book "LISP" goes in the book case with the dark shelves. Place it to the far right on the second shelf from the top.
-- the yellow file folder labeled "CATALOGUES". The file folder goes into the second drawer from the top in the black filing cabinet,
-- the file folder labeled "DOCUMENTATION". This file folder goes into the top drawer of the filing cabinet,
-- the calculator goes on the top of the large desk with no drawers. Place it to the far left and far away from the front of the table into the corner of the desk.

(9) Water the plant on the coffee table (the plant is artificial but water it anyway). The watering can is in the book case with the dark shelves.

(10) Before you end the day you must sign out. The yellow attendance book is in the book case with the light-colored shelves. It is on the fourth shelf. Write down your name and the time using the clock which is on the top of the large desk with no drawers.

You are finished with your secretarial tasks. Leave the office and I will meet you outside.

Appendix G

EXPERIMENT 2: SCORING PROCEDURE

Figure 14 shows the target items' correct locations. These are indicated by appropriate numbers (see Appendix C). In order for an item to be scored as correctly located, its relocated or indicated location had to be on a correct structure, for example on the desk, and within the boundaries delimited by the hairlines shown in Figure 14.

Specifically, items that belonged on the top of the desk and two tables had to be relocated in the correct 1/6th of the desk or table surface. The items that belonged on the shelves had to be relocated on the correct shelf and in the correct 1/3rd of the shelf. The items that belonged in the filing cabinet had to be in the correct drawer. The items that belonged in the drawers of the desk had to be in the correct drawer and those in the bottom drawer also had to be in the correct half of the drawer, that is, in either left or right half of the drawer. The items that belonged on the top of the coffee table had to be relocated on the correct half of the table surface. Finally, the items that belonged on the floor had to be relocated next to the appropriate structure, for example, the correct table.

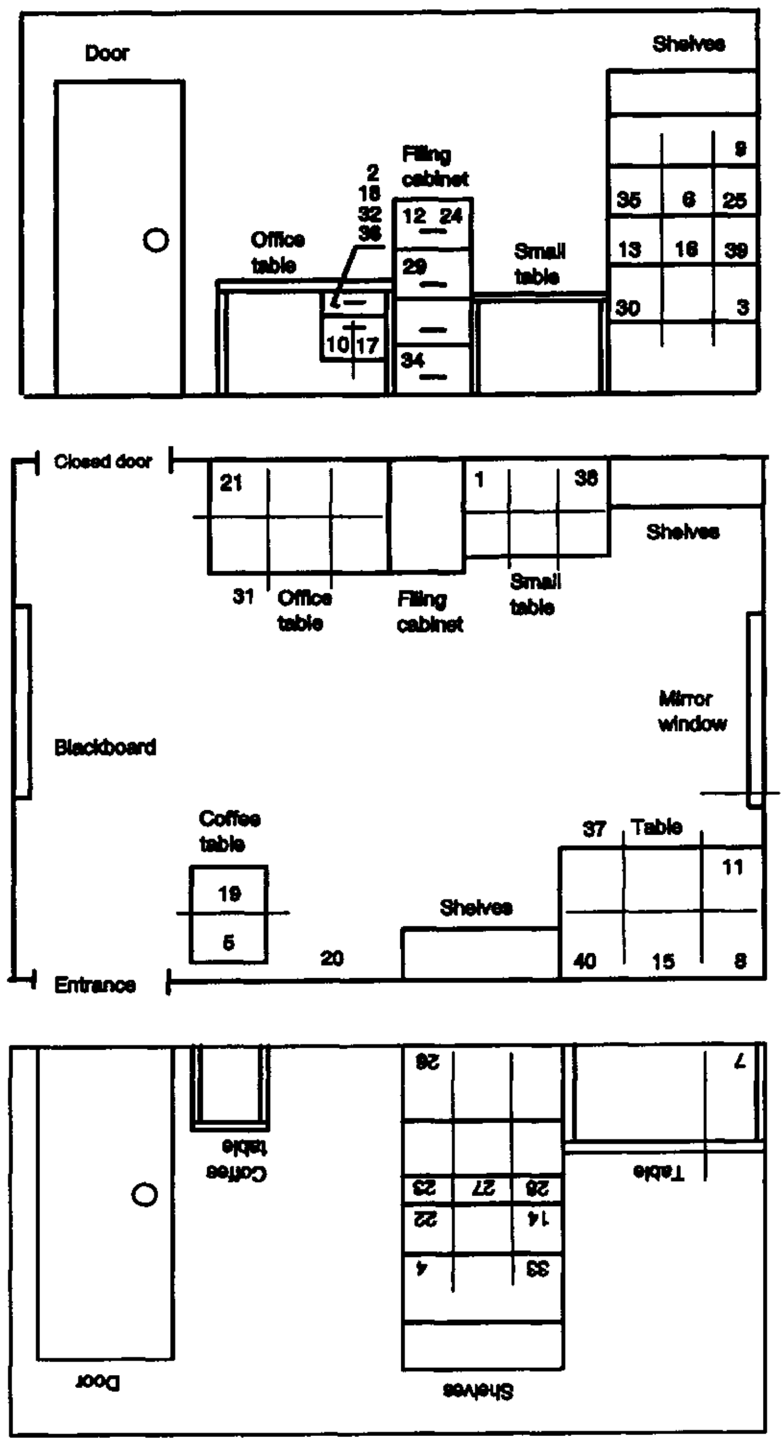


Figure 14. The floor plan of the office and correct locations of target items.