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The Hippocampal Contribution to Age-Related Decline in Memory for Spatial Location

Robin E. Cooney

A Thesis
in
The Department
of
Psychology

Presented in Partial Fulfilment of the Requirements
for the Degree of Doctor of Philosophy at
Concordia University
Montreal, Quebec, Canada

April, 1993

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ISBN 0-315-87303-5

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Abstract

The Hippocampal Contribution to Age-Related Decline in Memory for Spatial Location

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The present research evaluates two interrelated hypotheses: first, that age differences in memory for locations can be eliminated by the presence of a visually distinctive context and second, that the reason distinctive context is effective is because it reduces dependence on a hippocampally mediated processing system. In Experiment 1, 24 young and 26 older adults learned and recalled the spatial locations of 40 objects. Visual distinctiveness of context was manipulated by placing the objects on either a plain or colored map of a room. Hippocampal function was assessed by the Emergent Complex Figure task (ECF, Jones-Gotman, 1986). Wechsler Adult Intelligence Scale (WAIS) Symbol Substitution, a letter recall task and WAIS Block Design were used to assess processing speed, working memory capacity and spatial visualization ability, respectively. Results showed that in the plain condition the explained variance in memory for the location task was significantly increased by adding the ECF measure. The addition of color did not improve spatial location memory for either the young or old group and ECF performance remained the best predictor of memory for locations, although the contribution of processing speed, working memory capacity and spatial visualization measures to explained variance was somewhat enhanced. In Experiment 2 additional cues were provided in the distinctive condition in comparison to the plain condition to enhance its effectiveness. The results showed that the increased distinctiveness of contextual cues improved memory for the young and old group equally. There was, thus, no evidence that distinctive context would compensate for age-related decline. As in Experiment 1, the ECF measure of hippocampal function remained the best predictor in both conditions, although again the contribution of processing speed, working memory capacity and spatial visualization ability was somewhat enhanced in the distinctive condition. Experiment 3 involved a re-analysis of previously collected data from a study where compensation appears to have been effected, to determine whether, in this circumstance, the contribution of the ECF to memory for location would decrease significantly. Unlike the first two studies, the ECF no longer made a significant contribution to explained variance in the compensatory condition. The findings from the three studies are discussed in terms of the underlying physiological, cognitive and environmental factors which underlie age-related decline in memory for locations.

Acknowledgments

I would like to thank my supervisor, Dr. Tannis Arbuckle-Maag, for her guidance and support during the preparation of this thesis and throughout my career as a graduate student. My thanks also to Dr. Norman Segalowitz and Dr. Barbara Woodside for their thoughtful and insightful suggestions as committee members and their advice and encouragement over the years. In addition, I would like to thank Dr. Jones-Gotman for providing the Emergent Complex Figure task for use in this study. Finally, I would like to thank my husband, Ted Cooney, for his unwavering encouragement and support throughout this undertaking.

The financial assistance of the Fonds pour La Formation de Chercheurs et L'Aide a la Recherche in the form of a doctoral fellowship was greatly appreciated.

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The Hippocampal Contribution to Age-Related Decline In Memory for Spatial Location

Most people take their ability to find their way from one place to another for granted until something happens and they become lost. It is only then that they become acutely aware of the practical importance of spatial memory to everyday functioning. Indeed, such automatic actions as remembering the route through a well-known building or remembering where objects are located around the house require a complexity of spatial memories that must be accessible if an individual is to function at an optimal level in the environment. Given the importance of this spatial memory system to everyday functioning, it is not surprising that there is a growing body of research examining spatial memory in relation to possible age-related decline.

In the past two decades this research employed two broad approaches. The first approach focused on the study of age-related decrements on a variety of psychometric spatial tasks, measuring such abilities as spatial orientation and visualization. The second approach emphasized a more experimental orientation, studying areas such as mental rotation, perspective-taking, spatial memory and macrospatial cognition. Regardless of approach, studies reported that performance on spatial tasks declines with increasing age (for an overview see Kirasic, 1988). The challenge now to cognitive aging researchers is to identify the reasons for the findings of age decline.

This project was designed to respond to this challenge, specifically in the area of memory for spatial locations. The reasons for this choice are twofold. First, it may be assumed that memory for spatial locations plays a crucial role i. the daily lives of older adults. This memory enables older adults to locate objects and landmarks in space and to navigate within their environment. Signs of decline in such a complex system may lead to disruption of everyday functioning, disorientation and even confusion. It can be argued that a better understanding of the nature of this memory system will aid older adults in the management of age-related decline in spatial functioning.

Second, there is a growing body of research on memory for spatial locations. This research addressed Hasher and Zack's (1979) proposal for the automatic processing of spatial information and as such contributed to a growing debate on the role of context in attenuating or eliminating decline in memory for spatial locations. The availability of this research base provides a greater scope for examining central questions concerning the normal aging process and memory for spatial locations.

In order to address why there exists an age-related decline in spatial memory this study adopted a three part multi-step procedure advocated by Kirasic in 1988. Kirasic argued that in order to reach an understanding of age-related decline on spatial tasks there is a need to investigate age-related decline, not only within psychometric and experimental research, but also within the neurological literature. She proposed that such an investigation could be accomplished in three distinct stages. According to Kirasic, the first stage involves an examination of possible theories for age-related decline in the psychological and biological literatures. The second stage involves identifying useful psychometric instruments and the various functions they measure in order to test the possible theories. The third and final stage involves controlled laboratory experiments that examine age differences. It was Kirasic's belief that as a result of establishing links between age differences and psychometric instruments substantive conclusions could then be drawn determining how and why age-related decline exists.

In keeping with the first objective, the introduction provides a summary of the human developmental and physiological research in the area of memory for spatial locations. Within this summary, four different areas of research related to decline in spatial memory are reviewed. The first area reviewed contains a summary of research on the role of context in age-related decline of memory for locations. This summary is followed by an overview of the research on the role of reduced processing speed and working memory capacity in spatial memory. A third area of research, outlining the reasons for decline on the Block Design task, a subtest of the Wechsler Adult Intelligence Scale-Revised (WAIS-R), is then presented. Finally, animal and clinical research, linking underlying neurological mechanisms to age-related decline in memory for spatial locations, is reviewed.

In the final section,background/psychosocial contextual variables such as gender, education, visual acuity, self-reported health, depression as well as task related variables are discussed as possible explanations for the discrepant findings in the aging and spatial memory literature. Two questions are then raised: 1) is there evidence of age-related decline in memory for spatial locations? 2) if there is evidence for decline, what are the reasons that best account for this finding?

Human Developmental Literature

Evidence for Decline in Memory for Location

Research in the area of memory for spatial locations began primarily in response to Hasher and Zacks' (1979) proposal of age invariance as one of five criteria for the automatic processing of spatial information. According to these researchers, the processing of automatic stimulus information is minimally influenced by individual differences in cognitive functioning, intention to encode information, instructional manipulations, practice or age because the human organism has been genetically programmed to process such information at an optimal level. Thus, Hasher and Zacks predicted that old and young would not differ in memory for spatial locations. It can now be concluded that the majority of studies testing this hypothesis do find age-related decline in memory for spatial locations, demonstrating that the association of the automaticity of a process with this particular criterion may be of questionable merit and that memory for spatial information is not automatic.

One of the first studies to examine this hypothesis was conducted by Perlmutter, Metzger, Nezworski and Miller in 1981. These researchers tested young and older adults memory for building locations on three maps and found that older adults remembered significantly fewer building locations (47.4%) than young adults (57.9%). In the same year Charness (1981), testing recall of positions on a chess board, observed age-related differences in location memory for players of comparable skill.

These findings were replicated during the next decade leading researchers to conclude that age-related decline in memory for spatial locations was the rule. For example, age-related decline was reported in memory for map locations of buildings and structures (Light & Zelinski, 1983; Zelinski & Light, 1988), spatial location of picture, word stimuli and drawings of common objects (Naveh-Benjamin, 1987; Park, Puglisi & Savecool, 1983), location of line drawings (Park, Puglisi & Lutz, 1982), locations of small objects in a spatial array (Cherry & Park, 1989; Park, Cherry, Smith & Lafronza, 1990; Pezdek, 1983; Puglisi, Park, Smith & Hill, 1985), locations of buildings in a large model town (Bruce & Herman, 1986), locations of landmarks (Thomas, 1985), real-world location of buildings in a familiar, geographically defined downtown area (Evans, Brennan, Skorpanick & Held, 1984) and locations of salient route landmarks (Lipman,1991).

However, in 1981 Waddell and Rogoff suggested that such evidence of decline may simply be the result of task demands that do not take into account memory skills employed in everyday life. They proposed, instead, that age differences would disappear when spatial location information is organized in an interrelated, meaningful context. In order to test their hypothesis they asked middle-aged and older women to reconstruct spatial arrays, locating objects in either a contextually organized panorama or a noncontextually organized set of cubicles. As hypothesized, these researchers found no significant difference in the accuracy of location information when the spatial array was embedded within a meaningfully organized context. The researchers suggested that age differences in memory for spatial location may be explained by an age difference in reliance on meaningful contextual information within a spatial environment. Thus began the debate as to whether there is an age-related decline in memory for spatial location under all circumstances.

Age Differences in Reliance on Contextual Cues

There are three views in the literature regarding this issue. Proponents of the compensatory view argue that the reliance of older adults on the utilization of contextual cues will eliminate age-related decline in memory for location. Wadell and Rogoff (1981) were the first researchers to provide evidence for this point of view. In Waddell and Rogoff's study the performance of older adults was improved substantially more than the middle-aged with the inclusion of context. Similarly, Rankin and Collins (1985) and Park, Puglisi and Smith (1986) provided evidence that memory performance of older adults could differentially benefit from the presence of highly integrated visual or verbal context embedded within the target information.

Additional support for the compensatory view came with the publication of a series of studies by Sharps and Gollin (1987;1988). Sharps and Gollin (1987) reported surprising effects of quite large magnitude by simply manipulating the presence of visually distinctive context. With the addition of color to a plain map surface, they reported that the number of object locations recalled by older adults increased from 1.86 to 12.37, thus equalling the performance of young adults. When they used a painted model instead of a map, the performance of older adults increased to 22.86. Furthermore, when they placed these objects in a room, location memory increased again to 27.29, this time surpassing location memory of young adults at 22.71. Moreover, these researchers were able to replicate these findings for object memory (Sharps & Gollin, 1988) and for location memory (Sharps, 1991). These results led Sharps and Gollin to conclude that the presence of contextual information may differentially benefit older adults.

However, Sharps and Gollin's finding of an Age x Context interaction has been challenged within the aging literature. Park and her colleagues (Park, Cherry, Smith & Lafronza, 1990) conducted a series of experiments in order to examine the reliability of Sharps and Gollin's (1987) findings. These researchers replicated the painted model and room condition from the Sharps and Gollin (1987) experiment. They found that when objects were placed within the distinctive context (i.e., within a painted model or within the context of a room) memory for locations improved for young and older adults but age differences were not eliminated. Park et al. (1990) concluded that sampling error due to lack of control of psychosocial background variables (i.e., cognitive abilities) may be responsible for

Sharps and Gollin's findings of an Age x Context interaction.

In support of the compensatory hypothesis, Kirasic (1990; 1991) reported findings of an Age x Context interaction while investigating age differences in macrospatial cognitive tasks(i.e., tasks in which the spatial structure of the environment is so large that its entirety cannot be viewed from a single vantage point). However, unlike Sharps and Gollin, Kirasic emphasized the importance of familiarity with contextual cues in the facilitation of performance. For example, Kirasic (1990) found, that when the problems presented on a perspective-taking and mental rotation task used locations from the subjects' hometown instead of unfamiliar locations, age differences in performance disappeared. Consistent with this finding, Kirasic (1991) reported that older adults perform more accurately in a familiar setting than in a novel setting on distance ranking and route-execution tasks. Thus, Kirasic provides evidence that familiarity with already integrated context may be the crucial factor in eliminating age-related decline on spatial tasks, a conclusion not unlike that drawn by Wadell and Rogoff (1981).

Of interest, it should be noted that Winocur and his colleagues (Moscovitch & Winocur, 1983; Winocur & Moscovitch, 1983; Winocur, Moscovitch & Witherspoon, 1987) have demonstrated that the presence of salient contextual cues facilitates performance of Korsakoff amnesics and institutionalized elderly on tasks involving memory for a list of paired-associate words. Such facilitation was shown under conditions of induced high interference and when distinctive cues were provided at original learning. In contrast, older community dwelling adults were unresponsive to such contextual cuing. One explanation offered for this finding is that contextual cuing renders the learning event more distinctive, thereby decreasing susceptibility to interference effects. Winocur and his colleagues reasoned that such vulnerability to interference may be the result of a hippocampal and frontal lobe deficit which is more pronounced in Korsakoff amnesics and institutionalized elderly than in community dwelling older adults. Whether such results are applicable within the spatial memory area remains unknown since such studies have been limited to tasks involving the learning and memory of simple verbal associations.

The most widely accepted model regarding the role of context in eliminating age-related decline on memory tasks is advocated by Craik and his colleagues (e.g., Craik, 1986; Craik, Byrd & Swanson, 1987; Craik & McDowd, 1987). According to Craik, the reinstatement of context at retrieval drives the memory system back to its original configuration, lessening the need of older adults to engage in effortful retrieval operations (i.e., self-initiated operations) which are resource intensive. When context is not reinstated or is absent, Craik proposes that age differences on memory tasks are best explained by an age-related reduction in processing resources. According to this model then, age differences are reduced by the presence of context at retrieval because the contribution of processing resources is reduced. However, this explanation remains vague due to Craik's failure to precisely define processing resources.

Proponents of the second viewpoint argue that the presence of contextual cues facilitates performance in memory for locations but it does so equally for old and young. That is, there is not a shift with age to a greater utilization of contextual information. Support for this position comes from two sources. First, a number of researchers have shown that older adults do remember contextual information whether or not this context is spatial in nature (Park, Cherry, Smith & Lafronza, 1990; Park, Puglisi & Lutz, 1982; Park, Puglisi & Smith, 1986; Park, Puglisi, Smith & Dudley, 1987; Zelinski & Light, 1988). Secondly, the research on memory for spatial locations reports that contextual cues in the form of background detail or distinctive context facilitate recall for young and older adults alike. (Park, Cherry, Smith & Lafronza, 1990; Zelinski & Light, 1988).

Thus, at least according to this view, there is not an age-related deficit peculiar to memory for contextual information. This finding has received support from a recent study conducted by Denney and her colleagues (Denney, Miller, Dew & Levav, 1991). These researchers found that when they controlled for a general age-related deficit in episodic memory, there is no evidence for a differential deficit in contextual memory in older adults, only some level of episodic memory deficit for both target and contextual information.

Proponents of the third viewpoint suggest that older adults are not able to use contextual cues effectively to improve their performance on location tasks. For example, Pezdek, in 1983, reported age differences in the accuracy of relocating common objects on a 6 x 6 matrix regardless of the organizational context of the display. In contrast to young adults, who benefitted from an organized display, older adults displayed as much difficulty relocating objects in the organized as in the random display. Pezdek concluded that older adults experience difficulty utilizing distinctive organizational context during the encoding process. Bruce and Herman (1986) found that the presence of contextual cues during encoding does little to enhance memory for spatial location of older adults. These investigators demonstrated that older adults experience difficulty encoding building distinctiveness and thus do not profit from the presence of such contextual cues in the environment. Finally, McCormack (1982) found no significant age-related difference in the recall of location of words arranged in one of four quadrants on a card. One interpretation of this finding is that the absence of contextual cues prevented young and old alike from utilizing effective encoding strategies, thereby eliminating age differences due to an age-related contextual encoding deficit.

Taken altogether, these different perspectives of the role of context point to three differing conclusions. Advocates of the compensatory view propose that the presence of contextual information eliminates age-related decline in memory for location. Craik argues that age differences are markedly reduced on location tasks because the utilization of contextual cues reduces the contribution of processing resources, which decrease with age. Advocates of the second view suggest that there is no shift with age to a greater utilization of contextual information. The presence of contextual cues aids old and young equally. The third point of view argues that older adults are unable to utilize contextual information effectively and thus do not benefit from the presence of contextual information. These three points of view are illustrated in graphic form in Figure 1.

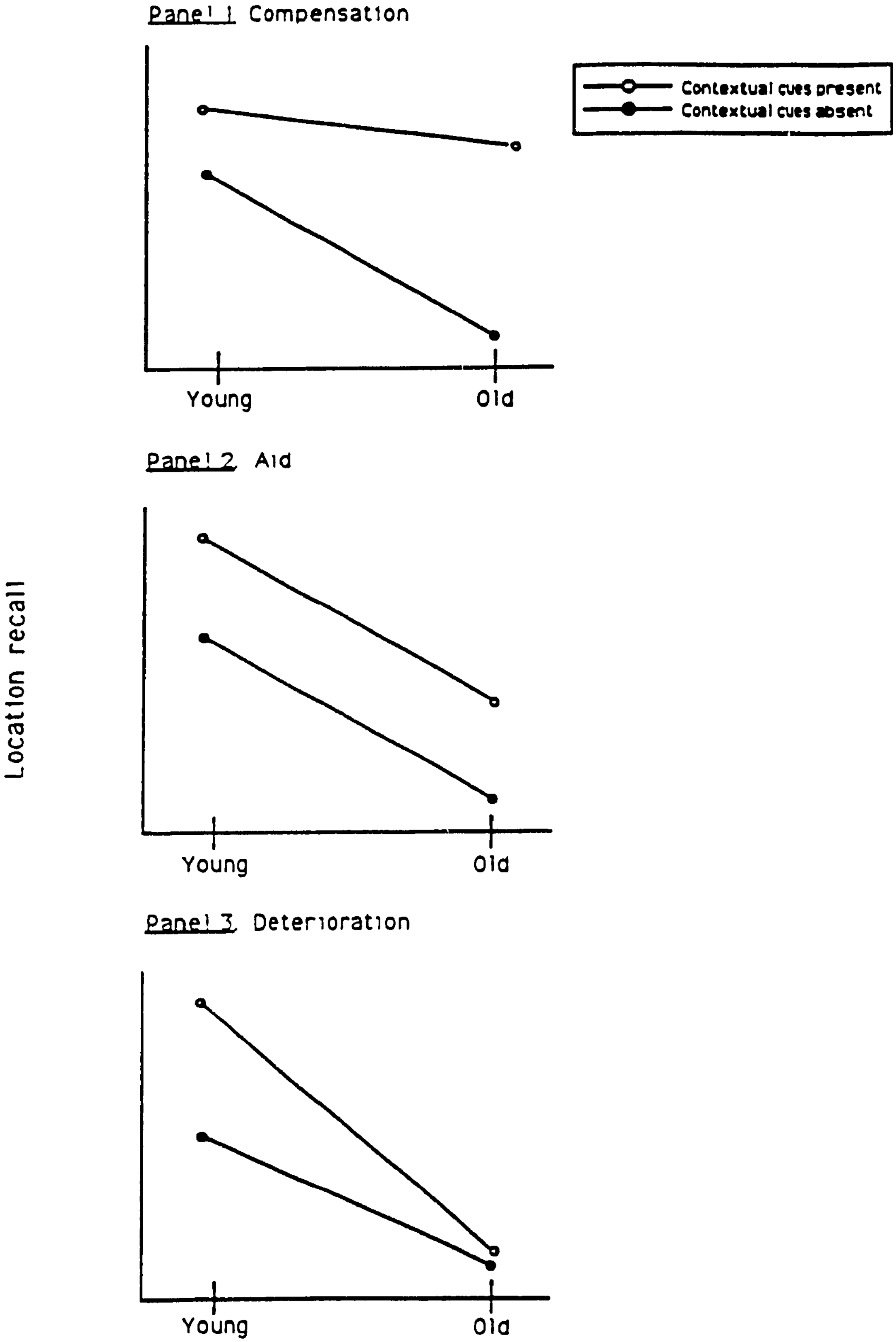


Figure 1 Possible outcomes of location recall as a function of age and context.

Age Differences in Processing Resources

The most widely held explanation is that age decline in spatial memory is due to a reduction in processing resources. In the early literature, processing resource was vaguely defined as mental energy utilized by the brain during the processing of information (Salthouse, 1988a; Salthouse, 1988b). This view held that physical changes associated with aging, such as biochemical and neuronal changes to the brain, reduced the quantity of processing resource. As a result, performance on any task that demands more in the way of processing resource than is available to older adults will be subject to age-related decline.

Salthouse in a series of studies (Salthouse, 1988a; Salthouse, 1988b; Salthouse, Kausler & Saults, 1988a; Salthouse, Kausler & Saults, 1988b) challenged the scientific merit of this explanation. According to Salthouse, not only is the term "mental energy" vague and therefore scientifically useless, the explanation of decline in processing resource is based on circular reasoning, not experimental evidence. That is, researchers infer a decline in processing resource from the observation of decline in performance of older adults and then use this very explanation to account for decline in performance of specific tasks. In order to rectify this situation, Salthouse proposes a different approach for testing the processing resource hypothesis.

In this approach processing resource is conceptualized in terms of space and time (Salthouse, 1988a; Salthouse 1988b; Salthouse et al., 1988a; Salthouse et al., 1988b). Salthouse and his colleagues defend this choice by arguing that age-related decline in the capacity (i.e, space) and rate (i.e., time) of cognitive operations is ubiquitous throughout the aging literature. Salthouse cites 40 articles in which age differences are interpreted by reference to processing resource as working memory space, processing time and/or attentional energy (Salthouse, 1988c). In addition, Salthouse argues that the slowing of performance of cognitive operations is one of the most reliable findings within the aging literature (Salthouse, 1985). Similarly, age-related deficits in working memory capacity have been documented many times in the aging literature (Dobbs & Rule, 1989; Light & Anderson, 1985; Rabinowitz, Craik & Ackerman, 1982; Wright, 1981). According to this argument, then, the constructs of speed and working memory capacity have a unique status as indices of processing resource within the aging literature.

The next logical step, at least according to Salthouse, is to test the hypothesis that decline in the amount and rate of cognitive operations best account for age-related decline across a variety of cognitive tasks. In order to test this hypothesis, Salthouse and his colleagues (Salthouse et al., 1988a; Salthouse et al., 1988b) selected measures that would serve as indices of speed and working memory (i.e., digit symbol time/number comparison time as measures of speed and verbal memory/spatial memory tasks as measures of working memory). These researchers then examined the proportional contribution of these measures to the observed relations between age and performance on a variety of verbal and spatial tasks. The results indicated that the effects attributable to processing resources on a variety of verbal and spatial memory tasks are much smaller than the direct effect of age. This finding suggests that processing resource, at least defined as processing speed and working memory capacity, cannot account for age difference on a variety of verbal and spatial tasks.

This finding is supported and extended by similar studies on speed and working memory in the aging literature. For example, in 1989 Cerella investigated the relationship between age and the slowing of reaction time over a variety of cognitive tasks. He found that not one but six different patterns of age-related slowing account for slowing of reaction time performance. He concluded that consideration must now be given to task analysis in addition to the proposition of central and/or peripheral decline in the rate of all cognitive operations.

Similarly, a meta-analysis of reaction time and electro-physiological studies (i.e., studies of the event-related brain potentials' P300 component latencies which are purported to be sensitive to changes in perceptual and cognitive processing, yet unaffected by peripheral response-related processes) has revealed that there is no one general slowing factor (Bashore, Osman & Heffley, 1989). Instead, the speed of some processes is sensitive to task difficulty while the speed of other processes is insensitive to increasing task difficulty. Thus, these studies are beginning to highlight the need to examine not only the quantitative aspects of age-related slowing but also the qualitative aspects in terms of the type of processing demanded by a given task.

In terms of working memory, Salthouse has continued to pursue the hypothesis that an age-related reduction in working memory best accounts for the effects of age decline. To this end, he has refined the definition of working memory to include structural and operational capacities. He defines structural capacity as the amount of information that can be remembered and operational capacity as the amount of processing operations that can be performed while still preserving the products of an earlier operation.

In a series of studies published in 1990 and 1991, Salthouse and his colleagues found that age differences appear to be largely independent of the number of relevant variables to be remembered as well as the number of required processing operations to be performed. These findings suggested to these researchers that young and older adults are similar in terms of working memory capacity (Babcock & Salthouse, 1990; Salthouse, Babcock & Shaw, 1991). However, Salthouse did point to a discrepancy with earlier spatial integration studies.

In these studies (Salthouse, 1987a; Salthouse & Mitchell, 1989) Salthouse and his colleagues examined the distinction between structural and operational capacity on a spatial integration task. This task consisted of the presentation of successive frames of line segments from a multisegment figure, followed by a complete comparison figure. These studies manipulated either the amount of information presented (i.e., number of line segments increased while the number of frames was held constant) or the number of integration operations (i.e., number of frames containing the to-be-integrated figure segments increased while the number of line segments in each frame was held constant). Subjects were instructed to decide whether their synthesized composite was identical to the comparison figure.

Salthouse reported that age differences increased significantly with each successive integration operation but remained constant across different quantities of information. This discrepancy led Salthouse to propose that the key factor influencing the magnitude of age differences in working memory tasks is the nature of the processing operations that must be performed while the information is being preserved. If these operations change the internal representation in the direction of becoming more complex then Salthouse proposes age-related deficits will appear in the operational capacity component of working memory.

In summary, it is fair to conclude that most studies attempting to account for age differences on a variety of cognitive tasks, including a number of spatial tasks, have not been able to explain these differences by an age-related decline in speed and/or working memory. However, upon closer examination of the literature, it also becomes evident that task demands are a key factor in determining whether speed and/or operational capacity component of working memory will impact on the performance of older adults. Accordingly, it could be assumed that under some conditions neither speed nor working memory would account for age differences in performance but under other conditions speed and/or working memory may provide the best explanation for this decline. The challenge, then, to researchers is to specify under what conditions speed and the operational capacity component of working memory would be factors.

In addition to the factors of speed and working memory, processing resource has sometimes been defined as attentional resources (Salthouse, 1988a). However, the concept of attentional resources has remained largely undefined in the literature. Stankov (1988), using a psychometric approach attempted to rectify this situation.

Stankov examined two hypotheses. The first hypothesis proposed that attentional factors can be disassociated from fluid intelligence (i.e., degree to which an individual has developed ways of thinking and organizing new information), crystallized intelligence (i.e., degree to which an individual has incorporated generalized knowledge and skills) and short-term acquisition and retrieval abilities. He then investigated if age-related changes in fluid and crystallized intelligence and short-term acquisition and retrieval abilities can be accounted for by these attentional factors.

In order to examine these hypotheses, Stankov gave a battery of 36 tests which served as operational measures of intelligence and attention (19 psychometric tests of intelligence and 17 measures of attentional processes) to individuals between 20 and 70. Using factor analysis to reduce these variables to common underlying dimensions, Stankov found that he was able to identify three specific attentional factors associated with the 17 measures of attentional processes. He termed these factors search, concentration and attentional flexibility. Stankov also found that these three attentional factors stand apart from psychometric measures of fluid intelligence, crystallized intelligence and short-term acquisition and retrieval abilities. Moreover, partial correlations indicated that, when these three attentional abilities are controlled for in a statistical equation, age-related decline in fluid intelligence disappears while the increase of crystallized intelligence is augmented. Although Stankov acknowledges that these results do not imply a causal link between attentional resources and intelligence, he does argue that there exists an important relationship between changes in these attentional processes and changes in fluid intelligence.

Such a relationship is of particular interest to the research on age differences in memory for locations for two reasons. First, it may be assumed that memory for locations can be construed as demanding fluid abilities, especially when memory for locations requires the integration and organization of new information. Thus, if decline in the three attentional factors of search, concentration and attentional flexibility, as measured by Stankov, can account for age-related decline on measures of fluid intelligence, these attentional factors may also account for decline in memory for locations.

Age Differences in Internal Representation of Spatial Information

Studies have documented dramatic declines in performance on the Block Design task, a visual-spatial subtest of the Wechsler Adult Intelligence Scale (WAIS-R) which requires individuals to reconstruct a pattern with a set of blocks in a given time period while this pattern is displayed on a card (e.g., Salthouse, 1982; Sands, Terry & Meredith, 1989). The sources of this age-related decline have been attributed to age-related speed differences, especially for the more difficult items (Sands, Terry & Meredith, 1989), reduced motor dexterity and age differences in segmentation or pattern analysis (Schorr, Bower & Kiernan, 1982). Salthouse designed a series of experiments which would minimize the role of design segmentation and motor dexterity in order to investigate the role of the block manipulation component on performance. He proposed that age-related differences in both time and efficiency of performance on the Block Design task would be due to differences in the quantity and quality of block-relevant information.

Young and older adults performed a computerized block design task in which they were required to select the optimum sequence of block manipulations to reproduce a stimulus design shown at the bottom of the screen. In order to reproduce this stimulus design subjects manipulated a three-dimensional block at the top of the screen. This block contained six possible patterns (i.e.,two patterns were all white, two were all black and two were half white and black with a solid line drawn from one of the four corners separating white from black) and only three of these patterns were visible at any one time on the screen. The instructions indicated that subjects were to fill in each of nine empty cells in the target pattern in sequence by matching the pattern on the block with the patterns in each of the nine cells of the stimulus design. The block could be rotated by pressing the appropriate arrows to locate the matching pattern. The dependent variables were the average number of seconds per trial (i.e., performance time) and the average number of block manipulations per trial (i.e., performance efficiency).

A further analysis of performance efficiency was based on the categorization of the minimum number of block manipulations necessary to reproduce the pattern. The category of 0-Minimum represented that no manipulations of the block were required to reproduce a match because the target pattern matched the front face of the block. The categories of 1-Visible and 1-Invisible represented that the pattern could be matched with a minimum of one manipulation of the block. For the 1-Visible category the pattern was visible on the top or right face of the block while for the 1-Invisible the pattern was hidden on bottom or left face of the block. The most complex category was the 2-Minimum. This consisted of a situation in which two manipulations were required to match the target pattern. As in the 1-Invisible category the pattern was hidden. The percentages of minimum manipulations of the 1-Invisible and 2-Minimum categories were interpreted by Salthouse as reflecting the quality and completeness of the subject's internal representation of the three-dimensional block because knowledge of hidden faces of blocks was necessary to achieve the minimum number of moves.

The results of this study indicated substantial age-related differences in the time and efficiency to match the target pattern. Salthouse (1987b) found that manipulation efficiency, defined as the percent of minimum manipulations to recreate target pattern, was significantly correlated with the percentage of minimum manipulations in the 1-Invisible and 2-Minimum categories. This correlation suggested to Salthouse that a major source of age differences in performance was due to the poor quality of the internal representation of the manipulated block. Moreover, Salthouse also found that manipulation efficiency not only accounted for the greatest proportion of variance in the score on the WAIS-R Block Design task but was an important factor in the magnitude of improvement exhibited with practice by young and old alike. Salthouse interpreted these findings as suggesting that age differences on the Block Design subtest are primarily due to the difficulty experienced by older adults in establishing and maintaining stable internal representations of the relevant features of a spatial design.

Such an hypothesis may explain why older adults experience difficulty remembering locations. It could be suggested that older adults are not able to establish and maintain internal representations of specific location information and therefore lose both target and contextual features of this information. It is this memory loss and not loss of context in particular or the reduced rate, capacity and/or flexibility of the processing system that best accounts for decline in memory for locations.

Physiological Literature

The animal and clinical literature have taken a different approach from the human developmental literature. This literature has assigned a primary role to the hippocampus in the processing of memory for location information. The focus of the research then has been to test the hypothesis that hippocampal dysfunction may be linked to a decline in the learning and recall of location and to examine possible cognitive correlates underlying hippocampal functioning.

Animal Research

O'Keefe and Nadel were the first researchers to provide a theoretical framework from which to study the behavioral effects of lesions to the hippocampus. In their now classic book "The Hippocampus as a Cognitive Map" (O'Keefe and Nadel, 1978) these researchers suggested that the hippocampus subserves a system which is necessary for normal performance on tasks in which an animal must learn spatial relationships. However, they proposed that animals with hippocampal damage may still be able to encode spatial aspects of their environment by relying on an alternate system that represents spatial information in terms of specific stimulus-response cues (e.g., orientation and guidance cues). According to these researchers, such a system is independent of hippocampal involvement.

In response to this hypothesis, a number of studies tested rats with hippocampal damage for their ability to learn location information. These studies used essentially two types of tasks to test memory for this information. In the configural task, the rat was required to locate a goal in a fixed location. This goal could not be discriminated on the basis of a single cue in the environment but only on the basis of the spatial arrangement of a variety of cues. It was predicted that animals with hippocampal damage would be impaired on such a task because it required knowledge of spatial relationships. In the associative task, the goal could be discriminated on the basis of a single cue. It was predicted that animals with hippocampal damage would not be impaired on this task because it required knowledge about the fixed relationship between the cues and not knowledge about spatial relationships as such. The eight-arm radial maze (Olton, Becker & Handleman, 1979) and water-maze (Morris, 1981) are the two most popular paradigms for testing impairment of hippocampal functioning on memory for location using these configural and associative tasks.

In the radial arm maze the food-deprived rat is placed on a central platform and required to choose among the baited arms that radiate from the maze. In the configural version of this task, all arms are physically identical and can only be discriminated with reference to the extramaze distal cues. In the associative version, each arm is physically distinct. There is overwhelming evidence that hippocampal impairment disrupts performance on the configural but not the associative version of the task (for review of this literature see Barnes, 1988).

Similar findings have also been reported using the water-maze paradigm. In this paradigm, the rat is placed in a circular tank filled with opaque water and required to navigate to an escape platform hidden just below the surface of the water. In the configural version of this task, the hidden platform can only be discriminated with reference to the cues outside the tank. In the associative version, the platform can be discriminated on the basis of a proximal cue. Researchers, using this paradigm, have found that damage to the hippocampal formation impairs performance on the configural version of the task but has little impact on the associative version (Morris, Garrud, Rawlins & O'Keefe, 1982; Kelsey & Landry, 1988; Okaichi, 1987).

Taken altogether, these studies provide substantial support for the hypothesis that hippocampal dysfunction disrupts memory for configural relationships. These studies also support O'Keefe and Nadel's notion of a dual memory-system for encoding location information. These early studies, however, assumed the abilities lost were specific to memory for spatial information. Recent research in this area now reports impairment on a wide range of learning tasks which involve an attention aspect and do not depend on the encoding of spatial information (for a review of this literature see, Sutherland and Rudy, 1989). These studies report severe impairments due to hippocampal damage on learning and memory tasks measuring recognition memory, latent inhibition, serial-compound conditioning, discrimination-reversal learning and stimulus-selection. Such findings in the literature have suggested to researchers that these learning and memory deficits reflect impairment specific to mnemonic processes subserved by the hippocampus, irrespective of the information content.

Such a suggestion is consistent with research conducted by a number of researchers involving cellular network recordings from the hippocampus of animals (Best & Thompson, 1989; Deadwyler, Breese & Hampson, 1989; Eichenbaum & Wiener, 1989; Olton, Wible, Pang & Sakurai, 1989). The results of these studies reveal that recordings from cellular networks within the hippocampal structure correlate not only with location behavior but behavior on a variety of tasks, such as behavior on a continuous nonmatch-to-sample task. This has been interpreted as indicating that hippocampal structure has mnemonic as well as spatial correlates.

There are at present three influential theories within the literature which attempt to identify the mnemonic processes subserved by the hippocampus: the working memory theory espoused by Olton and his colleagues (Olton, Becker & Handleman, 1979), the temporary memory buffer theory of Rawlins (Rawlins, 1985) and most recently, the configural association theory proposed by Sutherland and Rudy (1989).

The working memory theory proposes that hippocampal functioning is necessary for normal performance on tasks that require flexible, changing stimulus associations. However, this theory has not been able to explain why impaired performance is found in tasks which are not by definition working memory tasks, such as place navigation tasks (e.g., McNaughton, Barnes, Meltzer & Sutherland, 1989; Sutherland, Whishaw & Kolb, 1983), or why performance in other working memory tasks is not affected by hippocampal damage, such as learning cue relationships (e.g., Aggleton, Hunt, Rawlins, 1986; Winocur, 1980).

Rawlin's temporary memory buffer theory proposes that hippocampal functioning is necessary to store stimuli encoded over time until some form of organization can be imposed. However, studies have shown that delay in presenting stimuli is not necessary for producing impairment (e.g., Parkinson, Murray & Mishkin, 1988; Sutherland & Rudy, 1988). Thus, both of these theories prove inadequate in integrating the hippocampal literature .

The theory proposed by Sutherland and Rudy (1989), termed the configural association theory, purports to integrate a wide range of data relating to hippocampal functioning.[1] This theory can be traced to the notion first presented by O'Keefe and Nadel that the hippocampal structure is implicated in the formation of relational configurations as opposed to simple associations between two stimulus events. These researchers propose there are at least two learning and memory systems which depend differentially on hippocampal functioning.

According to Sutherland and Rudy, a distinction is made between two memory systems: the simple association system and the configural system. The simple association system involves the acquisition and storage of simple associations between stimulus events. Thus, response within the simple association system is determined on the basis of the strength of simple associations between stimulus events, as in discrimination learning and classical conditioning. For example, an animal can learn to discriminate between visual stimuli so that a red light signals food and a yellow light signals no food. This theory proposes that this system is spared in animals with hippocampal lesions.

In contrast, the configural system involves the acquisition, storage and retrieval of configural associations. In this system responding is determined on the basis of the relationship of at least two or more elementary stimuli to a controlling cue, as in place and discrimination reversal learning and latent inhibition. For example, the relationship of the red and yellow light to the presence and absence of food would depend on the controlling cue of the presence of a particular auditory stimulus. That is, when a high tone was sounded the red light would signal food and the yellow light would signal no food, whereas when a low tone was sounded the yellow light would signal food and the red light would signal no food. Thus, the simple association between the various stimuli changes in accordance with the controlling cue. This theory proposes that the hippocampal formation is necessary for the normal functioning of this system.

Support for the configural association theory comes from a series of recent experiments (Jagielo, Nonneman, Isaac & Jackson-Smith, 1990; Sutherland & McDonald, 1990; Sutherland & Rudy, 1989). For example, Sutherland and McDonald (1990) compared the performance of rats with hippocampal, amygdala, combined amygdala and hippocampal damage and sham lesion rats across different tasks. They found no difference when they compared the performance of rats with hippocampal damage to the sham lesion rats when the task required the formation and memory of simple associations. For example, performance was normal on non-matching-to-sample tasks when samples were in same modality and on tasks which required learning to respond to a tone or light signalling food. Such tasks involve the acquisition and recall of the relationship between a single cue which signals the presence of another cue (e.g., tone-food; light-food). In contrast, rats with hippocampal lesions and combined hippocampal/amygdala lesions were impaired on tasks in which the animal was required to learn configural associations. For example, performance was impaired on non-matching-to-sample tasks when samples were in different modalities or on tasks in which the animal acquired a conditioned defecation response to contextual cues paired with foot-shock. These tasks involve the acquisition and recall of the interrelation between cues in which the meaning of the relationship between cues is dependent on its relationship with another cue. Damage to the amygdala alone, however, did not have an effect on such tasks. Sutherland and McDonald concluded that this pattern of impaired and spared performance is consistent with the predictions of a configural association theory.

Clinical Research

Clinical studies also report deficits in the recall of location of objects among patients with right hippocampal damage, demonstrating that under similar conditions the performance of human patients bears a striking resemblance to that of animals with hippocampal lesions. Although the number of studies testing the hippocampal hypothesis is limited because there are relatively few subjects with hippocampal damage, there are a few studies which can be reviewed in this area.

Smith and Milner (1981) tested the recall of locations of objects in patients with lesions within the right and left temporal-lobe areas. They found that only lesions in the right hippocampus disrupted memory for locations. Lesions in the left hippocampus had little effect on the location task. In 1989 Smith and Milner raised the question as to whether this deficit was due to encoding difficulties or rapid forgetting of the information. They tested recall of the location of 16 small toys in patients with lesions within the left and right temporal-lobe areas either immediately after the presentation of the objects, or after an intervening verbal task, a spatial task or an unfilled interval. They found deficits in the recall of the locations of these objects in patients with right temporal lesions but only when recall was tested after a delay. Patients with such lesions were able to recall object locations as well as normal subjects when they were tested immediately. Moreover, the intervening task had no effect on the magnitude of this deficit. They interpreted these findings as suggesting that patients with right hippocampal lesions rapidly forget location information that has been encoded.

A study conducted by Goldstein, Canavan and Polkey (1989) attempted to reproduce the findings in the animal literature regarding configurational and associative tasks. These researchers investigated the role of right temporal lobe structures, including the hippocampal region, in configurational and associative learning of shape location under egocentric and non-egocentric conditions. In the egocentric condition, spatial location was defined in accordance with location of body while in the non-egocentric condition, spatial location was defined in accordance with knowledge of spatial relationships among cues. Based on findings from the animal literature, they hypothesized that in humans the right hippocampus is involved in non-egocentric memory for spatial relations but not egocentric or associative memory of locations.

In order to test this hypothesis, they compared patients with right and left temporal lobe damage and control subjects on memory for locations of shapes on a card. These shapes were presented either in an egocentric (i.e., cards were not rotated on response sheet with reference to body location) or a non-egocentric condition (i.e., cards were rotated on response sheet with reference to body location). These shapes were then either distributed on four corners of the card (i.e., configurational version of task; locations are recalled on the basis of memory for spatial arrangement of shapes on cards) or clustered in one corner of the card (i.e., associative version of the task; locations are recalled on the basis of the single cue). Statistical analysis revealed the right and left temporal lobectomy groups scored lower on location scores in the non-egocentric condition than the control subjects, suggesting that conditions requiring the learning of spatial relations are more sensitive to brain damage. This analysis also revealed that the right temporal lobectomy group recalled more shape locations in the clustered (i.e., associative) condition than in the distributed (i.e., configurational) condition when compared to normal subjects. There was no difference between these conditions for subjects in the left lobectomy group. This finding is consistent with the animal research which suggests that the hippocampal structures are involved in configurational but not associative learning of location information.

In summary, this research provides considerable support for the view that the hippocampus is involved in learning and remembering of location information for animals and the right hippocampus is involved in learning and remembering location information for humans. Both literatures also provide some support for the hypothesis that impairment in hippocampal functioning disrupts performance on configurational but not associative versions of location tasks. Of the various theories that have been offered, Sutherland and Rudy's (1989) proposal, that the hippocampus subserves a memory system which is primarily involved in the encoding, storage and recall of configural relations, regardless of the information content, appears to offer the most complete explanation of the research findings to date.

Age Differences in Hippocampal Functioning

Given that impairment of hippocampal functioning is related to a decline in memory for spatial locations and given that there is evidence that older adults experience such a decline, the obvious question to address at this juncture is: whether there is evidence of anatomic and physiologic changes within hippocampal areas as a result of the normal aging process that could account for age-related decline in memory for locations? The answer to this question comes from two sources, research on aged rats and autopsy studies of the brains of individuals who showed no evidence of dementia at the time of death.

Decrements in performance on tasks requiring memory for spatial relations have consistently been noted in experiments with aged rats. Moreover, these decrements are comparable to those observed in animals with hippocampal lesions. For example, aged rats experience more difficulty on the radial maze that measures memory for spatial relations (e.g., Barnes, Nadel & Honig, 1980; Davis, Idowu &

Gibson, 1983; de Toledo-Morrell, Morrell, & Fleming, 1984), on a complex blind-alley maze (Winocur & Moscovitch, 1990), on a holeboard task that measures spatial working and reference memory (van der Staay, van Nies,& Raaijmakers, 1990) and on spatial delayed non-matching-to-sample task, when the number of locations to be remembered was increased from one to two (Aggleton, Blindt & Candy, 1989). These observations have, in turn, led to the hypothesis that anatomic and physiological changes in the hippocampus of aging rats may contribute to deficits in configural memory. These changes include loss of synapses (Geinisman & Bondaroff, 1976), reduction in neuronal density (Landfield, Rose, Sandles, Wohlstader & Lynch, 1977), and decreases in ease of kindling and persistence of long-term enhancement (de Toledo-Morrell & Morrell, 1985) in hippocampal areas. Of particular interest to this study, similar anatomic and physiologic changes have been reported in intellectually intact older humans as well.

Studies of the brain of intellectually intact older adults surprisingly reveal a number of neuroanatomical, light microscopic and gross changes. Although these changes appear in many parts of the brain as a normal correlate of the aging process, they are usually first observed in the hippocampal areas of cognitively intact older adults (Kasziak, 1990; for a review of this literature see Petit, 1982). Documented neuroanatomical changes specific to hippocampal areas include the accumulation of lipofuscin in the cell body, increased neurofillamentous tangle formations (i.e., tangles which fill cytoplasm of the cell; exact cause or composition is unknown) and granulovacular changes (i.e., presence of small vacuoles in the neuronal cytoplasm or at the base of the dendrites). Although little is known about the effects of the accumulation of lipofuscin and neurofillamentous tangles in a cell, it has been suggested that this accumulation may interfere with the transport and movement of elements within the cytoplasm, interfering with the cell's metabolism and eventually causing cell death.

Light microscopic as well as gross changes have also been documented within the hippocampal area. The light microscopic changes include dendritic atrophy (i.e., dendrites decrease in length and there is a loss of horizontal and oblique dendritic branches), accumulation of senile plaques (i.e., consist of a central core of amyloid, resulting from catabolism of antigen anti-body complexes, as well as intracellular and extracellular debris) and cell loss. Gross changes refer to the progressive loss of neural tissue with increasing age; that is, the total brain mass, including hippocampal areas, shrink 10-15 percent.

This research highlights the extreme vulnerability of hippocampal areas to the normal aging process. At the very least, such changes suggest the possibility of an age-related decrease in the efficiency of hippocampal functioning which, according to the animal and clinical physiological research, would result in impaired performance on configural but not associative versions of location tasks.

Such peripheral and collateral evidence suggests that due to physiological changes within the hippocampal areas, older adults may be experiencing a reduction in hippocampal functioning. If so, this reduction may be causally related to decline in the learning and memory of configural but not associative location information. Such a causal relationship would offer an explanation as to why age-related decline is observed in memory for spatial relations but not in memory for locations that involves the simple association of contextual cues. However, before such a hypothesis can be tested, there first must be some way of independently testing if there is a link between age decline in memory for spatial location and decline in hippocampal functioning. To date, there is no such evidence because, until recently, there was no valid measure of hippocampal functioning. However, in 1986 Jones-Gotman was able to demonstrate the importance of the right hippocampal region to the recall of a behavioral measure (Jones-Gotman, 1986a).

Jones-Gotman investigated the hypothesis that the hippocampus is necessary for organizing unstructured material in memory. In order to test this hypothesis Jones-Gotman developed a variant of the Rey-Osterrieth task (Rey, 1964), a standard neuropsychological task which is sensitive to right temporal lobe impairment but not to the extent of hippocampal excision. She termed her task the Emergent Complex Figure (ECF) task. In the ECF task, as in the Rey-Osterrieth task, subjects first copy a geometric design and then after 40 minutes are asked to recall this figure. However, unlike the Rey-Osterrieth task in which the entire geometric figure is presented for the subjects to copy, in the ECF task the 18 individual elements that make up the complex figure are presented one at a time. On each new exposure, the subject sees and copies the new element, which is outlined in solid lines. All previously seen elements are also presented, outlined in dotted lines. It is only when the last element is presented for copying that the entire geometric figure emerges. According to Jones-Gotman, it is this piecemeal presentation that makes the organization of the elements an important factor (see Appendix A-2, Figure 4 for diagram of ECF design). Jones-Gotman predicted that if the hippocampus performs an organizing function, then those subjects with an intact hippocampus would be better able to integrate the 18 individual elements and, as a result, better able to recall the complex design.

In order to test this prediction Jones-Gotman compared performance on the ECF task of normal control subjects with that of patients with right and left temporal lobectomy that included either a large or a small excision. The 20 normal control subjects (NC) were chosen from among the relatives of patients and hospital support staff. The 63 subjects in the patient groups had undergone unilateral anterior temporal lobectomy for relief of epilepsy. The normal control and patient groups were matched in terms of age (mean ages ranged from 24.7 to 28.2 years), sex, education and Wechsler I.Q. score (mean scores ranged from 108.5-112.3).

The 63 subjects who had undergone a lobectomy were divided into four groups according to whether the excision involved the left or right hippocampal structure and according to extent of the hippocampal excision. Patients in whom the mesial temporal lobe excision did not exceed the pes of the hippocampus were categorized as having small hippocampal removal while those with greater mesial encroachment were categorized as having large hippocampal removal.

The first group consisted to 20 patients who had left temporal small hippocampal excision (i.e., LTh group). In this group the mean extent of removal was 4.81 cm. (range 3.0-6.5) along the Sylvian fissure and 5.27 cm. (range 3.0-7.0) along the base of the brain. The extent of amygdala removal was partial in three cases and complete in all others. The second group consisted of 12 patients with left temporal large hippocampal excisions (i.e., LTH group). In this group the mean extent of removal was 4.75 cm. (range 4.0-5.5) along the Sylvian fissure and 5.57 (range 4.5-7.8) along the base of the brain. The extent of amygdala removal was complete in all cases. The third group consisted of 20 patients with right temporal small hippocampal excisions (i.e., RTh group). In this group the mean extent of removal was 5.42 cm. (range 4.5-8.0) along the Sylvian fissure and 6.35 cm. (range 5.0-9.0) along the base of the brain. The extent of amygdala removal was partial in two cases and complete in all others. The fourth group consisted of 11 patients with right temporal large hippocampal excisions (i.e., RTH group). In this group the mean extent of removal was 5.62 cm. (range 4.5-7.3) along the Sylvian fissure and 6.75 cm. (range 5.5-8.0) along the base of the brain. The extent of amygdala removal was complete in all cases.

As predicted, the results showed the expected impairment on recall for those patients with small and large right temporal-lobe damage when compared to normal controls (approximate mean percent recall of NC = 53% differed from approximate mean percent recall of RTh = 40% and RTH = 27% groups). The results also showed both left temporal-lobe groups to be unimpaired when compared to the normal controls (approximate mean percent recall of NC = 53% did not differ from the approximate mean percent recall of LTh = 51% and LTH = 50% groups). Of particular interest, Jones-Gotman also found that patients with the large right hippocampal removal were significantly impaired on their recall of the ECF design when compared to those with a small removal (approximate mean percent recall of RTh = 40% differed from RTH = 27%). This finding was in direct contrast to the negative findings for recall of the Rey-Osterrieth figure (mean percent recall = 50.4% for those with small right hippocampal removal and 51.2% for those with a large right removal).

In a second experiment from the same study Jones-Gotman investigated an alternative hypothesis that the function of the hippocampus is to suppress interference effects, not to organize unstructured material. Jones-Gotman reasoned that if she reduced the spatial and organizational features of the ECF task and maximized the interference effects she would be able to test this hypothesis. Thus, in the second experiment she changed the task so that the subjects were required to copy and recall each of the 18 elements that formed the complex figure as 18 separate drawings. She found that deficits in recall of the 18 separate drawings of the right temporal patients versus controls were of the same magnitude when the hippocampal removal was small as when it was large. Thus, this finding did not support the interference hypothesis.

Jones-Gotman concluded that the difference between the large and small right hippocampal patient groups indicated that the right hippocampus plays an important role in the recall of the ECF figure. She reasoned that this function must be organizational and not spatial because of two factors. First, the extent of hippocampal removal was unrelated to recall of either the highly organized Rey-Osterrieth figure or the 18 independent designs. This finding suggested that the right hippocampus does not play an important role in recall of material that is already organized or where imposing organization is impossible. Second, the spatial component of the Rey-Osterrieth and the ECF task appears to be similar, yet performance on the Rey-Osterrieth was not related to the extent of right hippocampal removal. Thus, Jones-Gotman concluded that the difference on recall of the ECF between the patient groups with small and large hippocampal damage could only be explained by accepting the hypothesis that the right hippocampus performs an organizational function.

In a third study Jones-Gotman attempted to correlate performance on 21 verbal and visual-spatial memory tests, including the ECF task, with the extent of hippocampal removal (Jones-Gotman, 1987). The results showed that the ECF, unlike the other visual-spatial memory tasks, is sensitive to the extent of right hippocampal removal. Such a finding suggests that this task alone among all the visual-spatial tasks available may be the best behavioral measure of hippocampal involvement on a task.

Methodological Issues

Age Differences in Psychosocial/Background Variables

This study also focuses on the effects of possible background/psychosocial contextual factors on the measures of recall for each age group. The rationale for this additional focus is based on the increased awareness among researchers that a full understanding of the causes of age-related differences in cognitive functioning can only be achieved by taking a relativistic view of intellectual functioning. This view endorses the belief that psychosocial contextual factors such as gender, education, intelligence, socioeconomic status, health, feelings of psychological well-being and social and intellectual activity may affect the amount of age difference observed in cognitive functioning. Proponents of this view, such as Schaie (1983), have urged researchers to begin to study performance on cognitive measures in interaction with a variety of relevant social, health and life-style variables. Thus, a series of studies have now emerged examining the relationship between these psychosocial contextual factors and various cognitive measures.

For example, Arbuckle, Gold and Andres (1986) reported that such psychosocial contextual factors as education, intellectual activity, extroversion, neuroticism and lie scores from the Eysenck Personality Inventory accounted for more of the variance on memory measures than age. Their findings indicated that participants, aged 65 to 93, who scored higher on memory measures were better educated, engaged in more intellectual activities, were less extroverted and neurotic and had lower lie scores. Although younger age did predict higher scores on the memory measure, it was the least powerful predictor among the six variables.

Similarly, Craik, Byrd and Swanson (1987) found that socioeconomic status and level of social and intellectual activity were associated with memory for word lists, under conditions that varied the number of cues at encoding and recall. These authors reported that, under conditions providing substantial cues, active elderly people, regardless of socioeconomic status, recalled as much as college students. However, under conditions providing a moderate level of support to aid in the recall task, only elderly people of higher socioeconomic status performed as well as college students, while under conditions of least support all the elderly groups recalled significantly less than the young. Such results clearly point to a need to examine psychosocial contextual factors that may be relevant to cognitive abilities in the elderly.

In regard to spatial memory in particular, older adults have been shown to differ from young adults on a number of background/psychosocial contextual factors (i.e., gender, education, general intelligence, health, visual acuity) as well as task related variables (i.e., learning and recall time, usage of rehearsal). Moreover, these factors have been linked to performance on spatial memory tasks (for a review of this literature, see Foisy, 1991). Despite these findings, few studies comparing the spatial memory performance of older and young adults control for the effect of these factors. Foisy demonstrated that this failure may well account for some of the findings of age-related decline in memory for location.

Foisy conducted a meta-analysis of 20 studies on intentional memory for spatial location in small-scale space with the goal of examining the effect of aging on memory for location. He found that, although the effect of aging is large on these tasks, the average standard deviation is also large. He interpreted these findings as suggesting that the failure of studies to control for psychosocial contextual factors creates important methodological differences between these studies. It is these differences that account for such a large standard deviation. Foisy recommended that future research in this area control for these factors.

One of the most important psychosocial contextual factors in the area of spatial cognition is gender. Past research suggests male superiority in spatial cognition. This conclusion is based on findings of male superiority on two-dimensional spatial tasks,(e.g., the Space Relations subtest of the Differential Aptitude Test), on tasks in which subjects match an unfolded pattern to one of four completed figures varying in shape, shading or orientation (Bennett, Seashore & Wesman, 1959) and on paper-and-pencil spatial tasks in which subjects must locate a simple geometric form in a complex geometric design (Harris, 1981; Maccoby & Jacklin, 1974; Nyborg, 1983).

However, such findings should be interpreted cautiously in light of recent criticism. Caplan, MacPerson and Toblin (1985) question the validity of these findings, citing inconsistencies within the literature and methodological problems within individual studies. In addition to these problems, Caplan and her colleagues also cite unresolved definitional and construct validity issues with respect to what spatial ability means as well as a proclivity on the part of journals to publish studies in which sex differences are found but not the converse.

There is also increasing evidence that few sex differences in spatial cognition exist when spatial tasks involve or simulate real-life settings. For example, research has found no sex differences in spatial knowledge obtained from maps (Francescato & Mebane, 1973) or differences of memory of roadside information (Carr & Schussler, 1969). Money, Alexander and Walker (1965) found no sex-related differences on the Standardized Road-Map Test of Direction and Kozlowski and Bryant (1977) report no differences in self-ratings of sense of direction.

Moreover, ratings of sense of direction have been shown to be associated with performance on a variety of spatial tasks, ranging from maze learning to map drawing.

In response to these methodological issues, the present study controlled for gender, education, visual acuity, health and subjective-well being. These factors were selected either because past research had shown them to be relevant to individual differences in the cognitive functioning of the elderly or because they have some face validity as predictors of individual differences in performance on spatial tasks. The interest in including them in the present study was to examine the extent to which they would account for performance of the two age groups.

The Present Research

The goal of this research was to test the hypothesis of age-related decline in memory for locations and to identify the reasons that best account for findings of such decline. The human developmental and physiological literatures present four possible explanations for decline in memory for spatial location. Two of these explanations address the question of why contextual cues reportedly eliminate age-related decline for location information. The human developmental literature suggests that older adults may rely on contextual cues in order to reduce demand for processing resource (i.e., processing speed and working memory capacity), which decreases with age. The physiological literature suggests that reliance on contextual cues which promote the formation of simple associations may reduce reliance on an impaired hippocampal configural memory system.

In contrast, most researchers in the area of aging subscribe to the view that the presence of context either aids memory for young and older adults equally but age differences remain unchanged or older adults are not able to use contextual cues effectively. The two general factors usually cited within the aging literature as explanations for remaining age differences in the presence of context are: processing resources, defined as processing speed and working memory capacity, and/or spatial visualization ability. Proponents of the processing resource hypothesis maintain that task demands are the key factor determining whether age-related decline in processing resources will account for age differences in performance on cognitive tasks. According to this view, if a task demands more in the way of processing speed and working memory capacity than is available to older adults, then age differences will appear. Similarly, proponents of the spatial visualization hypothesis maintain that age-related decline in the quality of internal spatial information (i.e., spatial visualization ability) accounts for age differences on the Block Design task and in general decline on all measures of spatial memory.

In accordance with the findings of Sharps and Gollin, this experiment predicted that older adults rely on visually distinctive context to alleviate age-related decline in memory for location. It was hypothesized that age-related decline in the efficiency of the hippocampus to process configural location information would offer the best explanation as to why older adults rely on context. Specifically, it was proposed that the presence of visually distinctive context would enable older adults to process location information via the associative memory system which is not as dependent on hippocampal involvement and, therefore, is not compromised by age-related decline.

It was expected that the more general factors of processing speed, working memory capacity and spatial visualization ability would also contribute to memory for location. This expectation was based on the assumption that memory for location is a complex process involving, not just one, but many interrelated factors acting in conjunction with one another. In accordance with this assumption, it was predicted that the four factors cited in this study would be interrelated and would each contribute together and separately to the functioning of spatial memory systems. In particular, it was assumed that processing speed and working memory capacity would be required for the functioning of all operations and spatial visualization ability would be required for the functioning of all spatial memory systems. The question was whether, over and above the contribution of processing speed, working memory capacity and spatial visualization ability, the measure of hippocampal involvement would make a specific contribution to performance on configural location tasks processed within the hippocampal memory system but not associative location tasks.

Finally, this study controlled for a variety of background/psychosocial contextual factors such as gender, education, visual acuity, health, subjective well-being as well the task variable of learning time. Thus, age differences on location tasks cannot be accounted for by failure to control for these factors.

Experiment 1

Experiment 1 used a partial replication of Sharps and Gollin's (1987) design to examine explanations for age-related decline in memory for object locations. Specifically, two of Sharp and Gollin's visual distinctiveness conditions, Plain Map and Colored Map, were replicated as exactly as possible. Thus, participants were required to learn and remember the spatial locations of 40 objects placed on either a plain or a colored map of a room.

It was predicted that there would be an overall effect of age in that the older adults would have greater difficulty in recalling the object locations than young adults. Based on Sharps and Gollin's findings, it was predicted that there would be an overall effect of context with both age groups having greater difficulty in recalling the object locations in the plain condition than in the colored condition. Further, it was predicted that these main effects of age and context would be qualified by an Age x Context interaction, such that age differences would be found in the plain map condition but not in the colored map condition. This finding would be consistent with the hypothesis that age differences in reliance on context would be the best explanation of age-related decline in memory for locations. Because few gender differences have been reported in the literature examining real-life tasks, no gender differences in the recall of locations and no interactions between gender and the other design variables were expected.

The present study also examined the variables that account for individual differences in performance on spatial memory tasks in an attempt to identify the variables underlying age declines in spatial ability. In accordance with the physiological literature, it was predicted that the explained variance in memory for locations on the spatial location task would be significantly increased by adding the

ECF as a behavioral measure of right hippocampal involvement to more general measures of processing speed, working memory capacity and the mental manipulation of visual spatial information (i.e., spatial visualization ability). The rationale for this proposal was based on the evidence presented by Jones-Gotman. This evidence indicated that, in addition to other learning components, the right hippocampus is involved in the recall of the ECF figure. Although Jones-Gotman's evidence was derived from a clinical sample, this study will focus on relatively healthy, independent living elderly adults. Such a movement from a clinical to a nonclinical population is supported and encouraged by researchers, such as Kirasic. According to Kirasic, there is a greater need for studies to move away from associating spatial deficits with particular sites of lesion to the examination of the relationship between normal brain-behavior functioning and spatial abilities of healthy independent living older adults (Kirasic, 1988).

It should be noted that all cognitive measures included in the study would be expected to make demands on the processing resource measures and the measure of hippocampal involvement would be expected to make demands on spatial visualization ability. As a result, these cognitive measures would be expected to be moderately intercorrelated to the extent that they are measuring the same underlying processes. Therefore, it was expected that the measures of processing speed, working memory capacity, attentional flexibility, spatial visualization ability and hippocampal involvement would be moderately intercorrelated. The question was whether, over and above any shared effects with the other cognitive measures, the ECF would make a unique contribution to explained variance in the absence of context and whether this unique contribution would be reduced significantly by the presence of context. Support for these predictions would suggest that age-related decline in hippocampal involvement, not in the measures of processing resource, best explains why the presence of context eliminates age-related deficits in memory for locations.

Method

Subjects

The 50 participants in this experiment were recruited on a voluntary basis from the university and community at large. The young group consisted of 24 subjects aged 18 to 30 (*M* = 23; *SD* = 3.2); the older group consisted of 26 subjects aged 65 to 81 (*M* = 68; *SD* = 13). There was an equal number of males and females in the young age group and two more females than males in the older age group.

Testing of all subjects took place at the university. All participants were self-sufficient, active members of their communities.

All participants were paid for their services. Participants were also told that all individual results are confidential and that they would be informed, if they should wish, about the outcome of the study at a later date.

Tasks and Measures

The tasks and measures used in the experiment were of five types: (a) the task to measure the criterion variable, memory for spatial location, (b) the Emerging Complex Figure test (ECF), used as a measure of hippocampal functioning, (c) measures of processing speed and working memory, (d) the WAIS Block Design test, used as a measure of visual-spatial ability and (e) demographic and psychosocial variables.

Spatial Location Task . The primary stimulus materials used in this task consisted of two schematic maps, measuring

163cm. in length and 117cm. in width, outlining a series of structures (e.g., tables, carpets, lockers) found in a room. The schematic arrangements of structures were drawn to be an exact replication of the materials used by Sharps and Gollin (1987). This map is presented in reduced size in Appendix A-1 Figure 3. In the plain map condition, the outline of the structures on the map were in black ink. In the colored map condition, the structures were painted in the same shades of brown, black, grey, yellow and green as had been used by Sharps and Gollin (1987).

Forty small, common objects were used as stimulus objects. In 37 of the 40 cases, the objects used were exemplars of the same objects as those used by Sharp and Gollin. Three objects, orange, watch and vase, were substituted for apple, radio and kettle respectively in the Sharps and Gollin study. The stimuli used to test location recall were 40 white 4cm square cardboard cards, each with the name of one of the 40 stimulus objects typed on it.

The principal recall measure was a count of the number of object locations correctly recalled. This count reflected the correct card placement within 5 cm of the correct location on the map. This scoring system was found by Sharps and Gollin (1987) to be congruent with other types of spatial measurements based on less precise placement. For this reason this measure was retained for this experiment. The number of correct responses for each subject was counted and these scores were used as a measure of spatial memory for locations.

Emergent Complex Figure. The materials used in this task were an exact replication of the materials used by Jones-Gotman (1986a). A complex geometric figure was divided into 18 components which were presented one at a time in a fixed sequence. The new component being presented on each exposure was drawn in bold black continuous lines while any components that had already been shown were drawn in lighter dotted lines. An illustration of what was shown to the subject, when the eleventh and eighteenth components were presented, is given in Appendix A-2 Figure 4.

Scoring of the ECF followed the exact procedure outlined by Jones-Gotman (1986a). Each of the 18 components received a maximum of two points which were awarded based on accuracy of the design and correct location. The maximum score was 36. Scoring was performed for the copy and then the recall, after which the scores were converted to a measure of percent recalled:

100 x {1 - (copy score - recall score/ copy score)}

To measure the reliability of the scores, a second rater, blind as to age group and condition, was trained on the protocols of 10 subjects and then independently scored the copy and recall of the remaining 40 subjects. Inter-rater reliability for the 40 cases was .80 for the copy and .96 for the recall of the ECF. The reliability score was low for the copy measure in comparison with the recall measure because of differences between the raters in the scoring of accuracy of two designs. The second rater consistently scored designs 9 and 15 as inaccurate if the copied designs did not exactly match the original. The second rater would tend to score for inaccuracy if the subject had overlaid the design with extra lines.

Measures of Processing Speed and Working Memory. In this study two measures of processing resource, as defined by Salthouse, were used: Digit Symbol Substitution as a measure of speed and Verbal Memory as a measure of working memory capacity (i.e., the structural capacity or amount of information that can be retained). These measures of speed and working memory capacity were chosen because they were shown in previous research by Salthouse and his colleagues (Salthouse et al, 1988a; Salthouse et al, 1988b) to satisfy the major criteria as indices of processing resource.

The Digit Symbol Substitution worksheet had a code table in the upper portion. This code table displayed pairs of digits and symbols in a row of double boxes. In the upper portion of each box the digits 1 to 9 were displayed while the lower portion of each box contained a matching symbol. On the lower portion of the worksheet were four rows with 25 boxes in each row. Each of these boxes had a number in the top part while the squares at the bottom remained empty. Participants were required to use the code table to write in each of the empty squares the matching symbol below each digit. They were instructed to perform this task as quickly and as accurately as possible. The first seven squares served as practice items. Scoring for the Digit Symbol Substitution task differed from the standard procedure outlined in the WAIS-R manual. The scoring procedure used in this experiment replicated the procedure used by Salthouse (Salthouse et al., 1988a; Salthouse et al., 1988b). The amount of time taken to place all symbols in their correct boxes was recorded as a measure of the processing resource of speed. Although accuracy was not used as a measure, it was recorded in order to ascertain age differences in accuracy. The accuracy rate for young and older subjects was 99.9% and 99.8%, respectively.

The materials used in the Digit Symbol Substitution task were derived from the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Wechsler, 1981). The paper-and-pencil version of the Digit Symbol Substitution task was administered. Salthouse designed a computer version to minimize the impact of age-related decline in visual-motor coordination and dexterity on the measure of processing speed. However, a comparison between the paper-and-pencil and computer versions revealed only slight differences (Salthouse et al., 1988b). Accordingly, Salthouse concluded that both versions were reliable and valid measures of processing speed.

The Verbal Memory task replicated the task used by Salthouse and his colleagues (Salthouse et al., 1988a; Salthouse et al., 1988b). This task required participants to remember the identities of seven target letters from a matrix of 25 letters. The 25 letters were arranged within a 15cm x 15cm matrix so that 18 of these letters printed in black and seven target letters printed in red appeared in different locations within each of four matrices. All the letters of the alphabet were used in each of these four matrices except the letter Q. The seven target letters were randomly chosen from the 25 letters to appear in different locations on each of the matrices. All seven target letters differed in each of the matrices with the exception of the letters N, S and Y. The letter Y appeared in the first and second set. The letter S appeared in the first and third set and the letter N appeared in the second and fourth set. A total of four trials were presented in this task with the average number of letters correctly recalled across these trials serving as the measure of performance. The maximum score was 7.

Measure of Attentional Flexibility. The Anagram task as a measure of attentional flexibility (i.e., measure of flexibility to change mental set/attention switching) was added because Stankov has shown this measure to stand apart from measures of fluid intelligence, crystallized intelligence and short-term acquisition and retrieval. This measure also predicts decline on tasks demanding fluid abilities, such as memory for location.

The first part of the Anagram task required participants to solve a set of six 4 letter anagrams by unscrambling the letters to form a word. All six anagrams were constructed in the same way, making it possible to solve them all by applying the same rule: place the third letter in the first position, and then move the last letter to the third position (e.g., IGKN = KING; IKML = MILK). In the second part of the Anagram task five 4 letter anagrams were constructed making it possible to solve them by either following the same rule induced in the first part of the Anagram task or selecting another more frequently occurring word. For example CEAN can be solved by using the same rule induced in the first part of the Anagram task. The word selected would then be ACNE. This anagram may also be solved by selecting the more frequently occurring word, CANE. The number of frequently occurring words formed in the second part of the Anagram task served as a measure of the participants' tendency to change their mental set and select the new way of solving anagrams. According to Stankov, a measure of this tendency reflects the construct of flexibility/rigidity. The maximum score was 5. Word frequencies from the list comprised by Kucera and Francis (1967) were used to establish the frequency of words in the language. See Table Appendix A-3, Table 1 for copy of task with accompanying word frequency measures.

Block Design Task . In order to assess the ability of individuals to form accurate and stable internal representations of spatial information, the Block Design subtest from the WAIS-R was given. This task required individuals to reconstruct a pattern with a set of blocks in a given time period while this pattern was displayed on a card. Standard procedure, as outlined in the WAIS-R manual, was followed (Wechsler, 1981).

Participants were shown the different sides of four blocks, which were all red on two sides, all white on another two sides and half red and half white on the remaining two sides. Participants were given two examples in which they were shown how to construct a design from these four blocks so that the tops of these blocks replicated the design on the presented card. They were then given four scrambled blocks arranged so that a variety of surfaces faced up (i.e., only one out of four blocks could have a red/white side facing up) and were instructed to look at the picture of the design and make one just like it with these blocks as quickly as possible. When design six was reached the participants were given an additional five blocks. There were nine designs presented in all.

The scoring followed the standard procedure used by the WAIS manual. For designs 1-2, 2 points were allotted for passing on the first trial; 1 point for passing on the second trial. For designs 3-9, 4 points were allotted for each design successfully completed within the time limit, plus a maximum of 3 bonus points per design for quick, perfect performance. For designs 1-6 participants had a time limit of 60 seconds. For designs 6-9 participants were given 120 seconds to complete the designs. No credit was given for partially correct or incomplete performance. The maximum score was 51 points for the raw Block design score. This raw score can also be scaled according to age. However, in order to maintain consistency with the scoring procedure used by the reviewed literature in this area, the raw Block Design score served as a measure of performance.

Psychosocial/Background Variables. The psychosocial background measures included education, visual acuity, psychological well-being and health. The number of years of education was recorded for each participant and reflected either his/her current university status or total years of formal education with added years for commensurate work experience or work training when warranted. This addition of a credit to the years of education score was suggested by Poon, Krauss and Bowles (1984) as a possible solution to resolve the issue of qualitatively different types of education received by older and younger adults. Thus the following formula was used to account for different types of learning situations: first, all years of education and training were counted, taking the highest level to represent the measure of current educational status. Second, in order to quantify educational type experiences among the elderly, informal training related to work experience (e.g., work-related courses) as well as informal learning situations (e.g., setting up a business) were given credit (Young: *M* = 14.3; *SD* = 1.3; *Range* = 13.1-15.2; Old: *M* =14.6; *SD* =1.6; *Range* = 13.1-15.9).

The visual acuity measure was one developed by Regan (1988). This measure consisted of a high-contrast chart containing eight lines with eight letters per line to be viewed from a distance of 10 feet. The size of the letters decreased systematically from row 1 to row 8.

The visual acuity score was determined using the Snellen Acuity equivalents for the high-contrast chart as delineated by Regan. Participants received a visual acuity score which corresponded to the number of lines read with accuracy with their best eye. The cut-off was more than two errors per line.

To evaluate psychological well-being the Memorial University of Newfoundland Scale of Happiness (MUNSH; Kozma & Stones, 1983) was given. The MUNSH measures the emotional state of an individual. It consists of four bipolar subscales of positive and negative affect and positive and negative experience. High scores obtained from the two subscales of affect and experience indicate a state of well-being; low scores indicate depression. Because these four subsections are part of the total MUNSH, the total MUNSH score served as a measure of psychological well-being.

A health measure taken from a longer scale created by Linn and Linn (1984) to assess specifically the health of elderly adults was also administered. This measure consisted of a list of 21 medications and 20 health conditions as well as a category termed other. The count of medications taken and health conditions reported served as a measure of health medications and conditions respectively. The two measures correlated highly, r = .60. Because the conditions measure appeared to present the more overall view of the person's health, it was retained for use in the analysis.

Procedure

The testing session lasted approximately one hour. Participants were told that the purpose of the study was to determine how individuals find their way in the real world. The tasks they would be asked to perform were described briefly and they were asked to read and sign a consent form before the testing session commenced.

At the beginning of the session subjects read as many rows of letters as they could with each eye separately. Reading was done with any corrective lenses in place. The Emergent Complex Figure (ECF) was given next, using the procedure of Jones-Gotman. Subjects were given a single sheet of 8 x 11 paper in a horizontal orientation and told that this was a drawing test in which they must copy some simple drawings as carefully as possible, making their copies the same size and situating them in the same place on their paper as in the drawing. They were told that these simple drawings would build up on their page so that when they were finished, the simple drawings would form one complicated drawing.

The 18 pages were then shown one at a time while subjects copied the new component, drawn in bold lines, onto their drawing. When the entire figure was drawn (i.e., after all 18 pages had been shown), subjects had 15 seconds to check over their finished copy. For the next 40 minutes subjects continued with the other experimental tasks after which they were asked unexpectedly to draw the figure again from memory.

After the copy phase of the ECF was completed, the medical questionnaire and the MUNSH scale were administered. This was followed by the task which required subjects to remember object locations on either a plain or colored map.

The procedure on the memory task was identical to the one used by Sharps and Gollin (1987). Subjects were told that they would be taken into a room and shown a number of objects which were laid out on a map. Their task was to remember the locations of the objects. Upon entering the room the experimenter then took the subjects on a "tour" of the map, pointing out each of the objects and waiting 5 seconds in between object presentations. The tour was conducted in the same order for all subjects. At the conclusion of this tour of the map, the subject left the room and the objects were removed from the map. The subject then returned to the room two minutes later and was given 40 cards, one card at a time, and was asked to place each card face down on the map where the given object had been located. These 40 cards were presented in seven different random sequences which were distributed as evenly as possible across age, gender and context conditions. After completing this task, participants were asked to describe how they went about learning the locations of the objects on the map.

After a break, the WAIS-R Symbol Substitution, Verbal Memory and Anagram tasks were administered with short breaks in between each of these tasks. Instructions for the WAIS-R Symbol Substitution task followed the exact procedure outlined in the Wais-R manual with the exception that subjects were instructed to fill in all the boxes. No time limits were given. In the Verbal Memory task subjects were allowed three minutes to scan the matrix before being asked to recall the target letters. Four trials were given using different matrices. In the Anagram task subjects were told to solve the anagram by unscrambling the letters to form a word. They were told also that they could use a piece of paper and a pencil to help them unscramble these letters.

In all three tasks subjects were given a practice exercise in order to acquaint them with the procedure.

Exactly 40 minutes after the administration of the Emergent Complex Figure task, subjects were asked to draw the figure again from memory. Time allotment per task was planned so that no task would be interrupted in order for subjects to redraw the ECF. This recall task was followed by the WAIS-R Block Design which terminated the session. The participants were then debriefed and paid for their participation.

Design

Six men and six women in the young age group were nonsystematically assigned to the plain map condition and the other six men and six women in this age group were assigned to the colored map condition. Six men and seven women in the old age group were likewise assigned to each of the plain and colored map condition. All participants were asked to recall the locations of objects in either the plain or the colored map conditions. The design was thus a 2 (age) x 2 (gender) x 2 (visual distinctiveness of map) factorial design.

Results

The primary focus of Experiment 1 was to examine the recall of object locations in relation to age, gender and visual distinctiveness of a map and to ascertain relationships between spatial memory for location and the several variables under consideration as explanatory factors of age changes in spatial memory.

Preliminary Analyses

As a first step in data analysis, data screening information was analyzed. According to the results of these tests, assumptions for normality and homogeneity of variance were not violated. As a second step, product-moment correlations were calculated among the predictor variables including age in years, the cognitive explanatory measures and the psychosocial background measures (see B-1). Inspection of the correlation matrix showed that older age was significantly correlated, at an experiment-wise error rate of .05/13, with poorer health and with poorer performance on all cognitive explanatory variables except the anagram scores. The matrix also revealed moderate intercorrelations among the cognitive explanatory measures of the ECF, Digit Symbol Substitution, Verbal Memory and Block Design suggesting that to some degree they are sharing variance. These explanatory cognitive variables were all moderately correlated with the outcome measure.

Apart from these correlations, the various ECF measures were significantly intercorrelated. To reduce the number of variables under consideration, it was decided to retain percent recall as the only ECF measure to be used in further analysis. The measure was retained because it took into account both copy and recall scores and because Jones-Gotman had found it to be the measure most sensitive to hippocampal damage.

As a third preliminary step, a 2 (age group) x 2 (gender) x 2 (condition) multivariate analysis of variance (i.e., MANOVA) was performed on the nine predictor variables retained for further analysis (see means and standard deviations as well as source tables on explanatory and psychosocial variables for Age x Gender x Condition in Table C-1). The purpose of this analysis was to examine relationships between the design factors and the explanatory and psychosocial/background variables. The MANOVA showed a significant multivariate effect of Gender x Condition, F (9,34) = 2.17, $p < .05$ and a significant multivariate effect of age, F (9,34) = 13.55, $p < .001$, but no significant effects of gender or condition and no other interactions. As can be seen from the results for individual measures (Table 1), the effects of age group on the individual measures paralleled the correlations with age described above.

Table 1

Means for the Cognitive Explanatory and Psychosocial Measures in Relation to Age (Experiment 1)

	Age Level	
	Young	Old
ECF	55.4	32.1**
Digit Symbol Substitution	137.6	179.8**
Verbal Memory	6.1	5.1**
Anagram	3.6	4.0
Block Design	38.9	27.2**
Education	14.3	14.6
Health Conditions	.34	1.7**
MUNSH	25.8	28.3
Visual Acuity	23.2	25.8

** $p < .05$

The analysis of the effect of Gender x Condition on the individual measures revealed a significant univariate effect on the ECF score, *F* (1,42) = 7.9, *p* < .01 and the Digit Symbol Substitution scores, *F* (1,42) = 7.4, *p* < .01. The means of the interaction on the ECF and Digit Symbol Substitution scores are presented in Table 2. Post hoc Tukey tests on the means for the ECF measure showed that males in the colored conditions performed significantly (*p* < .05) more poorly on the ECF task than females in the colored condition whereas the reverse was true for the plain condition. Similar post hoc tests on the Digit Symbol Substitution measure showed that males in the colored condition had significantly slower times than either males in the plain condition or females in the colored condition.

Principal Analyses

A three-way ANOVA was conducted for age, gender and condition on number of object locations correctly recalled. This analysis showed a significant main effect for age, *F* (1,42) = 11.8, *p* < .001. The young subjects recalled more object locations correctly than did the old subjects. The means of the two age groups are presented in Table 3. Contrary to expectations, there was no effect of Condition and no Age x Condition interaction.

Table 2

Means and Standard Deviations for the ECF and Digit Symbol Substitution measures in Relation to Gender and Condition

(Experiment 1)

The Percent measure Of the ECF:

Condition	Gender	
	Female	Male
Plain	37.8 (15.0)	46.9 (9.9)
Colored	50.9 (8.1)	37.1 (17.2)

The Digit Symbol Substitution :

	Female	Male
Plain	155.5 (34.6)	149.6 (27.0)
Colored	139.1 (20.6)	190.5 (49.3)

Table 3

Means and Standard Deviation for Recall of Exact Locations in Relation to Age, Gender and Condition

(Experiment 1)

Gender	Condition	Age level		Mean
		Young	Old	
Plain	Female	19.6 (10.2)	9.4 (8.3)	14.5
	Male	22.0 (4.5)	16.0 (8.2)	19.0
	Mean	20.8	12.7	16.8
Distinctive	Female	23.3 (6.2)	11.7 (5.1)	17.5
	Male	12.8 (7.3)	12.2 (8.5)	12.5
	Mean	18.1	12.0	15.0
	Mean	11.5	8.3	

The analysis also showed a significant Gender by Condition interaction, F (1,42) = 4.9, $p < .05$. The means for this interaction are shown in Figure 2. The females recalled fewer object locations than did the males in the plain map condition while the males recalled fewer object locations than did the females in the colored map condition. Post-hoc Tukey tests on the interaction means for location on recall showed that for each map condition the difference was statistically reliable at $p < .05$ (see source table D-1).

There was no main effect of Gender, nor were the Gender x Age or Gender x Age x Condition interactions significant.

Regression Results

To assess relations between each of the predictor variables and task performance, a series of multiple regression analyses were performed. The interest in performing these analyses was to determine, first, the relative contributions of the psychosocial/background factors as well as age versus the explanatory variables. The second point of interest was to determine whether the ECF, after adjusting for processing resource and spatial visualization ability, contributed significantly to explained variance in the plain as well as the colored conditions. The variables used as predictors included age in years, gender, education, health, visual acuity and MUNSH, Digit Symbol Substitution, Verbal Memory, Anagram,

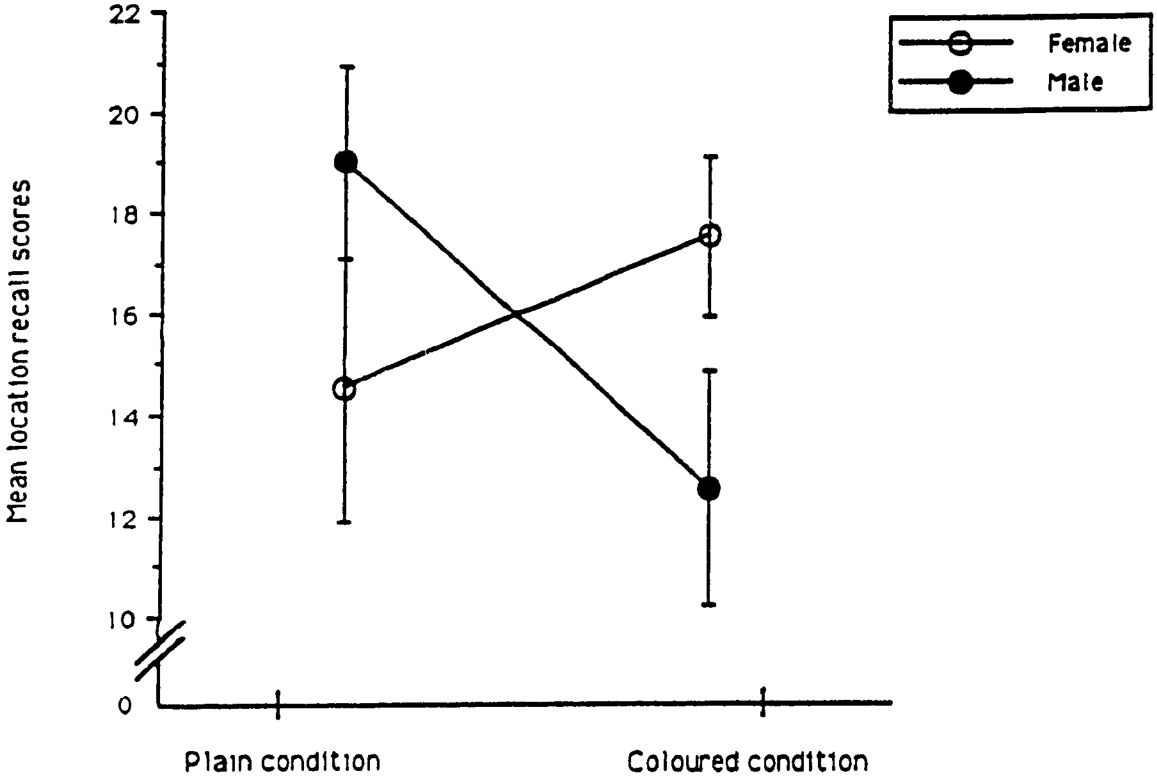


Figure 2: Mean location recall scores as a function of condition and gender

Block Design and the percent recall on the ECF. Memory for location was the criterion variable.

Analysis on Context Groups Combined

In the first analysis, the predictors of gender, education, health, visual acuity and MUNSH were entered at Stage 1, followed by age at Stage 2 and finally the five explanatory variables at Stage 3. As presented in Table 4, this analysis revealed that the psychosocial/background variables were not significant predictors of memory for location. To reduce the number of variables under consideration, the psychosocial variables were dropped from further analyses. In addition, gender was not a significant predictor and was also dropped from further analyses. Finally, the Anagram variable was dropped from the variable set because the interest was in the relative contributions of age versus the explanatory variables and the Anagram measure had a relatively low correlation with age.

In order to ascertain the relative contribution of Age vis-a-vis the four remaining explanatory variables two hierarchical regressions were performed combining the two conditions. In the first hierarchical analysis Age was entered at Stage 1, followed at Stage 2 by the explanatory variables of Digit Symbol Substitution, Verbal Memory, Block Design and ECF measure, entered as a block. As Table 5 shows, when Age was entered into the regression, it accounted for 22% of the variance and the remainder of the

Table 4

Hierarchical Regression of Psychosocial Variables (Stage 1), Age (Stage 2) and Cognitive Explanatory Variables (Stage 3) (N = 50) on Location Recall

(Experiment 1)

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Education	.02			
Gender	.01			
Vision	-.03			
MUNSH	.08			
Health	-.19			
Stage 1 Result		.04	.04	.40
Entered at Stage 2				
Age	-.46			
Stage 2 Result		.30	.25	15.5***
Entered at Stage 3				
Verbal Memory	.40			
Digit Symbol	-.35			
Anagram	-.32			
Block Design	.49			
ECF	.77			
Stage 3 Result		.65	.36	7.8***

*** $p < .001$

explanatory variables accounted for 41% of the variance for a total R^2 of 63%.

In contrast when the explanatory variables were entered as a block at Stage 1 and Age at Stage 2, Age only accounted for 1% of the variance while the measures of Digit Symbol Substitution, Verbal Memory, Block Design and the ECF account for 62% of the variance (see Table 6). It can therefore be concluded that much of the apparent relationship between age and the location measure can be explained by measures of processing resource, spatial visualization ability and hippocampal functioning.

Finally, when these four explanatory variables were entered directly into a regression analysis without age, the ECF emerged as the only predictor, accounting for 57% of the variance (see Table 7). Thus, of the explanatory variables, it is the ECF that is explaining the major portion of the variance in location memory.

In order to ascertain whether the ECF alone can account for age differences on the memory for location task, the ECF measure was entered as a covariate in the reanalysis of the location score for Age, Gender and Condition. The results indicated that the age effect was no longer significant, the adjusted ratio for age being $F = (1,41) = .62$, $p, > .43$. The observed and adjusted means for recall of locations are presented in Table 8. The source table is presented in D-2.

Table 5

Hierarchical Regression of Age (Stage 1)
and Cognitive Explanatory Variables
(Stage 2) (N = 50) on Location Recall
(Experiment 1)

Variable	r	R^2	R^2 change	Fchange
Entered at Stage 1				
Age	-.46			
Stage 1 Result		.22	.22	13.2***
Entered at Stage 2				
Verbal Memory	.40			
Digit Symbol	-.35			
Block Design	.49			
ECF	.77			
Stage 2 Result		.63	.41	12.5***

*** $p < .001$

Table 6

Hierarchical Regression of Cognitive Explanatory Variables (Stage 1) and Age (Stage 2) (N = 50) on Location Recall (Experiment 1)

Variable	*r*	R^2	R^2 change	Fchange
Entered at Stage 1				
Verbal Memory	.40			
Digit Symbol	-.35			
Block Design	.49			
ECF	.77			
Stage 1 Result		.62	.62	18.5***
Entered at Stage 2				
Age	-.46			
Stage 2 Result		.63	.01	1.3

*** $p < .001$

Table 7

Direct Entry of Cognitive Explanatory Variables (N = 50) on Location Recall

(Experiment 1)

Variable	*r*	*Sr*	*t*
Verbal Memory	.40	.09	.97
Digit Symbol	-.35	.13	1.4
Block Design	.49	.06	.63
ECF	.77	.57	6.1***

R^2 change = 63 F change = 18.5***

*** $p < .001$

Table 8

Observed and Adjusted Means in Covariate Analysis for Recall of Exact Locations in Relation to Age, Gender and Condition with the ECF Measure as Covariate

(Experiment 1)

Gender	Condition	Age Level			
		Young		Old	
		Obs	Adj	Obs	Adj
Female	Plain	19.6	16.1	9.4	15.7
	Colored	23.3	14.6	11.7	14.5
Male	Plain	22.0	15.6	16.0	19.5
	Colored	12.8	12.8	12.2	16.9

Analyses on Context Groups Separately

A series of hierarchical regressions were performed separately for the two contexts to examine whether, despite not finding a context effect, there were nonetheless differences between the two conditions in the pattern of relationships between the explanatory variables and outcome. Specifically, the question was whether the ECF contributed significantly to explained variance in both conditions.

These analyses were hierarchically ordered so that the more general explanatory variables were entered before the ECF measure. Thus, the measures of Digit Symbol Substitution and Verbal Memory were chosen because Salthouse had used these measures as indices of processing resources. Block Design was also retained as a third control variable, adjusting for spatial visualization ability. Because, as reported previously, these three measures were significantly intercorrelated with each other and with the ECF, it can be assumed that, in fact, all three are to some degree measures of general processing resource and possibly also spatial visualization ability. The question is whether, with processing resource and spatial ability controlled for, the ECF still contributes significantly to explained variance under each of the context conditions. A significant contribution in a given context condition would suggest that the ECF measures ability that is specifically related to memory for spatial locations under that context condition.

In the first hierarchical analysis under the plain map condition the Digit Symbol Substitution, Verbal Memory and Block Design were entered at Stage 1 as a block, followed by the ECF measure at Stage 2. As Table 9 shows, when the more general explanatory variables were entered into the regression, they accounted for 27% of the variance while the ECF measure accounted for 33% of the variance. Only the contribution of the ECF measure to explained variance was significant.

In the second hierarchical analysis under the colored map condition again the more general explanatory variables were entered at Stage 1 as a block, followed by the ECF measure at Stage 2. The results indicated that under the colored condition the more general explanatory variables accounted for 41% of the variance while the ECF measure accounted for 29% of the variance. In contrast to the plain condition, the contribution to explained variance was significant for the more general explanatory variables as well as the ECF measure (see Table 10).

To summarize, the regression results under the plain condition indicated that only the ECF measure explains a significant portion of the variance for location memory, even after adjusting for the more general explanatory variables of processing resource and spatial visualization ability. This finding indicated that the ECF, over and above the more general processing variables, is making a

Table 9

Hierarchical Regression of General Explanatory Variables (Stage 1) and the ECF (Stage 2) (N = 25) on Location Recall in the Plain Condition

(Experiment 1)

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Verbal Memory	.35			
Digit Symbol	-.43			
Block Design	.41			
Stage 1 Result		.27	.27	2.5
Entered at Stage 2				
ECF	.76			
Stage 2 Result		.60	.33	16.5***

*** $p < .001$

Table 10

Hierarchical Regression of General Explanatory Variables (Stage 1) and the ECF (Stage 2) (N = 25) on Location Recall in the Colored Condition (Experiment 1)

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Verbal Memory	.45			
Digit Symbol	-.27			
Block Design	.61			
Stage 1 Result		.41	.41	4.9**
Entered at Stage 2				
ECF	.80			
Stage 2 Result		.70	.29	19.5***

** $p < .01$

*** $p < .001$

specific contribution to memory for locations. However, under the colored condition, the regression results revealed a somewhat enhanced contribution of the more general processing resource and spatial visualization measures and a somewhat reduced specific contribution of ECF.

Discussion

Three patterns emerge from Experiment 1. First, older adults experienced greater difficulty recalling object locations than the young. This finding lends further support to the hypothesis that there is an age-related decline in memory for locations. Second, this study found that color had no impact on memory for locations in either the young or the older age group. Thus, this experiment not only failed to replicate the Age x Context interaction as reported by Sharps and Gollin but also failed to replicate the facilitatory effect of color on memory for locations.

This failure to find a context effect is inconsistent with other studies which report that context manipulations usually facilitate memory for locations at different age levels (e.g., Zelinski & Light, 1988). However, it could be argued that the addition of color by itself was not salient enough to facilitate memory for locations and that the context effect and the Age x Context interaction reported by Sharps and Gollin was due to sampling error.

Such a conclusion has support within the aging literature. Park, Cherry, Smith & Lafronza (1990), unable to replicate the interaction reported by Sharps and Gollin, concluded that sampling error due to lack of control of psychosocial variables may be responsible for Sharps and Gollin's findings. However, researchers, such as Kirasic, maintain that Age x Context interactions can be obtained through context manipulation while controlling for sampling error. Therefore, there is a need to clarify whether, in fact, Age x Context interactions are the result of sampling error or a real finding within the aging literature.

Third, this experiment found a clear-cut pattern of age-related decline on the measure of percent recall from the ECF, the processing measures of speed and working memory capacity and the spatial visualization measure of raw Block Design. However, in the plain condition only the percent recall measure of the ECF explains a substantial portion of the variance in memory for object locations, even after adjusting for general measures of processing resource and spatial visualization ability. In addition, when the ECF measure is used as a covariate, age disappears as a significant contributor to age-related decline in memory for locations. Thus, it can be concluded that the ECF measure is measuring some capacity that underlies the age effect in memory for location tasks.

Of interest, the mean percent recall on the ECF figure for older adults (i.e., 32.1%) replicates the finding for the mean percent recall for the patient group with large right hippocampal removal (i.e., approximately 27%) in Jones-Gotman's study. Similarly, the mean percent recall for younger adults (i.e., 55.4%) replicates the finding for the mean percent recall for the normal control and left lobectomy groups (i.e., approximately 50%)

The results also indicate that, in the presence of color, the contribution of the measures of processing resource and spatial visualization to memory for locations is somewhat enhanced while the contribution of the hippocampal measure is somewhat reduced. Thus, the ECF measure continues to make a unique contribution to memory for location, albeit a reduced contribution, when the contextual cue of color is provided. However, this finding cannot be properly interpreted, given the failure of this experiment to find an Age x Context effect.

Experiment 1 also found gender differences on memory for locations in relation to whether the map was plain or colored. Males recalled more locations than females in the plain condition while females recalled more object locations than males in the colored condition.

Examination of the means in the colored map condition reveals that young males in the colored condition performed as poorly as the older male participants in the same condition (i.e., young males recalled 12.8 locations and older males recalled 12.2 locations). Moreover, their performance on the recall task was significantly below the means of all young participants, regardless of condition. It is possible that the sample of six young males in the colored condition may have been unrepresentative of young adults in the general population. One hypothesis to account for the Gender x Condition interaction then may be sampling error. This conclusion is consistent with the multivariate findings that males in the colored condition performed more poorly on the ECF task than females in the colored condition and had slower times on the Digit Symbol Substitution task when compared to males in the plain condition and females in the colored condition.

Another plausible explanation is that females are differentially influenced by the salience of the colored stimuli and it is this greater salience of color that enables them to outperform males. Without the salience of color in the environment males outperform females on location tasks. Although the literature does not speak directly to the effects of color on gender differences in memory for location tasks, there is the suggestion that females may differentially benefit by the presence of salient context within the environment (i.e., real world environments) such that gender differences in memory for locations tasks are eliminated (e.g., Caplan, MacPerson & Toblin, 1985). The second study was designed to disentangle these two explanations.

In summary, this experiment provides support for the hypothesis of age-related decline in memory for locations. Furthermore, the results indicate that the ECF task, which is sensitive to right hippocampal involvement (Jones-Gotman, 1987), accounts for individual and age group differences in memory for locations. However, since the context manipulation was ineffective, it could not be ascertained if older adults increasingly rely on context to eliminate age-related decline in memory for location and if such reliance compensates for decline within the hippocampally mediated memory system. Thus, this second study was designed to maximize the likelihood of obtaining a context effect.

Experiment 2

Results of Experiment 1 suggest that there is an age-related decline in memory for locations and that the ECF task, which is sensitive to right hippocampal involvement, best accounts for individual and age differences on performance of location tasks in the presence and absence of context. The intention of this second study was to replicate the findings from Experiment 1 and extend these findings so as to understand better the nature of the relationship between context, age and memory for spatial location. It was reasoned that, provided that a context effect could be produced, an examination of that effect in relation to observed age changes in performance on spatial location tasks would accomplish three goals.

First, such an examination would test the generalizability of the ECF link to recall of locations, with a different task, under different conditions, thereby providing further validation of the ECF as a predictor of memory for locations. Second, this examination would allow the testing of three hypotheses concerning how context might be related to age differences in memory for location. The first hypothesis, proposed by Sharps and Gollin, predicts that age differences in reliance on contextual cues will be the best explanation of age-related decline in memory for locations. According to this hypothesis then, the presence of context differentially facilitates the performance of older adults on spatial tasks and thereby eliminates age differences in memory for locations. The second hypothesis predicts that there are no age differences in reliance on contextual cues. The presence of context will facilitate memory for locations for young and older adults alike but age differences will remain, despite this faciliatory effect. The third hypothesis predicts that context does not facilitate memory for locations in older adults because older adults do not utilize contextual cues as effectively as young adults.

Third, this examination would help identify the impact of context on age differences in the processing of location information in a more precise manner. It would establish which is the better of the two explanations of age differences under various conditions of contextual support. According to Craik, age differences in memory for locations can be reduced by the presence of context because there is a reduced need for self-initiated operations, thus placing minimum demands on processing resource, defined as processing speed and working memory capacity. This hypothesis, therefore, suggests that reduction in the demand for processing speed and working memory capacity underlies the compensatory effect of context on memory for locations. The physiological literature predicts that age differences in memory for locations can be reduced by the presence of context because the hippocampal contribution, which declines with increasing age, is decreased in such associative versions of location tasks. This hypothesis suggests that reduction on the demands on the hippocampally based processing system underlies the compensatory effect of context on memory for locations.

In accordance with the intention to examine the role of context in relation to age differences in memory for location, the spatial materials were designed to create a context effect. It was reasoned that the addition of color in Experiment 1 had not been salient enough to produce a context effect. Thus, the materials used in the two conditions in this study were contrasted in terms of the amount and kind of contextual cues available in the background environment in order to make the contextual cues more salient. In the plain condition, which was designed to exemplify the "configural" condition of the hippocampal studies, no visually distinctive cues were available on the background structure. In the distinctive condition, however, visually distinctive cues of pictures of furniture organized into rooms of a house (e.g., kitchen, bedroom) were placed on the background structure. These cues were available to the subjects at encoding and retrieval and were meant to make this condition analogous to the "associative" condition of the hippocampal studies. It was reasoned that these pictorial cues would be the critical factor involved in the facilitation of memory for locations for young and older adults.

It was predicted that young adults would recall more object locations than older adults. Again, no gender differences were predicted on the expectation that the Gender x Condition interaction in the first study was due to sampling error. It was also predicted that young and older individuals would remember more object locations in the distinctive than in the plain condition because of the saliency of these distinctive cues.

In accordance with the hypothesis proposed by Sharps and Gollin, it was predicted that the main effect of age and context would be qualified by an Age x Context interaction, such that age differences would be found in the plain but not the visually distinctive condition. This finding would be consistent with the hypothesis that age differences in reliance on salient contextual cues explain age-related decline in memory for locations.

It was predicted that again the measure of ECF and not the processing or the Block Design measures would emerge as the strongest predictor of memory for location. Finally, it was predicted that the contribution of the ECF to explained variance would be smaller when age-related decline in memory for locations is eliminated by the presence of context. Such a finding would suggest that age deficits in memory for locations are reduced by the presence of context because of the reduced dependence on hippocampal involvement on such location tasks.

Method

Subjects

The 80 participants in this experiment were recruited on a voluntary basis from the university and community at large. The young group consisted of 20 men and 20 women aged 18 to 33 (*M* = 22.1; *SD* = 3.5) and the old group consisted of 20 men and 20 women aged 60 to 78 (*M* = 66.5; *SD* = 10.4).

Testing of all subjects took place at the university. All participants were self-sufficient, active members of the community. All participants were paid for their services. They were also informed that all individual results are confidential and that they would be informed, if they so wished, about the outcome of the study at a later date.

Task and Measures

The tasks and measures used in this experiment were, as in Experiment 1, of five types: (a) the task to measure the criterion variable, memory for spatial location (b) the Emergent Complex Figure task (ECF) used as a measure of hippocampal functioning (c) measures of processing speed and working memory (d) the WAIS Block Design test as a measure of visual-spatial ability (e) and psychosocial background measures.

Since all measures used in Experiment 2 were identical to the measures used in Experiment 1 with the exception of the spatial location measure, only this measure will be described in detail.

Spatial Location Task. The primary stimulus materials were two 115cm. x 73 cm. pieces of cardboard and 24 small common objects (e.g., stamp, penny, nail). On each piece of cardboard a 2.5cm. x 2.5 cm. square matrix had been drawn in faint lines. This matrix was drawn for scoring purposes and was drawn faintly so that it would not be useful as a strategic device to aid memory for spatial locations. Subjects confirmed in a pilot study and in retrospective questioning that they had not used the matrix to aid memory for locations.

In the plain condition 24 small common objects were placed on two pieces of matrixed cardboard joined in the center. No other distinctive cues were available on the cardboard. In the distinctive condition, the same 24 objects were placed on the cardboard on which pictures of furniture had been pasted. The pictures of furniture, cut from an IKEA catalogue, formed five recognizable rooms. On the left cardboard, three rooms were created from cutouts of furniture: kitchen (i.e., sink, cupboard; stove, table), dining room (i.e., table, chairs) and study (i.e., stereo, bookcase, desk, chair). On the right cardboard, two rooms were created: bedroom (i.e, bed, bureau with lamp) and living room (i.e., bookcase, T.V., couch and chair). See Appendix E-Figure 5 for a small scale presentation of rooms and objects on the matrixed cardboard.

There were five recall scores measuring the number of objects correctly recalled. The first recall score, termed the strict location score, was derived from a strict scoring procedure and as such replicated the scoring procedure used for Experiment 1. This score reflected correct placement of the object within a 5 cm. radius or within 2 units from the exact location. The second recall score, termed the lenient location score, reflected correct placement of the object within a radius of 12.5 cm radius or 5 units from the exact location. Finally, there were three measures of dislocation on the matrix. The first measure was the overall dislocation score. This score was obtained by counting the number of units a recalled object was moved horizontally and vertically from its original location and summing these scores for all 24 objects. The second and third measures were the measures of dislocation on the vertical and horizontal matrices, respectively.

All other measures followed the exact procedure used for scoring as outline in Experiment 1. Inter-rater reliability on the ECF measure for the 80 cases in this second study was .80 for the copy and .96 for the recall. The low reliability for the copy measure was due to differences between the raters in the scoring of designs 9,8 and 18. The second rater was consistently stricter in her scoring for accuracy for these designs. The accuracy rate of the Symbol Substitution task for young and older adults was 99.8% and 99.7%, respectively.

The procedure in Experiment 2 was identical to the procedure in Experiment 1 except for the memory for spatial location task. On this memory task subjects were told they would be taken to a room and shown 24 objects on a piece of cardboard and their task was to remember the locations of these objects. In the distinctive condition, subjects were informed that cutouts of furniture had been pasted on the cardboard and that these cutouts of furniture would remain on the cardboard. The experimenter then took subjects into the room with the objects, allowing subjects to view these objects for 3 minutes. They were asked to leave the room for another 2 minutes while the experimenter removed the objects and then asked to return. They were then given the original objects back in a box and told to place these objects in their correct locations. Subjects were also asked to guess if they could not remember the locations of the objects.

Design and Measures

Ten men and ten women in the young group were nonsystematically assigned to the plain condition and the other 10 men and 10 women in this age group were assigned to the distinctive condition. Ten men and ten women in the old age group were likewise assigned to the plain and distinctive condition. All participants were asked to recall the locations of the objects. Thus, the design was a 2 (age) x 2 (gender) x 2 (distinctiveness) factorial design with half the subjects in each age group and each gender being nonsystematically assigned to the plain condition and the other half to the distinctive condition.

Results

The primary focus of Experiment 2 was similar to Experiment 1. The goal was again to examine the recall of object locations in relation to age, gender and visual distinctiveness of the matrix and to ascertain the relationships between spatial memory for location and the several variables under consideration as explanatory factors of age changes in spatial memory.

Preliminary Analyses

According to data screening information, tests for normality and homogeneity of variance revealed that these assumptions were not violated. Product-moment correlations were then calculated among the various predictor variables including age in years, the cognitive explanatory measures, the psychosocial background measures and the dependent measures (see F-1). Examination of the correlation matrix showed that older age was significantly correlated, at an experiment-wise error rate of .05/13, with poorer health and visual acuity and with poorer performance on all cognitive explanatory variables except the anagram scores. The matrix also revealed moderate intercorrelations among the cognitive explanatory measures of the ECF, Digit Symbol Substitution, Verbal Memory and Block design suggesting that to some degree they are sharing variance. The explanatory cognitive variables were all moderately correlated with the outcome measure as well as with the visual acuity measure.

In addition, the various ECF measures were significantly intercorrelated. To reduce the number of variables under consideration, it was decided to retain percent recall as the only ECF measure to be used in further analysis for the same reasons cited in Experiment 1.

Apart from these correlations, the five measures of object memory for locations were significantly correlated with each other. To reduce the number of measures under consideration, it was decided to retain the strict location score. This measure was retained because Sharps and Gollin had found it to be the best measure of location recall.

As a second preliminary step, a 2 (age group) x 2 (gender) x 2 (condition) multivariate analysis of variance was performed on the nine predictor variables retained for further analysis (see means and standard deviations as well as source tables on explanatory and psychosocial variables for Age x Gender x Condition in Table G-1). The purpose of this analysis was to examine relationships between the design factors and the explanatory and psychosocial variables. One case (an older male subject) was deleted from the analysis because of missing data on the visual acuity score (i.e., the individual did not have glasses and felt he could not perform visual acuity task adequately).

The MANOVA showed a significant multivariate interaction of Age x Condition, $\underline{F}$ (9,63) = .71, $\underline{p}$ < .05, and significant multivariate main effects of gender, F (9,63) = 2.1, p <.05 and age, F (9,63) = 20.2, p < .001, but no other main effects or interactions. As can be seen from the results for individual measures (Table 11), the effects of age group on the individual measures paralleled the correlations with age.

The examination of the effect of Gender on the individual measures revealed a significant univariate effect of Gender on the Block Design scores, F (1,71) = 8.8, p < .001. As can be seen from the results for individual measures (see Table G-1 for listing of means; M for females = 29.3; M for males = 35.1) the performance of females was poorer than the males on the Block Design measure.

Finally, the analysis of the effect of the Age x Condition on the individual measures revealed a significant univariate effect on the Visual Acuity score, F (1,71) = 5.8, the Education, F (1,71) = 4.3 and MUNSH scores, F (1,71) = 4.1, all less than p < .05. The means of the interaction on the Visual Acuity, Education and MUNSH scores are presented in Table 12. On the visual acuity measure older adults had poorer visual acuity than the young adults in the distinctive condition. On the education measure older adults in the distinctive condition had a higher education level than older adults in the plain condition.

Table 11

Means for the Cognitive Explanatory and Psychosocial Measures in Relation to Age

(Experiment 2)

	Age Level	
	Young	Old
ECF	55.4	34.3**
Digit Symbol Substitution	123.1	190.1**
Verbal Memory	6.0	5.4**
Anagram	3.6	3.8
Block Design	38.6	25.7**
Education	15.0	14.5
Health Conditions	.23	1.4**
MUNSH	27.6	27.8
Visual Acuity	22.5	30.6**

** $p < .05$

Table 12

Means and Standard Deviations for the Visual Acuity, Education and MUNSH measures in Relation to Age and Condition

(Experiment 2)

The Visual Acuity measure:

Condition	Age	
	Young	Old
Plain	24.1 (8.0)	27.0 (8.8)
Distinctive	20.8 (1.9)	34.3 (13.0)

The Education measure:

	Young	Old
Plain	15.0 (.83)	13.6 (2.1)
Distinctive	15.0 (.92)	15.3 (2.9)

The MUNSH measure:

	Young	Old
Plain	28.1 (2.9)	26.6 (3.6)
Distinctive	27.1 (5.2)	29.0 (3.2)

Post-hoc Tukey tests on the visual acuity and education interaction means showed the difference was statistically significant at $p < .05$. However, post-hoc Tukey tests did not detect any significant differences on the MUNSH interaction means.

Principal Analyses

A three-way analysis of variance was conducted for age, gender and condition on number of object locations recalled. This analysis showed a significant main effect for age, F, $(1,72) = 12.64$, $p<.001$. The young subjects recalled more object locations correctly than the old subjects. This analysis also revealed a significant main effect for condition, F, $(1,72) = 24.67, p<.001$. Individuals recalled more object locations in the distinctive condition than in the plain condition. The means of the two age groups and the two conditions on the measure of strict locations are presented in Table 13 (see source table H-1). Contrary to expectations, there was no Age x Condition interaction nor did Gender have an effect either alone or in interaction.

Regression Results

To assess relations between each of the predictor variables and task performance, a series of multiple regression analyses were performed. The variables used as predictors included age in years, gender, education, health, visual acuity and MUNSH, Digit Symbol Substitution,

Table 13

Means and Standard Deviation for Recall of Exact Locations in Relation to Age, Gender and Condition

(Experiment 2)

Gender	Condition	Age level		Mean
		Young	Old	
Plain	Female	8.1 (5.3)	7.3 (2.0)	7.7
	Male	9.8 (3.3)	5.4 (2.7)	7.6
	Mean	9.0	6.4	7.7
Distinctive	Female	14.7 (5.3)	11.6 (4.4)	13.2
	Male	13.1 (3.9)	8.8 (3.2)	11
	Mean	13.9	10.2	12.1
	Mean	11.5	8.3	

Verbal Memory, Anagram, Block Design, and the percent recall on the ECF. Memory for location was the criterion variable. The interest was, as in Experiment 1, to ascertain the relative contribution of the psychosocial/background variables, to assess the relative contribution of age vis-a-vis the explanatory variables and finally to determine whether the ECF measure contributed significantly to explained variance in both conditions.

Analyses on Context Groups Combined

In the first analysis, the predictors of gender, education, health, visual acuity and MUNSH were entered at Stage 1, followed by age at Stage 2 and finally the five explanatory variables at Stage 3. As presented in Table 14, this analysis revealed that the background/psychosocial variables of education, gender, visual acuity, health or well-being as measured by the MUNSH were not significant predictors of memory for location. To reduce the number of variables under consideration, the psychosocial variables were dropped from further analysis. In addition, gender was not a significant predictor and was also dropped from further analyses. Finally, the Anagram variable was dropped from the variable set because the interest of these analyses was in the relative contribution of age versus the explanatory variables and the Anagram variable had a low correlation with age.

Table 14

Hierarchical Regression of Psychosocial Variables (Stage 1), Age (Stage 2) and Cognitive Explanatory Variables (Stage 3) (N = 80) on Location Recall (Experiment 2)

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Education	.19			
Gender	-.11			
Visual Acuity	-.22			
MUNSH	.001			
Health	-.03			
Stage 1 Result		.10	.10	1.7
Entered at Stage 2				
Age	-.32			
Stage 2 Result		.17	.06	5.4*
Entered at Stage 3				
Verbal Memory	.31			
Digit Symbol	-.37			
Anagram	.14			
Block Design	.43			
ECF	.62			
Stage 3 Result		.49	.32	8.5***

** $p < .05$

*** $p < .001$

In order to ascertain the relative contribution of Age vis-a-vis the four remaining explanatory variables two hierarchical regressions were performed. In the first reduced hierarchical analysis, Age was entered at Stage 1, followed by the explanatory variables of Digit Symbol Substitution, Verbal memory, Block Design and ECF measure, entered as a block. As Table 15 shows, when Age was entered first into the regression, it accounted for 11% of the variance and the reminder of the explanatory variables accounted for 30% of the variance for a total R^2 of 41%.

In contrast when the explanatory variables were entered as a block at Stage 1 and Age at Stage 2, Age only accounted for 1% of the variance while the measures of Digit Symbol Substitution, Verbal Memory, Block Design and the ECF account for 40% of the variance (see Table 16). It can, therefore, be concluded that the apparent relationship between age and the location measure can be explained by measures of processing resource, visual-spatial ability and hippocampal functioning.

Finally, when these four explanatory variables were entered simultaneously into a regression analysis without age, the results indicated that the ECF emerged as the only predictor, accounting for 45% of the variance (see Table 17). Thus, of the explanatory variables, it is the ECF that is explaining the major portion of the variance in location memory.

Table 15

Hierarchical Regression of Age (Stage 1) and Cognitive Explanatory Variables (Stage 2) (N = 80) on Location Recall (Experiment 2)

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Age	-.32			
Stage 1 Result		.11	.11	9.5***
Entered at Stage 2				
Verbal Memory	.30			
Digit Symbol	-.37			
Block Design	.44			
ECF	.62			
Stage 2 Result		.41	.30	9.4***

*** $p < .001$

Table 16

Hierarchical Regression of Cognitive Explanatory Variables (Stage 1) and Age (Stage 2) (N = 80) on Location Recall (Experiment 2)

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Verbal Memory	.30			
Digit Symbol	-.37			
Block Design	.44			
ECF	.62			
Stage 1 Result		.40	.40	12.7***
Entered at Stage 2				
Age	-.32			
Stage 2 Result		.41	.01	.68

*** $p < .001$

Table 17

Direct Entry of Cognitive Explanatory Variables (N = 80) on Location Recall

(Experiment 2)

Variable	r	Sr	t
Verbal Memory	.30	.09	.92
Digit Symbol	-.37	.01	.13
Block Design	.44	.08	.87
ECF	.62	.45	4.9**

R^2 change = 37 F change = 5.1***

*** $p < .001$

When percent recall scores were used as covariates in a reanalysis of the location recall score, the age effect was no longer significant, the adjusted $\underline{F}$ ratio for age being $\underline{F}$ (1,71) = .004 p > .96. However, the condition effect remained, the adjusted $\underline{F}$ ratio for condition being $\underline{F}$ (1,71) = 18.9, p <.001. The observed and adjusted means of the two age, gender and condition groups on the measure of locations are presented in Table 18 (see source table H-2).

Analyses on Context Groups Separately

A series of hierarchical regressions were performed separately for the two contexts. The aim of this examination was to determine whether the pattern of relationships between the explanatory variables and outcome would differ in the two context conditions, given a context effect. In particular, the question was whether the ECF contributed significantly to explained variance in both conditions.

These analyses were hierarchically ordered so that the more general explanatory measures of Digit Symbol Substitution, Verbal Memory and Block Design scores were entered sequentially before the ECF measure. Because the intercorrelations among these measures were significant, it can be assumed that all three are measuring general processing resource and possibly spatial visualization ability. A significant contribution of the ECF in a given context condition would support the hypothesis that the ECF

Table 18

Observed and Adjusted Means in Covariate Analysis for Recall of Exact Locations in Relation to Age, Gender and Condition with the ECF Measure as Covariate

(Experiment 2)

Gender	Condition	Age Level			
		Young		Old	
		Obs	Adj	Obs	Adj
Female	Plain	8.1	7.5	7.3	9.2
	Distinctive	14.7	12.2	11.6	12.4
Male	Plain	9.8	8.6	5.4	7.3
	Distinctive	13.1	11.2	8.8	10.5

measures ability that is particularly related to memory for spatial locations under that context condition.

In the first hierarchical analysis under the plain condition the Digit Symbol Substitution, Verbal Memory and Block Design were entered at Stage 1 as a block, followed by the ECF at Stage 2. As Table 19 shows, when the more general explanatory variables were entered into the regression, they accounted for 15% of the variance while the ECF measure accounted for 22% of the variance. Only the contribution of the ECF measure to explained variance was significant.

In the second hierarchical regression under the distinctive condition, again the more general explanatory variables were entered at Stage 1 as a block, followed by the ECF measure at Stage 2. The results indicated that in the distinctive condition the more general explanatory variables accounted for 35% of the variance while the ECF measure accounted for 11% of the variance. In contrast to the plain condition, the contribution to explained variance was significant for the more general explanatory variables as well as the ECF measure (see Table 20).

To summarize, the regression results under the plain condition indicated that only the ECF measure explains a significant portion of the variance for location memory, even after adjusting for the more general explanatory variables of processing resource and spatial visualization

Table 19

Hierarchical Regression of General Explanatory Variables (Stage 1) and the ECF (Stage 2) (N = 40) on Location Recall in the Plain Condition (Experiment 2)

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Verbal Memory	.22			
Digit Symbol	-.24			
Block Design	.37			
Stage 1 Result		.15	.15	2.1
Entered at Stage 2				
ECF	.60			
Stage 2 Result		.37	.22	12.2**

** $p < .001$

Table 20

Hierarchical Regression of

General Explanatory Variables (Stage 1) and

the ECF (Stage 2) (N = 40) on Location Recall

in the Distinctive Condition

(Experiment 2)

Variable	r	R^2	R2 change	F change
Entered at Stage 1				
Verbal Memory	.42			
Digit Symbol	-.48			
Block Design	.50			
Stage 1 Result		.35	.35	6.4**
Entered at Stage 2				
ECF	.62			
Stage 2 Result		.46	.11	7.4**

** $p < .01$

*** $p < .001$

ability. This finding indicated that the ECF, over and above the more general processing variables, is making a specific contribution to memory for locations. However, in the distinctive condition, the regression results revealed a somewhat enhanced contribution of the more general processing resources and spatial visualization measures and a somewhat reduced specific contribution of the ECF.

Discussion

Three patterns emerge from this study. The first pattern reveals a decline in memory for spatial locations, even when visually distinctive cues are readily available in the background environment. Young adults recall more locations than older adults. This finding replicates Experiment 1, thereby supporting the view that there exists an age-related decline in memory for locations.

The second pattern reveals that both young and older adults remember more locations in the distinctive condition. Thus, there is no evidence that visual distinctiveness is differentially benefitting young or older adults as proposed by Sharps and Gollin or that older adults do not use contextual cues effectively. Instead, this pattern supports the hypothesis that there are no age differences in reliance on context cues in memory for locations. The presence of context, by allowing individuals to be more exact in their placement of objects, benefits young and old to an equal extent but age-related decline in memory for locations remains. This finding is consistent with the view advocated by Park and her colleagues concerning the role of context in explaining age differences in memory for location (e.g., Park, Cherry, Smith & Lafronza, 1990; Zelinski & Light, 1988). This finding also further supports their suggestion that the Age x Condition interaction observed by Sharps and Gollin is due to sampling error.

The third pattern replicates the findings of Experiment 1 in two important ways. First, the ECF measure again explains a substantial portion of the variance on memory for the location measure in the plain and distinctive condition, even after adjusting for the more general measures of processing resource and spatial visualization. When the ECF is used as a covariate, age disappears as a significant contributor to age-related decline. In addition to these findings, the mean percent recall for the older adults (34.3%) and young adults (55.4%) again replicates Jones-Gotman's findings for the patient group with the large hippocampal excision and normal controls. Second, the results indicate a somewhat enhanced contribution of the more general processing resource and spatial visualization measures and a somewhat reduced specific contribution of the ECF measure in the distinctive condition.

Finally, the failure to replicate the Gender x Condition interaction from Experiment 1 lends support to the hypothesis that gender differences found in Experiment 1 with respect to map condition are the result of sampling bias and not the result of females differentially benefitting by the presence of salient context.

Taken as a whole, this experiment provides support for age-related decline in memory for locations, even when these locations are embedded within contextual cues and psychosocial/background factors are controlled. Most importantly, this experiment offers valuable clues as to the nature of the relationship between context, age and memory for spatial location. The first clue is derived from the finding in Experiment 1 and 2 of a strong link between the ECF measure and memory for locations.

Findings of such strong links between psychometric and spatial tasks are considered unusual in the research literature. In fact, researchers who have attempted to document such links have met, for the most part, with failure (e.g., Kirasic, 1991; Salthouse, Kausler & Saults, 1988a; Salthouse, Babcock & Shaw, 1991). In light of this failure, the discovery of this link as a direct result of testing predictions based on the physiological literature must be considered of some significance and interpreted as such.

One interpretation of this link is that the ECF measure is indeed measuring hippocampal involvement despite the fact that the relation between the ECF recall and location memory remained significant under the distinctive context condition. It could be argued that the relationship between the ECF performance and memory does not diminish substantially when contextual cues facilitate location recall because the mere presence of contextual cues is not enough to create a shift from the hippocampal configural system to the nonhippocampal associative system.

Another interpretation of the failure of the ECF measure to make differential contributions to location memory under different contextual conditions is that the ECF is not measuring hippocampal involvement but some as yet unknown variable which predicts memory for location under all circumstances. If this interpretation is valid then the ECF will always predict memory for location tasks, no matter the type of task, the nature of the manipulation or the presence or absence of contextual cues.

The second clue is derived from the finding that, in the presence of contextual cues, more of the variance in location memory appears to be accounted for by general processing resources and spatial visualization measures and less by the specific factor measured by the ECF. Such a pattern suggests that the processing of contextual information as well as the to-be-remembered information may place a greater strain on general cognitive abilities including processing speed, working memory capacity and spatial visualization ability. It could be proposed that in the presence of context this strain on general cognitive abilities emerges as a limiting factor and as such maintains age differences.

Although the finding that the ECF accounts for individual and age group differences in memory for locations in the plain and distinctive conditions is inconsistent with the hippocampal hypothesis, it is unclear if these results are applicable only to the particular form of context manipulation used in Experiment 1 and 2 or if these results can be generalized beyond these experiments. Before concluding that the ECF significantly predicts memory for location regardless of the presence or absence of context, it becomes necessary to replicate this result using a different task and different manipulations.

Thus, in order to test whether the ECF measure significantly predicts memory for location regardless of the presence or absence of context, a data set from a previous study on memory for locations were reanalysed (Cooney, 1987). This data set was chosen for three reasons. First, the task, manipulation and results were different from the task, manipulation and results in Experiment 2. In the previous study, participants had to recall locations of rooms in a house. The effects of differential access to knowledge-based schemata (i.e., prior knowledge of a typical house layout) on memory for room locations was examined in relation to age. It was found that when the to-be-learned house layout conformed to a typical house layout or schema, age differences in memory for location were eliminated. When it conformed to an atypical house layout, age differences were large. A two-way analysis of variance for Age x Schema Condition was conducted using the data from the 12 older adults who had also participated in Experiment 1 and for whom, therefore, measures were available on the Emergent Complex Figure, Digit Symbol Substitution and Block

Design tasks. The performance of these 12 older adults on the house plans was compared with that of the entire sample of 32 young adults who participated in the previous study. This reanalysis with a reduced sample of older adults replicated the effect of schema at $p < .001$ as well as the effect of Age and Age x Condition, at $p < .10$ (See Appendix I-1 for source table). Thus, in a general sense, the older adults chosen for the reanalysis were comparable in performance to the complete set of older adults who had participated in the original study.

Participants in the previous study were in both house plan conditions, unlike participants in Experiment 1 and 2. This within-subject design controls for the possible impact of sampling bias on the two conditions. Any changes in the relationship between the ECF, the Digit Symbol Substitution, Block Design and memory for location measures would be directly attributable to the impact of the condition and not sampling bias, thus, reducing the risk of drawing both false positive and false negative conclusions.

Experiment 3: Reanalysis of Data from a Previous Study

The aim of the present reanalysis of data was to examine further the relation between the ECF factor and memory for locations on configural tasks. Specifically, the objective was to establish whether, under a task condition known to result in statistically equivalent memory performance for young and older adults, the power of the ECF to predict memory for locations would be eliminated. This finding would lend support to the hypothesis that when older adults rely on spatial schemata, not contextual cues, to process location information, this reliance offsets age-related decline within the hippocampally mediated memory system.

It was predicted that the measure of ECF would emerge as the strongest predictor of memory of locations when contextual cues are absent from the spatial environment, as in the case with an atypical house layout. However, in accordance with the reasoning regarding the hippocampal and nonhippocampal memory systems, it was predicted that in the presence of a spatial environment that conformed to a spatial schema (i.e., typical house layout) the ECF measure would no longer be a predictor of memory for locations.

Method

Subjects

The data from this study were collected from 12 subjects, aged 64 to 78 (M = 68.8; SD = 3.5), who had participated in Experiment 1. There were 7 men and 5 women in this sample.

Materials

The stimulus materials consisted of four layouts of a one-story house consisting of 7 rooms and 3 closets, plus a front and back yard. Two of the layouts incorporated eight features previously defined in a pilot study as belonging to a typical house. The eight features mentioned as typical were: front entrance led into hallway, entrance to living room off hall near front entrance, bedrooms clustered together and living room, dining room and kitchen clustered together, doorway between kitchen and dining room, bathroom near bedrooms and closet in each bedroom and in hallway by front door. This layout was termed "typical" and as such contained familiar, meaningful and integrated contextual information about room and closet location. The second layout termed "atypical" employed similar dimensions and room sizes used in the construction of the typical house. However, 7 of the 8 typical features were violated in the development of the two atypical layouts. Consequently, these layouts provided mostly spatial and not schema relevant information about room and closet locations.

Examples of the typical and atypical layouts are shown in Appendix J.

A computer program of the typical and atypical layout was developed for an Apple 2+ microcomputer. This program permitted individuals to view each room of the house on the computer screen by manipulating the joystick control. When this control was manipulated, an "X" would move in the direction of the joystick manipulation. In order to get from one room of the house to another, this "X" would have to be moved through a doorway of a room. After a .9 second delay, the current room would then disappear and the adjacent room would appear with the "X" located in it.

Each room appearing on the screen was drawn to scale and was identified by a label underneath (e.g., you are now in the living room). The computer program kept a record of the number of entries to each room and indicated when all rooms had been entered at least once. The typical house required a minimum of 17 and the atypical a minimum of 15 entries to complete a tour of the house.

Procedure and Design

The data from this study consisted of the recall scores of 12 older adults in both the typical and atypical house layout condition with order of presentation of the two layouts counterbalanced across subjects. Seven subjects received the typical house plan first while 5 subjects received the atypical house plan first.

All participants were told that the goal of the task was to explore each house as quickly as possible and to learn the locations of the rooms and closets so that they could recall these locations after their exploration. A practice session was provided in order to acquaint participants with the task.

Subjects always began their exploration by entering the hallway from the front yard. They would then explore the first house until they had entered each room at least once. They were provided a checklist to ensure they had entered every room. Once they had viewed every room and closet in the house they were given an outline of the exterior walls of the house and asked to write the name of each room and closet in its approximate location.

Measures

The Recall measure was defined as the number of rooms and closets correctly located on the outline drawing of the house after the first exploration of the house. To measure the reliability of the recall scores, a second rater, blind as to age group and condition, was trained on the protocols of 13 subjects and then independently scored the recall of the remaining 51 subjects in the M.A. study. Inter-rater reliability for those 51 cases was .96 for the typical plan and .95 for the atypical plan. Because the small size constrained the number of predictors that could be entered into the equation to a maximum of two, only the scores from the percent recall measure from the Emergent Recall Figure task and the Digit Symbol Substitution or the Block Design scores were entered as predictors. These data had been collected in Experiment 1 and were scored according to the procedures described there.

Results

The goal of this analysis was to examine the ability of the percent recall measure from the Emergent Complex Figure, the Digit Symbol Substitution or the Block Design tasks to predict memory for location under conditions in which familiar, meaningful and integrated context conformed to a spatial schema (i.e., typical house condition) and under conditions in which schema relevant contextual cues were absent (i.e., atypical house condition).

A series of hierarchical regressions were performed separately for the two contexts to examine whether, with the elimination of age differences in the typical house condition, there were differences between the typical and atypical house condition in the pattern of relationships between the explanatory variables and outcome. Specifically, the question was whether the ECF contributed significantly to explained variance in both conditions.

These analyses were hierarchically ordered, as in Experiment 1 and 2, so that the more general explanatory variables of Digit Symbol Substitution or Block Design were entered before the ECF measure. Because the small number of subjects constrained the number of predictors to two, one set of hierarchical regressions was performed with the Digit Symbol Substitution and another set with the Block Design measure entered at Stage 1. In both sets of regressions the ECF measure was entered at Stage 2. The question was whether, with processing resource or spatial visualization controlled, the ECF still contributed significantly to explained variance under each of the context conditions. A significant contribution in a given context condition would suggest that the ECF measures an ability that is specifically related to memory for spatial locations under that context condition.

As Table 21 shows, in the atypical house condition, the Digit Symbol Substitution measure accounted for 11% of the variance while the ECF measure accounted for 46% of the variance. In the typical house condition, the Digit Symbol measure accounted for 27% of the variance while the ECF accounted for 5% of the variance.

Similarly, Table 22 indicates that in the atypical house condition the Block Design measure accounted for 5% of the variance while the ECF measure accounted for 37% of the variance. In the typical house condition the Block Design measure accounted for 34% of the variance while the ECF accounted for 13% of the variance.

To summarize, the regression results show that under the atypical house condition (i.e., contextual cues are absent from spatial environment) the ECF measure explains a significant portion of the variance for location memory, even after adjusting for the more general measure of processing speed or spatial visualization ability. This finding indicated that the ECF, over and above the more

Table 21

Hierarchical Regression of

Digit Symbol Substitution (Stage 1) and

the ECF (Stage 2) (N = 12) on Location Recall

(Experiment 3)

Atypical House Condition

Variable	r	R^2	R^2 change	F change
Entered at Stage 1				
Digit Symbol	−.34			
Stage 1 Result		.11	.11	1.3
Entered at Stage 2				
ECF	.64			
Stage 2 Result		.57	.46	9.5**
Typical House Condition				
Entered at Stage 1				
Digit Symbol	−.52			
Stage 1 Result		.27	.27	3.7
Entered at Stage 2				
ECF	.55			
Stage 2 Result		.32	.05	.63

** $p < .01$

Table 22

Hierarchical Regression of

Block Design (Stage 1) and

the ECF (Stage 2) (N = 12) on Location Recall

(Experiment 3)

Variable	r	R^2	R2 change	F change
Atypical House Condition				
Entered at Stage 1				
Block Design	.22			
Stage 1 Result		.05	.05	.51
Entered at Stage 2				
ECF	.64			
Stage 2 Result		.42	.37	5.6*
Typical House Condition				
Entered at Stage 1				
Block Design	.58			
Stage 1 Result		.34	.34	5.1*
Entered at Stage 2				
ECF	.55			
Stage 2 Result		.47	.13	2.3

* $p < .05$

general processing variables is making a specific contribution to memory for location in this condition. Under the typical house condition (i.e., spatial materials conform to schema of typical house) the regression results revealed a somewhat enhanced contribution of the spatial visualization measure at $p < .05$ and the speed measure at $p < .10$ and a reduced specific contribution of the ECF measure.

Discussion

The results of Experiment 3 indicate that the percent measure of the ECF explains a substantial portion of the variance in memory for configural locations (i.e., atypical house plan), even after adjusting for the processing resource of speed or spatial visualization ability. However, when the house layout conforms to the schema (i.e., typical house layout) and the task condition is known to eliminate age differences in memory for location, then the ECF measure no longer makes a unique contribution to explained variance, over and above that made by the processing speed measure or the spatial visualization measure. Moreover, since all subjects were in both conditions sampling bias cannot account for this result.

Such a finding is consistent with the hippocampal literature which predicts that the hippocampal contribution to explained variance, as measured by the ECF, should be correspondingly smaller when context is present and greater when context is absent. However, Experiment 3 suggests that such context must be consistent with schematic information about spatial arrangements already stored in semantic memory if the contribution of the ECF hippocampal measure is to be reduced. When the target information must be integrated with contextual cues, as in Experiment 1 and 2, the link between the ECF measure of hippocampal involvement and memory for locations, although reduced, remains quite strong.

The regression results also replicate the finding from Experiment 1 and 2 that when contextual cues are present general explanatory variables begin to play a more important role in the processing of location information. The results indicated that, in particular, spatial visualization ability plays an enhanced role in processing of location information that conforms to a schema. The regression analyses also revealed a somewhat enhanced contribution of the speed measure at $p < .10$ in the typical house plan condition.

General Discussion

The goal of this study was to answer two questions. First, is there evidence of age-related decline in memory for locations? Second, if there is evidence for decline, which explanation best accounts for this finding? In order to answer these questions young and older adults were tested on memory for location tasks. Four possible explanations, selected from the human developmental and physiological literatures, were examined in relation to age-related decline on these tasks. The first two explanations were linked to the view that the presence of context eliminates age differences because older adults increasingly rely on such cues to process location information. Craik maintained that such reliance was due to decline in processing speed and working memory capacity while the physiological literature proposed that this reliance was due to decline within the hippocampally mediated memory system. The remaining two explanations were tied to the view that older adults do not differentially benefit from the presence of context. This view links age-related decline to the more general factors of processing speed and working memory capacity and/or spatial visualization ability.

The pattern of results in Experiment 1 and 2 presents clear-cut evidence of an age-related decline in memory for locations, even when distinctive cues are available in the spatial environment and psychosocial/background factors are controlled. Thus, age-related decline in memory for locations is a robust phenomenon.

Experiment 2 also presents evidence that there are no age differences in the utilization of contextual cues per se. Young and older adults are able to benefit equally from the presence of contextual cues but age differences remain. Thus, Sharps and Gollin's hypothesis that the presence of distinctive context will eliminate age differences was not supported. Neither was the view that older adults are not able to utilize contextual information effectively. This finding is consistent with the recent study by Park and her colleagues in which these researchers were also unable to replicate the Age x Context interaction reported by Sharps and Gollin (Park, Cherry, Smith & Lafronza, 1990). This finding is also consistent with the majority of the research on context within the aging literature.

If older adults do not differentially benefit from the presence of context, then which explanation best accounts for age differences in memory for locations? The results of this study present a more complicated view of the relationship between age, context and memory for locations than originally predicted by either the human developmental or the physiological research literatures.

The results indicated that the ECF task is a strong predictor of memory for location in both the plain and the visually distinctive conditions. In fact, in Experiment 1 and 2 there was only a minimal reduction in this relationship in the distinctive context condition. In contrast, when age-related decline in memory for locations is eliminated under the typical house plan condition in Experiment 3, there is a substantial reduction in the relationship between the ECF and location recall.

One interpretation of these findings is that the hippocampally mediated memory system is still involved in processing location information regardless of the presence or absence of context. This memory system can be bypassed only when spatial materials conform to an already acquired schema, as in the typical house condition in Experiment 3. It can be reasoned that age differences are eliminated because the age impaired hippocampal structure is no longer involved in the processing of such schematic location information.

Of course, such an interpretation may be challenged on the basis that the ECF task does not measure hippocampal involvement. If such an argument is adopted then the challenge is to identify a more appropriate explanation for the link between the ECF task and memory for locations under the varying task conditions. From the current reading of the research literature, there does not seem to be another explanation that can account as well for this changing relationship. However, if the ECF task is accorded the status of a neuropsychological measure of hippocampal involvement, then certain implications can be pursued.

In addition to this finding, the results of Experiment 1 and 2 indicated that the more general measures of Digit Symbol Substitution, Verbal Memory and Block Design play a more prominent role than the ECF factor in the processing of distinctive context. One interpretation of these results is that the general processing factors measured by these tasks (i.e., processing speed, the structural aspects of working memory capacity defined as the amount of information that can be retained and spatial visualization ability) play an enhanced role in the processing of contextually laden information, over and above the somewhat reduced role of the hippocampally mediated memory system. One possible conclusion that can be drawn is that even though distinctive context facilitates memory for location by reducing somewhat the involvement of the hippocampal memory system, age-related decline in processing speed, working memory structural capacity and spatial visualization ability remain as limiting factors for older adults.

This type of trade-off implies there is both a cost and benefit for older adults during the processing of distinctive context. The cost is reflected in continued age differences while the benefit is reflected in the facilitatory effect of distinctive context. It could be suggested that older adults do not increasingly rely on distinctive context to process location information because of this cost.

It should be noted that such an interpretation does not support Craik's proposal that the presence of distinctive context at encoding and retrieval eliminates age differences by reducing demand for limited processing speed and working memory capacity. In fact, demand for these limited resources appears to increase when distinctive context is provided except in the case where the contextual information conforms to a spatial schema.

Such an explanation for age differences in memory for locations focuses on the interplay among four important factors: the hippocampally mediated memory system, processing speed, working memory structural capacity and spatial visualization ability. Furthermore, this explanation proposes that environmental conditions act as a catalyst, determining the nature of the interactions among these factors. The aim of the remainder of this discussion is to explore fully these interactions in order to gain some insight into the underlying causes of age-related decline in memory for locations.

Hippocampal Functioning and Memory for Locations

The relationship between the ECF with memory for locations under the varying task conditions has been interpreted as suggesting that age-related loss in memory for location is due to physiological decline within the hippocampal structure. This argument is strengthened by the finding that the ECF measure emerged in Experiment 1 and again in Experiment 2 as a better predictor of age-related decline in memory for location than age. According to Salthouse, such a finding provides a statistical basis for suggesting that a particular explanation, in this case age-related decline in hippocampal involvement, best accounts for age-related decline on the memory for location task.

Whether, of course, such decline is similar to the hippocampal deficits found in the right hippocampally impaired patient groups in Jones-Gotman's 1986a study is a matter of speculation. Although the mean percent ECF recall scores of older adults in Experiment 1 and 2 is similar to the mean percent ECF recall scores of patient groups with large excisions from the right hippocampal structure (i.e., approximately 30%) it would be erroneous to conclude that the level of hippocampal functioning in older adults is the same as the level of functioning in individuals with large right hippocampal damage. The reason for this is based on the inherent limitations involved in neuropsychological testing.

Neuropsychological tasks, such as the ECF task, are reliable and valid sources of information about changes in organically based behavior which deviate from the normal range of behavior. While these behavioral changes are predictive of future difficulties on tasks similar to the neuropsychological task, these changes do not imply physiological damage or indicate level of damage without corroborating physiological evidence. Thus, in relation to this particular study, it could be proposed that the 30% score on the ECF task by older adults indicates that older individuals will experience difficulties in performing tasks similar to the ECF task, such as memory for locations. The underlying reason for difficulties on the ECF task and memory for locations has been interpreted as due to age-related decline in hippocampal involvement. However, this 30% score does not indicate the amount of decline or even the nature of this decline. The answers to such questions can only be inferred from the aging literature on hippocampal functioning.

One explanation for age-related behavioral changes on the ECF task inferred from this aging literature is age-related neuroanatomical, light microscopic and gross changes within the hippocampal structure outlined by Petit (1982). Whether such age-related changes within the hippocampal structure are of the same magnitude as small or large right hippocampal impairment would have to be determined by further study. However, given the high level of cognitive functioning of the older adults in this study, a finding of significant brain damage in older adults would be surprising.

A second plausible explanation, currently explored within animal aging research, is that the presence of glucocorticoids modifies the functions of the septal-hippocampal system under conditions of chronic stress (e.g., Spencer, Miller, Young & McEwen, 1990). Thus, for some young adults the presence of glucocorticoids may be responsible for their low scores on the ECF measure. Whether the long-term presence of glucocorticoids eventually leads to changes within the hippocampal structure as outlined by Petit accompanied by behavioral changes on the ECF task of some older adults is not known. Not all older adults would be predisposed to such changes because either their ability to cope with chronic stress modifies the physiological processes or they have been spared chronic stress. Whatever the explanation, it is clear that older adults when compared to young adults are showing behavioral changes on the ECF task that may be interpreted as due to some kind of inefficiency within the hippocampally mediated processing system. The nature and cause of this inefficiency are unknown.

However, in order to understand the implications of such an explanation it is necessary to reconsider the cognitive functions performed by the hippocampally mediated processing system. The animal research on hippocampal functioning aids in this process by providing three viable theories concerning the cognitive function of the hippocampal component of this system.

Configural Association Theory. The first of these theories, termed the "Configural Association" theory, proposes that the hippocampus subserves a memory system involved in the acquisition, storage and recall of configural associations (Sutherland & Rudy, 1989). This theory provides evidence that hippocampal impairment will disrupt performance on any task that involves the acquisition and recall of configural associations, regardless of the type of information. Since memory for locations involves the acquisition of configural associations among spatial cues, this theory predicts hippocampal impairment will disrupt the performance of such tasks. However, this theory proposes that the hippocampal structure is not necessary for the normal functioning of the system involved in the acquisition and storage of simple associations between stimulus events. Since simple associative versions of location tasks engage this Simple Association system, this theory predicts that hippocampal impairment will not disrupt performance on such tasks.

The results of Experiment 1 and 2 are consistent with this theory of hippocampal functioning. It could be suggested that the hippocampal ECF measure was a predictor of memory for locations in these experiments, whether or not contextual cues were present or absent, because location information was acquired, stored and retrieved as a series of configural associations. The presence of contextual cues in Experiment 1 and 2 may have somewhat decreased reliance on the configural memory system by also eliciting the acquisition of simple associations during the processing of information. However, the critical factor was that most of the location information was processed as a series of configural, not associative relationships.

It may be concluded that the absence or presence of cues was not as important as the type of processing demands required to acquire, store and recall this information. If the processing demanded complex integration operations, such that configural associations were formed, then the ECF measure of hippocampal involvement would be the best predictor of memory for locations.

In contrast, the results of Experiment 3 indicated that the hippocampal ECF measure did not predict memory for locations on a location task involving spatial materials that conformed to a spatial schema. The reason for this may be because the task did not involve the acquisition and recall of configural associations. The configural associations of room locations had already been acquired by numerous experiences with typical houses and stored as schematic information (i.e., a set of expectations concerning the locations of rooms in a typical house).

The task, instead, involved the recognition and match between the stored schema of the typical house plan and the incoming information. Once these materials were recognized as familiar and matched, only the acquisition, storage and recall of the simple association between the schematic and perceived representation was involved. Recall, then, would be driven by the schematic representation of a typical house within the Simple Association or some as yet unknown processing system.

It could be suggested that the ECF measure is not a predictor in such circumstances because location information has been acquired and retrieved by the system involved in memory for schematic information which does not require hippocampal input. Thus, if an individual was impaired in terms of hippocampal functioning, memory loss for location information could be eliminated by relying on such an alternative system to process location information.

Temporary Memory Store Theory The second theory, advocated by Rawlins in 1985, proposes that the hippocampus may serve as a high capacity intermediate-term memory buffer for information. The role of this buffer is to store stimuli that are temporally discontiguous until some sort of organization can be imposed on these stimuli. Whether this organization involves the acquisition of simple or configural associations is not addressed by this theory.

According to Rawlins, then, damage to the hippocampus reduces the capacity of this structure to retain information in this buffer, with new information crowding out early items. The end result is disorganized or poorly organized information. However, hippocampal damage will have no impact on the short-term storage of small amounts of information presented within a short temporal framework or on the storage of associations in a long-term memory store.

Some support for this viewpoint is found in the clinical research of Jones-Gotman (1986b). Jones-Gotman found that patients with right temporal lobectomy with large hippocampal excisions were not only deficient in learning and remembering a list of abstract designs but also recalled significantly fewer of the first items of the list. In contrast, patients with small hippocampal excisions, left temporal lobectomy and/or the normal control group were not impaired in their performance on these tasks.

If such a theory were applied to this study, then the ECF would be measuring the capacity of a buffer system to store temporally discontiguous location information until it could be organized. Accordingly, older adults would experience age-related diminished capacity to store this information. However, when this theory is applied to this study, it is difficult to explain why the ECF measure would predict memory for locations in the atypical house plan but not in the typical house plan in Experiment 3. The temporal gap between the presentation of each room location in the typical and atypical house plan in Experiment 3 was the same.

It could be suggested that the key to understanding why the ECF would predict memory for locations in the atypical house plan but not in the typical house condition in Experiment 3 is not so much whether the information is temporally discontiguous or not but the type of information presented. Rawlins does not take into account whether this information demands the acquisition of simple schematic or configural associations. Once these factors are taken into consideration, then Rawlins theory becomes akin to the Configural Association theory. That is, if this temporally discontiguous information demands the engagement of the Configural Association system, then, hippocampal impairment will disrupt the processing of this information. If, however, temporally discontiguous location information engages the Simple Association or another unknown processing system, as in the typical house condition, then this hippocampal processing system will be bypassed.

Working Memory Theory The third theory, termed the "Working Memory" theory, contends that hippocampal functioning is necessary for the normal performance on tasks that require flexible, changing stimulus associations, such as memory for spatial relations. This theory proposes that the hippocampal structure subserves a working memory system which provides the underlying conditions for the acquisition, storage and recall of spatial relations.

This study provides evidence that the working memory, defined as the number of relevant variables stored in short-term memory, is not a major explanatory factor per se in age-related decline in memory for locations. This finding is consistent with Salthouse's research on working memory and age-related decline on a variety of cognitive tasks (Salthouse, Babcock & Shaw, 1991). However, the working memory measure used in this study only measures structural and not operational capacity (i.e., the amount of processing operations that can be performed while still preserving the products of an earlier operation). Thus, it is possible that the operational capacity component of working memory may be a major explanatory factor in age-related decline in memory for locations.

Evidence in support of this hypothesis is presented in the spatial integration studies of Salthouse (Salthouse, 1987a; Salthouse & Mitchell, 1989). In these studies Salthouse and his colleagues examined whether age-related decline in structural or operational capacity would best explain age differences on a spatial integration task. These researchers reported age differences increased significantly with each successive integration operation but remained constant across different quantities of information. This finding led Salthouse to propose that, if these successive integration operations change the internal representation in the direction of becoming more complex, then age-related deficits in operational capacity but not structural capacity will account for age-related decline on spatial integration tasks.

It could be hypothesized that it is these age-related deficits in operational capacity that impair the efficient functioning of the Configural Association system in older adults. Furthermore, the hippocampus may be the physiological correlate of the operational component of the working memory system and as such subserves the Configural Association system.

This proposal would be consistent with the theory of working memory, advocated by Olton and his colleagues, which proposes that hippocampal functioning is necessary for normal performance on tasks that require flexible, changing stimulus associations. However, this proposal would differ from Olton's theory in that it specifies that these associations must require successive integrative operations in order to form configural associations. This proposal would also be consistent with Jones-Gotman's hypothesis (1986a) that the right hippocampus is involved in an organizational function.

In support of this hypothesis, it could be argued that the ECF task, which is sensitive to hippocampal functioning, is strikingly similar to a spatial integration task which requires successive integrative operations in order to form a series of configural associations among spatial cues. For example, the ECF task, during the copy phase, demands successive integration operations which changes the internal representation of the visual figure in the direction of increasing complexity. In fact, it could be suggested that, with the aid of the hippocampal working memory system, configural associations are acquired among the 18 simple designs. Thus, according to this hypothesis, the ECF task is sensitive to hippocampal functioning because it demands the input of the operational component of working memory in the acquisition, storage and recall of configural associations concerning the locations of the 18 simple designs.

In fact, the processing demands of the ECF task replicate almost exactly the demands placed on the processing system by the location tasks in Experiment 1 and 2 and the atypical house condition in Experiment 3. These tasks demanded the successive integration of spatial and contextual cues as each series of cues were processed, changing the internal representation of the spatial arrangement in the direction of becoming more and more complex until a configural association is formed. In contrast, in the typical house condition of Experiment 3, the integration of the spatial cues had already taken place and been stored as a schematic representation. Thus, the operational aspects of working memory were not needed and the Configural Association system was not engaged.

In summary, it may be proposed that there are two separate memory systems that process location as well as other types of information. One system, termed the Configural Association system, is subserved by the hippocampus which is primarily involved in the integration of successively presented stimuli. Age-related impairment in right hippocampal functioning results in age-related decline in memory for configural versions of location tasks. The other separate processing system, termed the Simple Association system, processes primarily simple association-cued location information and perhaps schematic-driven representations. This system is able to operate normally, despite age-related hippocampal dysfunction because the acquisition of simple associations and/or the recognition and matching of familiar configural associations with incoming information does not demand complex mental operations to integrate the information.

In order for the Simple Associative system to become operative the task materials must stimulate the use of strategies that allow the individual to process information within the associative and not the configural processing system. It would seem that the presence of information that closely resembles already acquired and stored spatial schemata would stimulate the use of schema-driven strategies that, in turn, would engage the Simple Associative but not the Configural processing system.

Such a theory has recently been proposed in the memory and hippocampal literature. Squire (1992) reached a similar conclusion after reviewing the extensive literature on the role of the hippocampus in memory function. He proposed that the hippocampus, together with related anatomical structures, is essential for the functioning of a specific kind of memory system which he termed declarative (i.e., this memory system is also termed explicit, relational and/or configural). Squire presents evidence that the hippocampal structure functions as a pivotal device within the declarative memory system for constructing and storing unique configurations or configural associations between unrelated stimuli. This function allows individuals to acquire information about verbal and spatial relationships that can then be expressed outside of the context in which they were originally acquired. Squire describes such kinds of information as relational and flexible.

Squire contrasts the declarative memory system with a second memory system which he terms nondeclarative. He presents evidence that this memory system which is mainly involved in the acquisition of habits, skills, simple conditioning or simple associations, priming and implicit memory does not require the hippocampus to function effectively.

In direct relation to this study Squire suggests that classification and prototype or schemata learning may depend not on hippocampal functioning but on the functioning of the neostriatum. He offers evidence from two studies (i.e., Packard, Hirsh & White, 1989; Wang, Aigner & Mishkin, 1990 as cited in Squire, 1992) that certain kinds of habit learning that involve classification and prototype learning are impaired by neostriatal lesions.

This study presents some evidence for Squire's theory concerning a dual memory system. According to Squire's theory, a task which is sensitive to hippocampal functioning, such as the ECF task, should predict performance on tasks that demand the acquisition of unique and flexible configurations but not performance on tasks that involve prototype learning. The reason for this prediction is based on the assumption that the hippocampus is pivotal for the acquisition of complex configurations but not for prototypical information which is mediated by the neostriatum. The results of this study demonstrate that, indeed, the ECF measure of hippocampal functioning does predict memory for complex spatial configural associations but not memory for prototypical information, such as memory for room locations in a typical house.

Squire also offers the suggestion that the strategy used by an animal may play a role in determining whether the animal has learned a location task by acquiring configural or simple associations. He cites evidence indicating that some configural tasks are successfully learned by rats with hippocampal lesions (e.g., Gallagher & Holland, 1992; Whishaw & Tomic, 1991, as cited by Squire, 1992). Squire explains this finding by suggesting that these hippocampally impaired animals used an associative strategy to learn a configural task, thereby engaging the non-hippocampal system and bypassing the impaired hippocampal system. Thus, according to Squire, the strategy used by an animal can change a primarily configural task into an associative task. Whether the schema-driven strategy used by older adults in Experiment 3 changed the configural task to an associative task is open to speculation. However, given Squire's interesting comments on strategy use, future research in this area would certainly be warranted.

Squire does not address directly the role of these memory systems in the learning and memory of location information. Nor does he discuss age-related decline within these memory systems. However, there is widespread acceptance within the aging literature that the functions described by Squire as performed by the declarative memory system (i.e., memory for relational and flexible information) experience age-related decline while the functions performed by the nondeclarative memory system (i.e., skills and habits, priming, implicit memory) remain relatively intact with increasing age. It is reasonable to conclude that those functions linked with the declarative memory system may experience age-related decline because of age-related decline of the hippocampal component of the declarative memory system. Such a conclusion is consistent with Squire's theory on the role of the hippocampus in memory functions and the findings from this study.

Processing Speed, Structural Working Memory Capacity and Memory for Locations.

It may be proposed that processing speed and working memory capacity (i.e., defined as structural capacity) are required and available to the Configural and Simple Associative memory systems. The results of this study indicated that age-related decline in these factors only impact on the processing of location information if more in the way of processing speed and working memory capacity were demanded than was available. When the resources available were sufficient for completing the task, as in the recall of the typical house plan, speed and working memory capacity ceased to be limiting factors in the processing of location information.

It may proposed that the sufficiency of processing speed and working memory capacity is determined by the amount and kind of information to be processed. If the information is highly familiar and integrated, as in materials that conform to a spatial schema, then these factors cease to be important. If, however, this information is acquired as many disparate bits, as in contextually laden materials, then processing speed and working memory capacity become more limiting factors. The critical determinants are the manner in which the information is acquired before it is stored and the amount of information to be processed.

Spatial Visualization Ability and Memory for Locations.

With respect to spatial visualization ability, it may be proposed that spatial visualization ability is required and available also to both memory systems. Results of this study indicated that age-related decline in spatial visualization ability only impacted on the processing of location information if more in the way of processing speed and working memory capacity were demanded than was available. When processing speed and working memory capacity were sufficient for the task, such as processing the typical house plan in Experiment 3, then age-related decline in spatial visualization ability did not impact on the processing of location information. However, such a conclusion is in need of further research.

In summary, since older adults are impaired on these general processing factors, then memory loss for location information cannot be eliminated unless the task itself is designed to eliminate such demands. The results of this study indicated that tasks requiring the processing of large amounts of contextually laden information demand more in the way of processing speed, structural memory capacity and spatial visualization ability than is available to older adults. Hence, it can be predicted that such tasks will always experience age-related decline. In contrast, the results of Experiment 3 indicated that if a task is designed to minimize the amount of information to be processed by organizing this information into an integrated and familiar chunk, as in the typical house plan, then demands on processing speed, structural memory capacity and spatial visualization ability are minimal. Age differences are eliminated on such tasks unless, of course, these tasks involve the hippocampally mediated memory system.

This explanation is consistent with the research findings of Kirasic (1990;1991), Wadell and Rogoff (1981), Rankin and Collins (1985) and Park and her colleagues (1986). These researchers provide evidence that familiarity with highly integrated context is the crucial factor in eliminating age-related decline in memory for locations.

Future Directions

This study highlights the need to develop and test hypotheses concerning the interplay of factors involved in memory for location. The first stage would involve the documentation of neuroanatomical, light microscopic and gross changes within the hippocampal structure of intellectually intact older individuals. Squire states that recent improvements in magnetic resonance imaging now permit the visualization of the hippocampus in detail. In addition, the presence of glucocorticoids that occurs as a result of chronic stress should also be documented. There is some evidence that such alterations may cause subsequent changes in septal-hippocampal functioning (see Nappi, Martignoni, Genazzani & Petraglia, 1990 for a review of this literature in relation to aging).

The second stage of this research would entail relating these physiological changes to age-related changes on a behavioral measure of hippocampal impairment. Evidence of such a relationship would establish that the ECF measure can be used as a reliable and valid neuropsychological test of right hippocampal involvement. It would also establish that changes on the ECF measure index changes involving the hippocampal structure.

Once the relationship between the physiological and ECF measures of right hippocampal involvement are established, the next stage would involve identifying the function performed by the hippocampal structure. This study presents a theoretical argument identifying the cognitive function as the operational component of working memory. One way of testing this hypothesis would be to establish the convergent and divergent validity of the ECF measure in terms of other tasks that purport to measure operational capacity. This approach has been used successfully by Salthouse to establish measures that index speed and working memory.

The final stage would be to build a model linking age-related decline in the operational capacity function of the hippocampal structure to decline on configural location tasks. Accordingly, this model would predict that, because hippocampal age-related impairment results in limited operational capacity, older adults would be impaired in their ability to acquire, store and recall configural but not simple or schematic associations. This model would hypothesize that only when the hippocampal configural memory system is bypassed and speed and spatial visualization ability are no longer limiting factors will age-related decline be eliminated.

The value in testing such a model would be to create a shift towards a more comprehensive understanding of age-related decline. Current aging research does not address the complex issue of interrelationships among physiological, cognitive and environmental factors involved in such decline. Instead, this research has focused on simple one factor explanations, such as environmental conditions, to account for age differences. Such explanations have not provided the depth and breadth of understanding needed to generate new hypotheses and new perspectives.

This study has deviated from such traditional approaches by providing a multi-factor model for decline in memory for locations. This model attempts to integrate physiological and cognitive aspects of aging across varying environmental conditions. It remains for future research to determine the value of such a model by testing the hypotheses proposed in this study.

References

Aggleton, J.P., Blindt, H.S., & Candy, J.M. (1989). Working memory in aged rats. Behavioral Neuroscience, 103, 975-983.

Aggleton, J.P., Hunt, P.R., & Rawlins, J.N.P. (1986). The effects of hippocampal lesions upon spatial and non-spatial tests of working memory. Behavioral Brain Research, 19, 133-146.

Arbuckle, T.Y., Gold, D., & Andres, D. (1986). Cognitive functioning of older people in relation to social and personality variables. Psychology and Aging, 1, 55-62.

Babcock, R.L., & Salthouse, T.A. (1990). Effects of increased processing demands on age differences in working memory. Psychology and Aging, 5, 421-428.

Barnes, C.A. (1988). Spatial learning and memory processes: The search for their neurobiological mechanisms in the rat. Trends in Neurosciences, 11, 163-169.

Barnes, C.A., Nadel, L., & Honig, W.K. (1980). Spatial memory deficit in senescent rats. Canadian Journal of Psychology, 34, 29-39.

Bashore, T.R., Osman, A., & Heffley, E.F. (1989). Mental slowing in elderly persons: A cognitive psychophysiological analysis. Psychology and Aging, 4, 435-244.

Bennett, G. K., Seashore, H. G., & Wesman, A.G. (1959). Differential aptitude test (3rd ed.). New York: Psychological Corporation.

Best, P.J., & Thompson, L. T. (1989). Persistence, reticence, and opportunism of place-field activity in hippocampal neurons. Psychobiology, 17, 236-246.

Bruce, P. R., & Herman, J. F. (1986). Adult age differences in spatial memory: Effects of distinctiveness and repeated experience. Journal of Gerontology, 41, 774-777.

Caplan, P.L., MacPherson, M., & Tobin, P. (1985). Do sex-related differences in spatial abilities exist? A multilevel critique with new data. American Psychologist, 40, 786-799.

Carr, S., & Schissler, D. (1969). The city as a trip: Perceptual selection and memory in views from the road. Environment and Behavior, 1, 7-36.

Cerella, J. (1989). Aging and information-processing rate. In J.E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (3rd ed). (pp. 201-221). New York: Academic Press.

Charness, N. (1981). Visual short-term memory and aging in chess players. Journal of Gerontology, 36, 615-619.

Cherry, K.E., & Park, D.C. (1989). Age-related differences in three-dimensional spatial memory. Journal of Gerontology, 44, 16-22.

Cooney, R. (1987). Spatial memory and aging. Unpublished master's thesis, Concordia University, Montreal, Quebec.

Craik, F.I.M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), Human memory and cognitive abilities. (pp. 409-422). Amsterdam: Elsevier Science Publishers B.V. (North-Holland).

Craik, F.I.M., Byrd, M., & Swanson, J.M. (1987). Patterns of memory loss in three elderly samples. Psychology and Aging, 2, 79-86.

Craik, F.I.M., & McDowd, J.M. (1987). Age differences in recall and recognition. Journal of Experimental Psychology: Learning, Memory and Cognition, 13, 474-479.

Davis, H.P., Idowu, A., & Gibson, G. E. (1983). Improvement of 8-arm maze performance in aged Fisher 344 rats with 3,4-diaminopyridine. Experimental Aging Research, 9, 211-214.

Deadwyler, S.A., Breese, C.R., & Hampson, R.E. (1989). Control of place-cell activity in an open field. Psychobiology, 17, 221-227.

Denney, N.W., Miller, B.V., Dew, J.R., & Levav, A.L. (1991). An adult developmental study of contextual memory. Journal of Gerontology, 46, 44-50.

deToledo-Morrell, L., & Morrell, F. (1985). Electrophysiological markers of aging and memory loss in rats. Annual Reviews of New York Academy of Science, 444, 296-311.

deToledo-Morrell, L., Morrell, F., & Fleming, S. (1984). Age dependent deficits in spatial memory are related to impaired hippocampal kindling. Behavioral Neuroscience, 98, 902-907.

Dobbs, A.R., & Rule, G. (1989). Adult age differences in working memory. Psychology and Aging, 4, 500-503.

Eichenbaum, H., Otto, T., & Cohen, N.J. (1992). The hippocampus - What does it do? Behavioral and Neural Biology, 57, 2-36.

Eichenbaum, H., & Wiener, S.I. (1989). Is place the only functional correlate? Psychobiology, 17, 217-220.

Evans, G.W., Brennan, P. L., Skorpanich, M., & Held, D. (1984). Cognitive mapping and elderly adults: Verbal and location memory for urban landscapes. Journal of Gerontology, 39, 452-457.

Foisy, P. (1991). Age-related differences in intentional memory in small-scale space: A meta-analysis and a methodological criticism. Paper presented at the annual convention of the Canadian Gerontological Association, Francescato, D., & Mebane, W. (1973). How citizens view two great cities: Milan and Rome. In R. Davies & D. Stea (Eds.), Image and environment. (pp. 131-147). Chicago: Aldine.

Geinisman, Y., & Bondaroff, W. (1976). Decrease in the number of synapses in the senescent brain: A quantitative electron microscopic analysis of the dentate gyrus molecular layer in the rat. Mechanisms of Aging and Development, 5, 11-23.

Goldstein, L.H., Cananan, A. G. M., & Polhey, C.E. (1989). Cognitive mapping after unilateral temporal lobectomy. Neuropsychologia, 27, 167-177.

Harris, L.J. (1981). Sex-related variations in spatial skill. In L.S. Liben, A.H. Patterson, & N. Newcombe (Eds.), Spatial representation and behavior across the life span: Theory and applications. New York: Academic Press.

Hasher, L., & Zacks, R.T. (1979). Automatic and effortful processes in memory. Journal of Experimental Psychology: general, 108, 356-388.

Jagilo, J. A., Nonneman, A. J., Isaac, W. L., & Jackson-Smith, P. A. (1990). Hippocampal lesions impair rats' performance of a nonspatial matching-to-sample task. Psychobiology, 18, 55-62.

Jones-Gotman, M. (1986a). Memory for designs: The hippocampal contribution. Neuropsychologia, 24, 193-203.

Jones-Gotman, M. (1986b). Right hippocampal excision impairs learning and recall of a list of abstract designs. Neuropsychologia, 24, 659-670.

Jones-Gotman, M. (1987). Commentary: Psychological evaluation - Testing hippocampal function. In J. Engel Jr. (Ed.), Surgical treatment of epilepsies. (pp. 203-211). New York: Raven Press.

Kasziak, A. (1990). Overview: Health and disease. Paper presented at the Cognitive Aging Conference, Atlanta.

Kelsey, J.E., & Landry, B.A. (1988). Medial septal lesions disrupt spatial mapping ability in rats. Behavioral Neuroscience, 102, 289-293.

Kirasic, K.C. (1988). Aging and spatial cognition: Current status and new directions for experimental researchers and cognitive neuropsychologists. In J. M. Williams & C.J. Long, (Eds.), Cognitive Approaches to Neuropsychology. (pp. 83-100). New York: Plenum Press.

Kirasic, K.C. (1990). Effects of age and environmental familiarity on adults spatial problem-solving performance: Evidence of a hometown advantage. Environmental Aging Research, 15, 181-185.

Kirasic, K.C. (1991). Spatial cognition and behavior in young and elderly adults: Implications for learning new environments. Psychology and Aging, 6, 10-18.

Kozlowski, L.T., & Bryant, K.J. (1977). Sense of direction, spatial orientation, and cognitive maps. Journal of Experimental Psychology: Human Perception and Performance, 3, 590-598.

Kozma, A., & Stones, M.J. (1983). Re-validation of the Memorial University Scale of Happiness. Canadian Journal of Aging, 2, 27-29.

Kucera, H., & Francis, W.N. (1967). Computational analysis of present-day American English. Providence, Rhode Island: Brown University Press.

Landfield, P. W., Rose, G., Sandles, L., Wohlstaden, T. C. & Lynch, G. (1977). Patterns of astroglial hypertrophy and neural degeneration in the hippocampus of aged, memory-deficient rats. Journal of Gerontology, 32, 3-12.

Light, L.L., & Anderson, P.A. (1985). Working memory capacity, age and memory for discourse. Journal of Gerontology, 40, 737-747.

Light, L.L., & Zelinski, E.M. (1983). Memory for spatial information in young and old adults. Developmental Psychology, 19, 901-906.

Linn, M.W., & Linn, B. S. (1984). Self-evaluation of life function (self) scale: A short, comprehensive self-report of health for elderly adults. Journal of Gerontology, 39, 603-612.

Lipman, P.D. (1991). Age and exposure differences in acquisition of route information. Psychology and Aging, 6, 128-133.

Maccoby, E.E., & Jacklin, C. N. (1974). The psychology of sex differences. Stanford, California: Stanford University Press.

McCormack, P.D., (1982). Coding of spatial information by young and elderly adults. Journal of Gerontology, 37, 80-86.

McNaughton, B.J., Barnes, C.A., Meltzer, J., & Sutherland, R.J. (1989). Hippocampal granule cells are necessary for normal spatial learning but not for spatially-selective pyramidal cell discharge. Experimental Brain Research, 76, 485-496.

Money, J., Alexander, D., & Walker, H. T. (1965). A standardized road-map test of direction sense. (manual) Baltimore: John Hopkins Press.

Moscovitch, M., & Winocur, G. (1983). Contextual cues and release from proactive inhibition in young and old people. Canadian Journal of Psychology, 37, 331-344.

Morris, R. G. M. (1981). Spatial localization does not require the presence of local cues. Learning and Motivation, 12, 239-260.

Morris, R. G. M., Garrud, P., Rawlins, J. N. P., & O'Keefe, J. (1982). Place navigation impaired in rats with hippocampal lesions. Nature, 297, 681-683.

Nappi, G., Martignono, E., Genazzani, A.R., & Petraglia, F. (1990). Stress and the aging brain. New York: Raven Press.

Naveh-Benjamin, M. (1987). Coding of spatial location: An automatic process? Journal of Experimental Psychology: Learning, memory and Cognition, 13, 595-605.

Nyborg, H. (1983). Spatial ability in men and women: Review and new theory. Advances in Behavior Research and Therapy, 5, 89-140.

Okaichi, H. (1987). Performance and dominant strategies on place and cue tasks following hippocampal lesions in rats. Psychobiology, 15, 58-63.

O'Keefe, J., & Nadel, L. (1978). The hippocampus as a cognitive map. Oxford: Clarendon Press.

Olton, D.S., Becher, J.T., & Handlemann, G. E. (1979). Hippocampus, space and memory. Behavioral Brain Science, 2, 313-365.

Olton, D.S., Wible, C.G., Pang, K., & Sakurai, Y. (1989). Hippocampal cells have mnemonic correlates as well as spatial cues. Psychobiology, 17, 228-229.

Park, D.C., Cherry, K. E., Smith, A.D., & Lafronza, V. N. (1990). Effects of distinctive context on memory for objects and their locations in young and elderly adults. Psychology and Aging, 5, 250-255.

Park, D.C., Puglisi, J. T., Lutz, R. (1982). Spatial memory in older adults: Effects of intentionality. Journal of Gerontology, 37, 330-335.

Park, D.C., Puglisi, J.T., & Smith, A.D. (1986). Memory for pictures: Does age-related decline exist? Psychology and Aging, 1, 11-17.

Park, D.C., Puglisi, J.T., Smith, A.D., & Dudley, N.N. (1987). Cue utilization and encoding specificity in picture recognition by older adults. Journal of Gerontology, 42, 423-425.

Park, D.C., Puglisi, J. T., & Sovacool, M. (1983). Memory for pictures, words and spatial location in older adults: Evidence for picture superiority. Journal of Gerontology, 38, 582-588.

Parkinson, J.K., Murray, E. A., & Mishkin, M. (1988). A selective mnemonic role for the hippocampus in monkeys' memory for the location of objects. Journal of Neuroscience, 8, 4159-4167.

Perlmutter, M., Metzger, R., Nezworski, T., & Miller, K. (1981). Spatial and temporal memory in 20 and 60 year old. Journal of Gerontology, 36, 59-65.

Petit, T.L. (1982). Neuroanatomical and clinical neuropsychological changes in aging and senile dementia. In F.I.M. Craik & S. Trehub (Eds.), *Aging and the cognitive processes*. (pp. 1-21). New York: Plenum Press.

Pezdek, K. (1983). Memory for items and their spatial locations by young and elderly adults. *Developmental Psychology*, *19*, 895-900.

Poon, L.W., Krauss, I. K., & Bowles, N. L. (1984). On subject selection in cognitive aging research. *Experimental Aging Research*, *10*, 43-48.

Puglisi, J.T., Park, D.C., Smith, A.D., & Hill, G.W. (1985). Memory for two types of spatial location: Effects of instructions, age and format. *American Journal of Psychology*, *98*, 101-118.

Rabinowitz, J.C., Craik, F.I.M., & Ackerman, B. P. (1982). A processing resource account of age differences in free recall. *Canadian Journal of Psychology*, *36*, 325-344.

Rankin, J.L., & Collins, M. (1985). Adult age differences in memory elaborations. *Journal of Gerontology*, *40*, 451-458.

Rawlins, J.W.P. (1985). Associations across time: The hippocampus as a temporal memory store. *The Behavioral and Brain Sciences*, *8*, 479-496.

Regan, D. (1988). Low contrast visual acuity test for paediatric use. Canadian Journal of Ophthalmology, 23, 224-227.

Rey, A. (1964). L'examen clinique en psychologie. Paris: Presses Universitaires de France.

Salthouse, T.A. (1982). Adult cognition. New York: Springer-Verlag.

Salthouse, T.A. (1985). A theory of cognitive aging. Amsterdam: North-Holland.

Salthouse, T.A. (1987a). Adult age differences in integrative spatial ability. Psychology and Aging, 2, 254-260.

Salthouse, T.A. (1987b). Sources of age-related individual differences in Block Design tests. Intelligence, 11, 245-262.

Salthouse, T.A. (1988a). Initiating the formalization of theories of cognitive aging. Psychology and Aging, 3, 3-16.

Salthouse, T.A. (1988b). Resource-reduction interpretations of cognitive aging. Developmental Review, 238-272.

Salthouse, T.A. (1988c). The role of processing resources in cognitive aging. In M.L. Howe & C. J. Brainer (Eds.), Cognitive development in adulthood. (pp. 185-239). New York: Springer Verlag.

Salthouse, T.A., Babcock, R. L., & Shaw, R. J. (1991). The effects of adult age on structural and operational capacities in working memory. Psychology and Aging, 6, 118-127.

Salthouse, T.A., Kausler, D. H., & Saults, J. S. (1988a). Investigation of student status, background variables, feasibility of standard tasks in cognitive aging research. Psychology and Aging, 3, 29-37.

Salthouse, T. A., Kausler, D. H., & Saults, J S. (1988b). Utilization of path-analytic procedures to investigate the role of processing resources in cognitive aging. Psychology and Aging, 3, 158-166.

Salthouse, T. A., & Mitchell, D. R. D. (1989). Structural and operational capacities in integrative spatial ability. Psychology and Aging, 4, 18-25.

Sands, L.P., Terry, H., & Meredith, W. (1989). Change and stability in adult intellectual functioning assessed by Wechsler item responses. Psychology and Aging, 4, 79-87.

Schaie, K. W. (1983). The Seattle longitudinal study: A 21 year explanation of psychometric intelligence in adulthood. In K. W. Schaie (Ed.), Longitudinal studies of adult psychological development, (pp. 64-135). New York: Guilford.

Schorr, D., Bower, G. H., & Kiernan, R. (1982). Stimulus variables in the Block design task. Journal of Consulting and Clinical Psychology, 50, 479-487.

Sharps, M. J. (1991). Spatial memory in young and elderly adults: Category structure of stimulus set. Psychology and Aging, 6, 309-312.

Sharps, M. J., & Gollin, E. S. (1987). Memory for object locations in young and elderly adults. Journal of Gerontology, 42, 336-347.

Sharps, M. J., & Gollin, E. S. (1988). Aging and free recall for objects located in space. Journal of Gerontology, 43, 8-11.

Smith, M., & Milner, B. (1989). Right hippocampal impairment in the recall of spatial location: Encoding deficit or rapid forgetting? Neuropsychologia, 27, 71-81.

Spencer, R.L., Miller, A.H., Young, E.A., & Bruce, S.E. (1990). Stress-induced changes in the brain: Implications for aging. In G. Nappi, E. Martignoni, A.R. Genazzani & F. Petraglia (Eds.), Stress and the aging brain. (pp. 17-29). New York: Raven Press.

Squire, L.R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys and humans. Psychological Review, 99, 195-231.

Stankov, L. (1988). Aging, attention and intelligence. *Psychology and Aging*, *3*, 59-74.

Sutherland, R.J., & McDonald, R. J. (1990). Hippocampus, amygdala and memory deficits in rats. *Behavior Brain Research*, *37*, 57-79.

Sutherland, R. J., & Rudy, J. W. (1988). Place learning in the Morris place navigation task is impaired by damage to the hippocampal formation even if the temporal demands are reduced. *Psychobiology*, *16*, 157-163.

Sutherland, R. J., & Rudy, J. W. (1989). Configural association theory: The role of the hippocampal formation in learning, memory and amnesia. *Psychobiology*, *17*, 129-144.

Sutherland, R. J., Whishaw, I. Q. & Kolb, B. (1983). A behavioral analysis of spatial localization following electrolytic, kainate or calchicine-induced damage to the hippocampal formation in the rat. *Behavioral Brain Research*, *7*, 133-153.

Thomas, J. L. (1985). Visual memory: Adult age differences in map recall and learning strategies. *Experimental Aging Research*, *11*, 93-95.

van der Staay, F. J., van Nies, J., & Raaijmakers, W. (1990). The effects of aging in rats on working and reference memory performance in a spatial holeboard discrimination task. *Behaviorial and Neural Biology*, *53*, 356-370.

Waddell, K. J., & Rogoff, B. (1981). Effect of contextual organization on spatial memory of middle-aged and older women. Developmental Psychology, 17, 878-885.

Wechsler, D. (1981). Manual for the Wechsler Adult Intelligence Scale-Revised. New York: Psychological Corporation.

Winocur, G. (1980). The hippocampus and cue utilization. Physiological Psychology, 8, 280-288.

Winocur, G., & Moscovitch, M. (1983). Paired-associate learning in institutionalized old people: An analysis of interference and context effects. Journal of Gerontology, 38, 455-464.

Winocur, G., & Moscovitch, M. (1990). Hippocampal and prefrontal cortex contribution to learning and memory: Analysis of lesion and aging effects on maze learning in rats. Behavioral Neuroscience, 104, 544-551.

Winocur, G., Moscovitch, M., & Witherspoon, D. (1987). Contextual cuing and memory performance in brain-damaged amnesics and old people. Brain and Cognition, 6, 129-141.

Wright, R.E. (1981). Aging, divided attention and processing capacity. Journal of Gerontology, 36, 605-614.

Zelinski, E.M., & Light, L.L. (1988). Young and older adults use of context in spatial memory. Psychology and Aging, 3, 99-101.

Footnotes

1. The Configural Association theory is one among many similar theories derived from O'Keefe and Nadel's original notion that the hippocampus plays a critical role in the learning and memory for spatial relations. Recent reviews by Eichenbaum (1992) and Squire (1992) have expanded on this notion by proposing that the hippocampal memory system mediates a declarative memory system which is responsible for the formation of relational networks. According to these researchers, these networks flexibly guide performance on spatial as well as nonspatial tasks under a wide range of conditions. Although such a proposal closely approximates Sutherland and Rudy's notion of a Configural Association memory system, Eichenbaum and Squire suggest that the critical factor determining hippocampal involvement is not solely the configural nature of the task. Instead these researchers emphasize such factors as the degree to which paradigm and strategy demand the involvement of the hippocampal mediated memory system as well as differences in the extent of hippocampal damage.

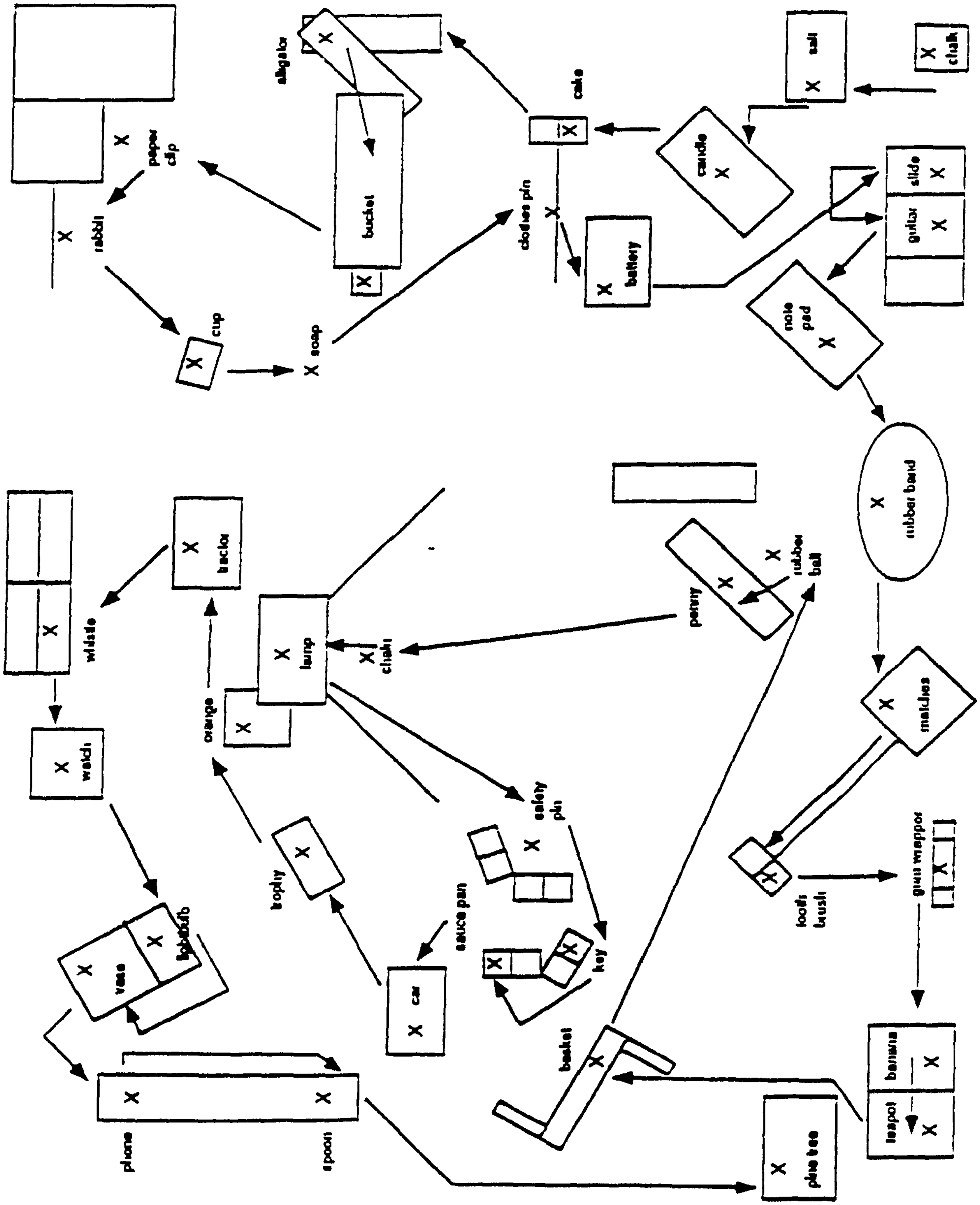
Appendix A -1

Task Materials

Stimulus Materials for Location Recall Task

(as Shown in Figure 3)

Experiment 1


alligator
bucket
paper clip
rabbit
cup
soap
clothes pin
cake
battery
candle
salt
chalk
slide
guitar
note pad
rubber band
matches
tooth brush
gum wrapper
banana
teapot
pine tree
basket
key
safety pin
penny
rubber ball
chain
lamp
orange
tractor
whistle
watch
bathtub
vase
trophy
car
sauce pan
phone
spoon

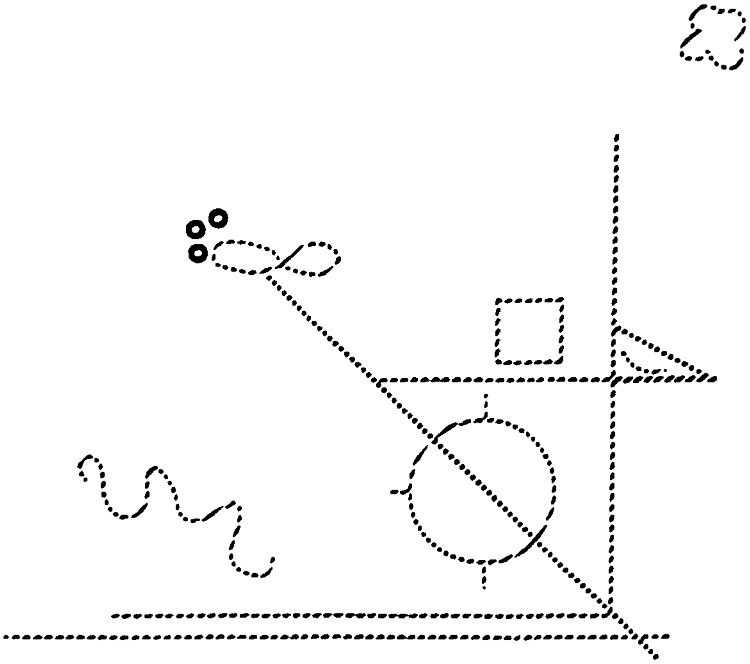
Appendix A - 2

Task Materials

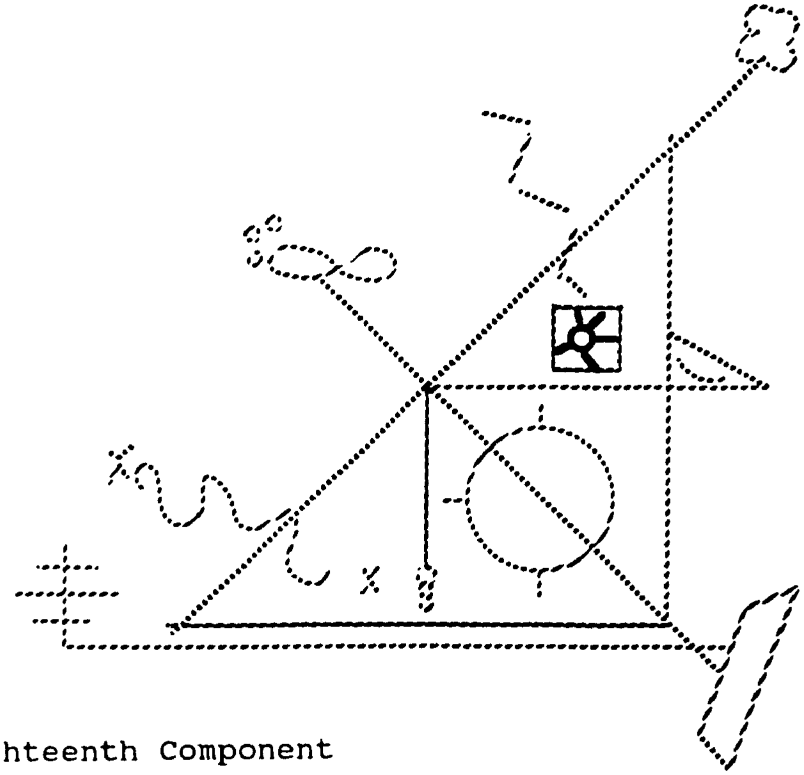
Two Stages of Drawing the Emergent Complex Figure

(as shown in Figure 4)

Experiment 1



Eleventh Component



Eighteenth Component

Appendix A - 3

Task Materials

Anagram Words and Frequencies

Experiment 1

Table 1

Anagram Words and Frequencies

	WORDS	FREQUENCIES
1.	IGKN = KING	88
2.	IKML = MILK	49
3.	AKBN = BANK	83
4.	ODGL = GOLD	52
5.	HPSI = SHIP	83
6.	EKDS = DESK	65
1.	CEAN = ACNE OR CANE	;19
2.	OESR = SORE OR ROSE	10;86
3.	EOVT = VETO OR VOTE	10;75
4.	OESL = SOLE OR LOSE	18;58
5.	OKCR = CORK OR ROCK	09;75

Appendix B

Correlation Matrices of Design, Explanatory and Psychosocial Background Variables Collapsed over Age and Gender

Experiment 1

Table 1

Intercorrelations of Design, Explanatory and Psychosocial Variables Collapsed over Age and Gender (Experiment 1)

	^{1}Loc	^{2}Age	^{3}Copy	^{4}Rec	^{5}Per	^{6}D	^{7}V^{M}	^{8}A	^{9}BD	^{10}ED	^{11}HC	^{12}VA	^{13}M
^{1}Location													
^{2}Age	-.46*												
^{3}Copy (ECF)	.35	-.42*											
^{4}Recall (ECF)	.78*	-.70*	.53*										
^{5}Percent (ECF)	.77*	-.67*	.40*	.98*									
^{6}Digit Symbol	-.35	.44*	-.58*	-.58*	-.56*								
^{7}Verbal Memory	.40*	-.41*	.23	.43*	.42*	-.35							
^{8}Analogy	-.32	.27	-.38	-.37	-.33	.13	-.22						
^{9}Block Design	.49*	-.62*	.43*	.63*	.60*	-.53*	.36	-.21					
^{10}Education	.02	.09	.05	.02	.02	.04	-.13	-.09	-.01				
^{11}Health	-.19	.65*	-.12	-.31	-.31	.36	-.23	.05	-.38	-.07			
^{12}Visual Acuity	-.03	.13	-.24	-.19	-.18	.25	.11	-.07	-.28	-.02	.16		
^{13}Munsh	.08	.25	-.22	-.09	-.06	.11	-.12	.01	.10	.15	.03	-.18	

Appendix C

Means and Standard Deviations for Age, Gender and Condition Groups for Explanatory and Psychosocial Background Variables

Experiment 1

Table 1

Percent Recall Measure of Emergent Complex Figure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	52.5 (13.9)	27.0 (16.0)	39.8
	Colored	65.8 (10.0)	36.0 (6.2)	50.9
	Mean	59.2	31.5	43.4
Male	Plain	59.7 (9.5)	34.2 (10.4)	47.0
	Colored	43.2 (15.8)	31 (18.8)	37.1
	Mean	51.5	32.6	42.1
	Mean	55.4	32.1	

Source	DF	MS	F
Age	1	6727.0	39.0**
Gender	1	138.8	.80
Condition	1	5.5	.03
Age x Gender	1	242.8	1.4
Age x Condition	1	63.0	.37
Condition x Gender	1	1372.0	7.9**
Age x Gender x Condition	1	242.8	1.4
Error	42	172.3	

** $p < .01$

Table 1 (Continued)

Digit Symbol Substitution Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	129.2 (24.0)	181.9 (45.2)	155.6
	Colored	141.0 (30.5)	137.1 (10.7)	139.1
	Mean	135.1	159.5	147.3
Male	Plain	127.7 (19.9)	171.5 (34.1)	149.6
	Colored	152.5 (26.2)	228.5 (72.4)	190.5
	Mean	140.1	200	170.1
	Mean	137.6	179.8	

Source	DF	MS	F
Age	1	22126.7	16.1**
Gender	1	6440.7	4.7
Condition	1	1863.8	1.4
Age x Gender	1	3920.7	2.8
Age x Condition	1	462.3	.34
Condition x Gender	1	10235.1	7.4**
Age x Gender x Condition	1	6121.3	4.4
Error	42	1379.0	

** $p < .01$

Table 1 (Continued)

Verbal Memory Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	5.9 (.92)	5.5 (.87)	5.7
	Colored	5.8 (.89)	5.1 (.45)	5.5
	Mean	5.9	5.3	5.6
Male	Plain	5.7 (.83)	5.0 (.62)	5.4
	Colored	6.3 (.50)	4.8 (.99)	5.6
	Mean	6.0	4.9	5.5
	Mean	6.1	5.1	

Source	DF	MS	F
Age	1	7.1	11.7**
Gender	1	.17	.28
Condition	1	.03	.04
Age x Gender	1	1.0	1.6
Age x Condition	1	.81	1.3
Condition x Gender	1	.56	.92
Age x Gender x Condition	1	.18	.30
Error	42	.61	

** $p < .01$

Table 1 (Continued)

Analogy Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	4.2 (.75)	4.1 (.90)	4.2
	Colored	2.8 (.75)	4.1 (.90)	3.5
	Mean	3.5	4.1	3.9
Male	Plain	3.8 (.99)	3.6 (.99)	3.7
	Colored	3.7 (.82)	4.3 (.52)	4.0
	Mean	3.8	4.0	3.9
	Mean	3.6	4.0	

Source	DF	MS	F
Age	1	2.4	3.2
Gender	1	.04	.05
Condition	1	.54	.70
Age x Gender	1	.48	.62
Age x Condition	1	3.65	4.8
Condition x Gender	1	2.6	3.4
Age x Gender x Condition	1	.19	.25
Error	42	.76	

** *p* < .01

Table 1 (Continued)

Block Design Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	36.5 (14.2)	27.0 (6.3)	31.8
	Colored	38.8 (4.7)	29.6 (8.2)	34.2
	Mean	37.7	28.3	33
Male	Plain	44.7 (5.9)	27.2 (8.7)	36.0
	Colored	35.5 (8.8)	24.7 (3.2)	30.1
	Mean	40.1	26.0	33.1
	Mean	38.9	27.2	

Source	DF	MS	F
Age	1	1725.1	26.4**
Gender	1	.01	.00
Condition	1	35.6	.54
Age x Gender	1	71.3	1.1
Age x Condition	1	37.1	.57
Condition x Gender	1	213.6	3.3
Age x Gender x Condition	1	32.1	.49
Error	42	65.5	

** $p < .01$

Table 1 (Continued)

Education Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	14.6 (1.5)	14.7 (1.9)	14.7
	Colored	14.2 (1.6)	13.7 (1.8)	14
	Mean	14.4	14.2	14.4
Male	Plain	14.3 (.82)	15.2 (1.7)	14.8
	Colored	13.8 (1.5)	14.5 (1.2)	14.2
	Mean	14.1	14.9	14.5
	Mean	14.3	14.6	

Source	DF	MS	F
Age	1	.93	.39
Gender	1	.25	.11
Condition	1	5.5	2.3
Age x Gender	1	2.8	1.2
Age x Condition	1	.35	.14
Condition x Gender	1	.09	.04
Age x Gender x Condition	1	.09	.04
Error	42	2.4	

** $p < .01$

Table 1 (Continued)

Health Condition Measure

Gender	Condition	Age Level Young	Old	Mean
Female	Plain	.33 (.82)	1.6 (.79)	.97
	Colored	.50 (.84)	1.3 (.76)	.90
	Mean	.42	1.5	.95
Male	Plain	.33 (.52)	1.5 (1.1)	.92
	Colored	.17 (.41)	2.3 (1.2)	1.2
	Mean	.25	1.9	1.1
	Mean	.34	1.7	

Source	DF	MS	F
Age	1	22.3	32.4**
Gender	1	.32	.47
Condition	1	.23	.33
Age x Gender	1	1.3	1.9
Age x Condition	1	.23	.34
Condition x Gender	1	.48	.70
Age x Gender x Condition	1	1.6	2.4
Error	42	.69	

** $p < .01$

Table 1 (Continued)

MUNSH Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	27.3 (5.0)	28.7 (2.5)	28
	Colored	26.0 (3.6)	27.3 (4.4)	26.7
	Mean	26.7	28	27.4
Male	Plain	27.7 (4.4)	29.3 (1.8)	28.5
	Colored	22.0 (5.7)	27.7 (5.7)	24.9
	Mean	24.9	28.5	26.7
	Mean	25.8	28.3	

<u>Source</u>	<u>DF</u>	<u>MS</u>	<u>F</u>
Age	1	77.8	4.2
Gender	1	5.5	.30
Condition	1	79.3	4.3
Age x Gender	1	16.9	.92
Age x Condition	1	11.9	.64
Condition x Gender	1	16.3	.88
Age x Gender x Condition	1	13.0	.71
Error	42	18.5	

** $p < .01$

Table 1 (Continued)

Visual Acuity Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	21.7 (2.6)	24.6 (16.1)	23.2
	Colored	26.7 (11.7)	23.1 (4.6)	24.9
	Mean	24.2	23.9	24.1
Male	Plain	15.2 (11.8)	22.8 (4.9)	19
	Colored	29.0 (11.8)	32.5 (12.6)	30.8
	Mean	22.1	27.7	24.9
	Mean	23.2	25.8	

Source	DF	MS	F
Age	1	86.5	.77
Gender	1	9.3	.08
Condition	1	570.0	5.1
Age x Gender	1	108.0	.96
Age x Condition	1	87.3	.78
Condition x Gender	1	308.9	2.8
Age x Gender x Condition	1	4.0	.04
Error	42	112.0	

** $p < .01$

Appendix D

Source Tables for Univariate and Covariate Analysis for Recall Location Measure in Relation to Age, Gender and Condition

Experiment 1

Table 1

Source Table for Analysis of Variance for Recall Location Measure in Relation to Age, Gender and Condition

Experiment 1

Source	DF	MS	F
Age	1	658.9	11.8*
Gender	1	.3	.01
Condition	1	32.0	.57
Age X Gender	1	179.5	3.2
Age x Condition	1	15.2	.27
Condition x Gender	1	272.5	4.9*
Age x Gender X Condition	1	35.1	.63
Error	42	55.9	

* $p < .05$

Table 2

Source Table for Covariate Analysis of Variance of Recall of Recall Location Measure in Relation to Age, Gender and Condition with the ECF as Covariate

Experiment 1

Source	DF	MS	F
Age	1	19.6	.62
Gender	1	14.3	.46
Condition	1	49.2	1.6
Age x Gender	1	52.6	1.7
Age x Condition	1	.26	.01
Condition x Gender	1	4.9	.15
Age x Gender x Condition	1	.01	.00
Error	41	30.9	

* $p < .05$

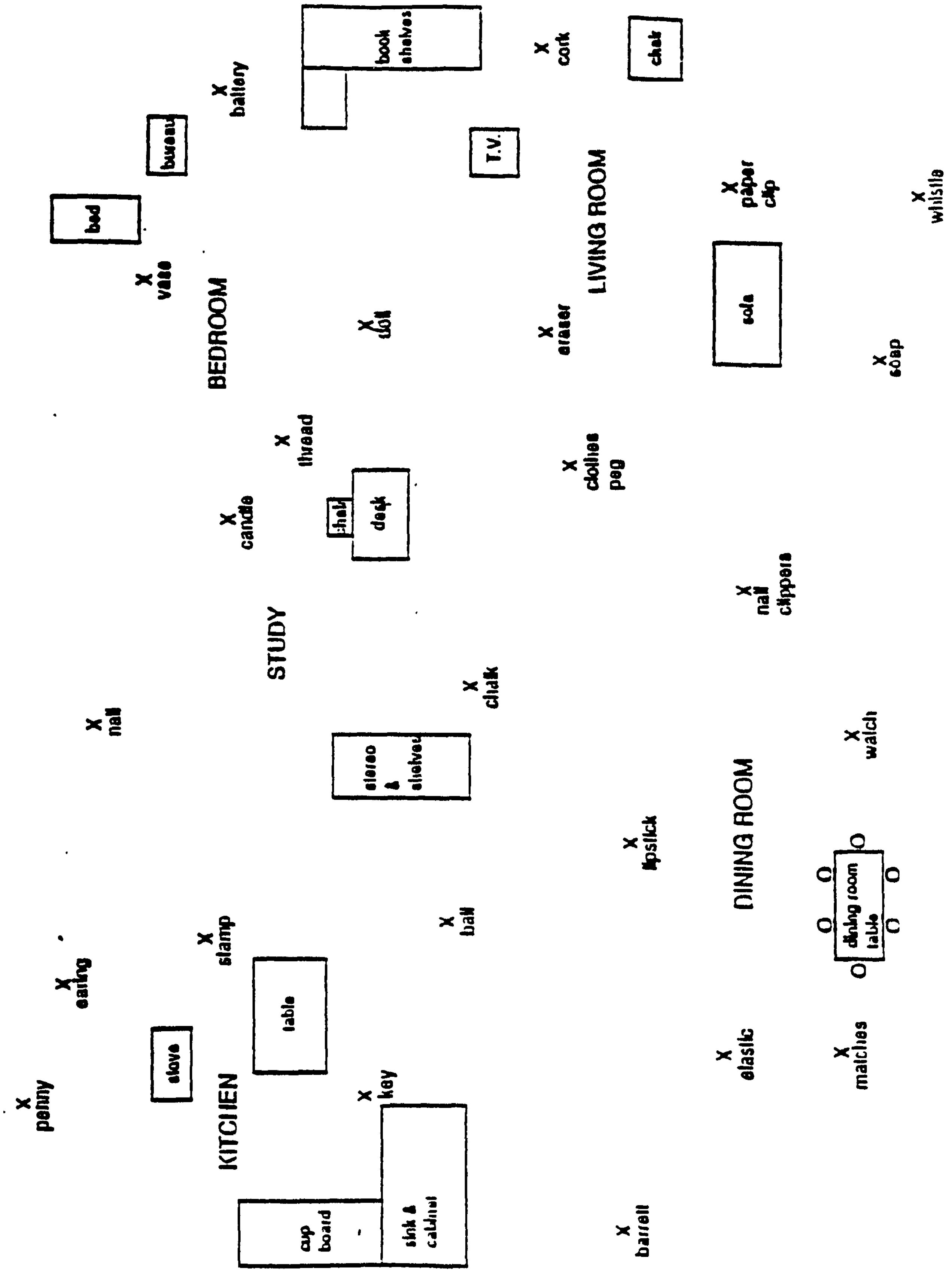
Appendix E

Task Materials

Stimulus Materials for Location Recall Task

(as Shown in Figure 5)

Experiment 2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bed
bureau
battery
vase
book shelves
T.V.
X cork
chair
LIVING ROOM
X paper clip
X whistle
sofa
X eraser
X doll
X soap
X thread
X candle
chair
desk
X clothes peg
STUDY
X nail clippers
X chalk
X nail
stereo & shelves
X watch
DINING ROOM
X lipstick
dining room table
X ball
X stamp
X earring
table
stove
X penny
KITCHEN
X key
cup board
sink & cabinet
X barrell
X elastic
X matches

Appendix F

Correlation Matrices of Design, Explanatory Psychosocial and Dependent Variables Collapsed over Age and Gender Experiment 2

Table 1

Intercorrelations of Design, Explanatory and Psychosocial Variables Collapsed over Age and Gender (Experiment 2)

	^{1}Loc	^{2}Age	^{3}Copy	^{4}Rec	^{5}Per	^{6}D	^{7}VM	^{8}A	^{9}BD	^{16}ED	^{11}HC	^{12}VA	^{13}M
^{1}Location													
^{2}Age	-.32												
^{3}Copy (ECF)	.39	-.53*											
^{4}Recall (ECF)	.65*	-.65*	.50*										
^{5}Percent (ECF)	.62*	-.60*	.36	.98*									
^{6}Digit Symbol	-.37	.78*	-.62*	-.64*	-.58*								
^{7}Verbal Memory	.30	-.40*	.46*	.40*	.35*	-.60*							
^{8}Analogy	.16	.02	.09	.05	.04	-.02	-.12						
^{9}Block Design	.44	-.57*	.59*	.66*	.60*	-.67*	.44*	-.14					
^{10}Education	.19	-.12	.24	.14	.11	-.27	.25	.02	.27				
^{11}Health	.03	.49*	-.40	-.27	.22	.49*	-.29	-.09	-.23	.01			
^{12}Visual Acuity	-.22	.47*	-.24	-.41*	-.40*	.35	-.01	.10	-.42*	.10	.12		
^{13}Munsh	.00	.04	.05	.24	.25	-.15	-.05	.20	.05	.08	-.14	.07	

Table 2

Intercorrelations of Dependent Measures Collapsed over Age and

(Experiment 2)

	Exact Strict Location	Lenient Location	VM	HM	DisMatric
Strict Location Score					
Lenient Location Score	.73*				
Dislocation on Vertical Matrix	-.76*	-.94*			
Dislocation on Horizontal Matrix	-.63*	-.88*	.74*		
Dislocation on Matrix	-.74*	-.87*	.91*	.95*	

*p < .002

Appendix G

Means and Standard Deviation for Age, Gender and Condition Groups for Explanatory and Psychosocial Background Variables

Experiment 2

Table 1

Percent Recall Measure of Emergent Complex Figure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	48.7 (16.1)	32.0 (10.5)	40.4
	Colored	61.9 (16.8)	39.5 (11.8)	50.9
	Mean	55.3	35.8	45.7
Male	Plain	53.2 (12.5)	32.1 (10.6)	42.7
	Colored	57.5 (17.7)	33.3 (12.6)	45.4
	Mean	55.4	32.7	44.1
	Mean	55.4	34.3	

Source	DF	MS	F
Age	1	8618.8	44.6**
Gender	1	33.5	.17
Condition	1	796.1	4.1
Age x Gender	1	36.1	.19
Age x Condition	1	113.4	.59
Condition x Gender	1	315.2	1.6
Age x Gender x Condition	1	4.0	.02
Error	71	193.2	

** $p < .01$

Table 1 (Continued)

Digit Symbol Substitution Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	125.5 (9.2)	207.5 (45.3)	166.5
	Colored	115.5 (16.2)	176.5 (24.4)	146
	Mean	120.5	192	156.3
Male	Plain	124.6 (14.1)	190.3 (24.7)	157.5
	Colored	126.6 (20.7)	185.8 (36.4)	156.2
	Mean	125.6	188.1	156.9
	Mean	123.1	190.1	

<u>Source</u>	<u>DF</u>	<u>MS</u>	<u>F</u>
Age	1	89536.0	115.3**
Gender	1	18.6	.02
Condition	1	2506.5	3.2
Age x Gender	1	336.1	.43
Age x Condition	1	1043.2	1.3
Condition x Gender	1	1679.7	2.1
Age x Gender x Condition	1	205.5	.26
Error	71	776.7	

** $p < .01$

Table 1 (Continued)

Verbal Memory Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	5.9 (.65)	5.2 (.94)	5.6
	Colored	6.1 (.53)	5.4 (.75)	5.8
	Mean	6.0	5.3	5.7
Male	Plain	6.0 (.58)	5.3 (.92)	5.7
	Colored	5.7 (.66)	5.4 (.84)	5.6
	Mean	5.9	5.4	5.7
	Mean	6.0	5.4	

Source	DF	MS	F
Age	1	9.1	16.5**
Gender	1	.21	.38
Condition	1	.12	.22
Age x Gender	1	.19	.34
Age x Condition	1	.32	.58
Condition x Gender	1	.29	.53
Age x Gender x Condition	1	.62	1.1
Error	71	.55	

** $p < .01$

Table 1 (Continued)

Analogy Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	3.7 (1.3)	3.6 (.84)	3.7
	Colored	3.9 (1.1)	4.2 (.42)	4.1
	Mean	3.8	3.9	3.9
Male	Plain	3.4 (.97)	3.7 (.71)	3.6
	Colored	3.5 (.71)	3.4 (.97)	3.5
	Mean	3.5	3.6	3.6
	Mean	3.6	3.8	

Source	DF	MS	F
Age	1	.17	.20
Gender	1	2.5	3.1
Condition	1	.50	.60
Age x Gender	1	.001	.002
Age x Condition	1	.001	.002
Condition x Gender	1	1.2	1.4
Age x Gender x Condition	1	.73	.88
Error	71	.82	

** $p < .01$

Table 1 (Continued)

Block Design Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	34.5 (12.2)	18.4 (5.1)	26.5
	Colored	38.1 (8.8)	25.8 (6.5)	32.0
	Mean	36.3	22.1	29.3
Male	Plain	41.3 (5.8)	28.1 (12.2)	34.7
	Colored	40.4 (10.3)	30.5 (7.7)	35.5
	Mean	40.9	29.3	35.1
	Mean	38.6	25.7	

Source	DF	MS	F
Age	1	3198.3	39.5**
Gender	1	714.1	8.8**
Condition	1	175.6	2.2
Age x Gender	1	42.4	.52
Age x Condition	1	52.6	.64
Condition x Gender	1	124.9	1.5
Age x Gender x Condition	1	1.4	.02
Error	71	81.0	

** $p < .01$

Table 1 (Continued)

Education Measure

Gender	Condition	Age Level Young	 Old	Mean
Female	Plain	15.3 (.95)	13.2 (2.1)	14.3
	Colored	15.1 (.74)	14.7 (3.0)	14.9
	Mean	15.2	14.0	14.6
Male	Plain	14.6 (.70)	14.0 (2.1)	14.3
	Colored	14.8 (1.1)	15.8 (2.7)	15.3
	Mean	14.7	14.9	14.8
	Mean	15.0	14.5	

Source	DF	MS	F
Age	1	6.6	1.8
Gender	1	.57	.16
Condition	1	15.3	4.3
Age x Gender	1	8.8	2.4
Age x Condition	1	15.3	4.3**
Condition x Gender	1	1.0	.30
Age x Gender x Condition	1	.02	.01
Error	71	3.5	

** $p < .01$

Table 1 (Continued)

Health Condition Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	.10 (.32)	1.2 (1.4)	.65
	Colored	.30 (.48)	1.4 (1.3)	.85
	Mean	.20	1.3	.75
Male	Plain	.20 (.42)	1.5 (1.2)	.85
	Colored	.30 (.48)	1.3 (1.8)	.80
	Mean	.25	1.4	.83
	Mean	.23	1.4	

Source	DF	MS	F
Age	1	25.6	23.2**
Gender	1	.16	.14
Condition	1	.07	.06
Age x Gender	1	.03	.03
Age x Condition	1	.16	.14
Condition x Gender	1	.38	.34
Age x Gender x Condition	1	.16	.14
Error	71	1.1	

** $p < .01$

Table 1 (Continued)

MUNSH Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	27.8 (2.9)	25.4 (3.4)	26.6
	Colored	28.2 (5.1)	27.9 (4.2)	28.1
	Mean	28.0	26.7	27.4
Male	Plain	28.4 (2.8)	27.7 (3.7)	28.1
	Colored	25.9 (5.2)	30.0 (2.2)	28.0
	Mean	27.2	28.9	28.1
	Mean	27.6	27.8	

Source	DF	MS	F
Age	1	.38	.02
Gender	1	8.1	.55
Condition	1	10.0	.68
Age x Gender	1	43.7	3.0
Age x Condition	1	61.2	4.1**
Condition x Gender	1	10.8	.73
Age x Gender x Condition	1	10.0	.68
Error	71	14.8	

** $p < .01$

Table 1 (Continued)

Visual Acuity Measure

Gender	Condition	Age Level		Mean
		Young	Old	
Female	Plain	24.7 (9.7)	31.5 (5.5)	28.1
	Colored	21.0 (2.1)	36.2 (16.0)	28.6
	Mean	22.9	33.9	28.4
Male	Plain	23.5 (6.3)	22.2 (12.0)	22.9
	Colored	20.5 (1.6)	32.4 (10.0)	26.5
	Mean	22.0	27.3	24.7
	Mean	22.5	30.6	

Source	DF	MS	F
Age	1	1603.7	22.9**
Gender	1	158.4	2.3
Condition	1	27.6	.39
Age x Gender	1	77.6	1.1
Age x Condition	1	405.4	5.8**
Condition x Gender	1	9.2	.13
Age x Gender x Condition	1	2.2	.03
Error	71	69.9	

** $p < .01$

Appendix H

Source Tables for Univariate and Covariate Analyses for Recall Location Measure in Relation to Age, Gender and Condition

Experiment 2

Table 1

Source Table for Univariate Analysis of Variance
for Recall Location Measure in Relation to
Age, Gender and Condition
Experiment 2

Source	DF	MS	F
Age	1	198.5	12.6**
Gender	1	26.5	1.7
Condition	1	387.2	24.7**
Age x Gender	1	28.8	1.8
Age x Condition	1	6.1	.39
Condition x Gender	1	22.1	1.4
Age x Gender x Condition	1	7.2	.46
Error	72	15.7	

** $p < .01$

Table 2

Source Table for Covariate Analysis of Variance
for Recall Location Measure in Relation to
Age, Gender and Condition
With the ECF as Covariate
Experiment 2

Source	*DF*	*MS*	*F*
Age	1	.04	.00
Gender	1	17.3	1.5
Condition	1	223.0	19.0**
Age x Gender	1	18.9	1.6
Age x Condition	1	1.0	.09
Condition x Gender	1	4.8	.41
Age x Gender x Condition	1	5.09	.43
Error	71	11.8	

* $p < .05$

Appendix I

Source Table for Univariate Analysis for Room Recall Measure in Relation to Age and Condition

Experiment 3

Table 1

Source Table for Univariate Analysis of Variance for Room Recall Measure in Relation to Age and Condition

Experiment 3

Source	DF	MS	F
Between			
Age	1	30.79	3.9*
Error	42	7.9	
Within			
Condition	1	144.7	17.4***
Age x Condition	1	31.2	3.8*
Error	42	8.3	

*** $p < .01$

** $p < .05$

* $p < .10$

Appendix J

Task Materials

Stimulus Materials for Location Recall Task

(as Shown in Figures 6, 7, 8 and 9)

Experiment 3

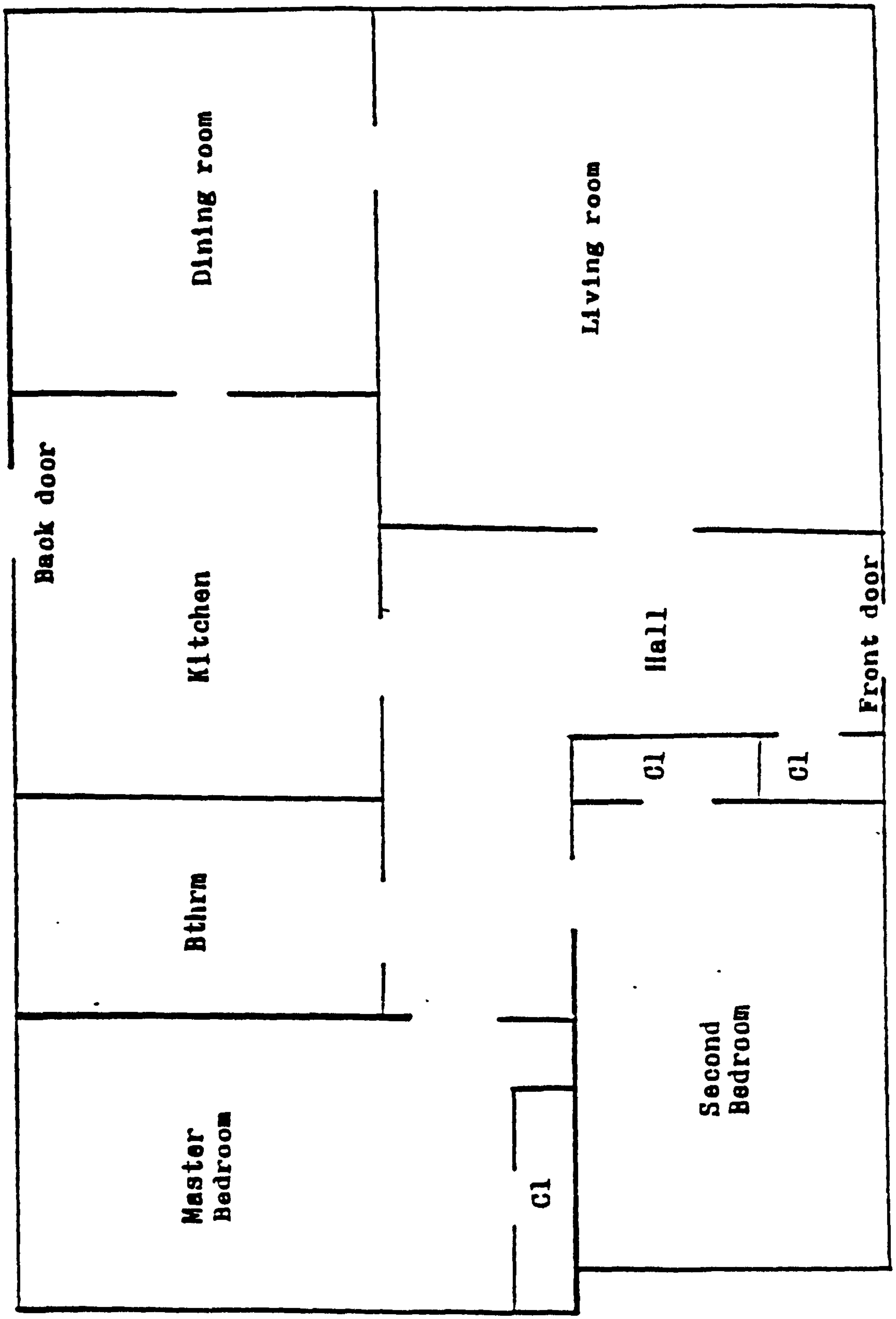

Figure 6. Typical House Plan: Version A.

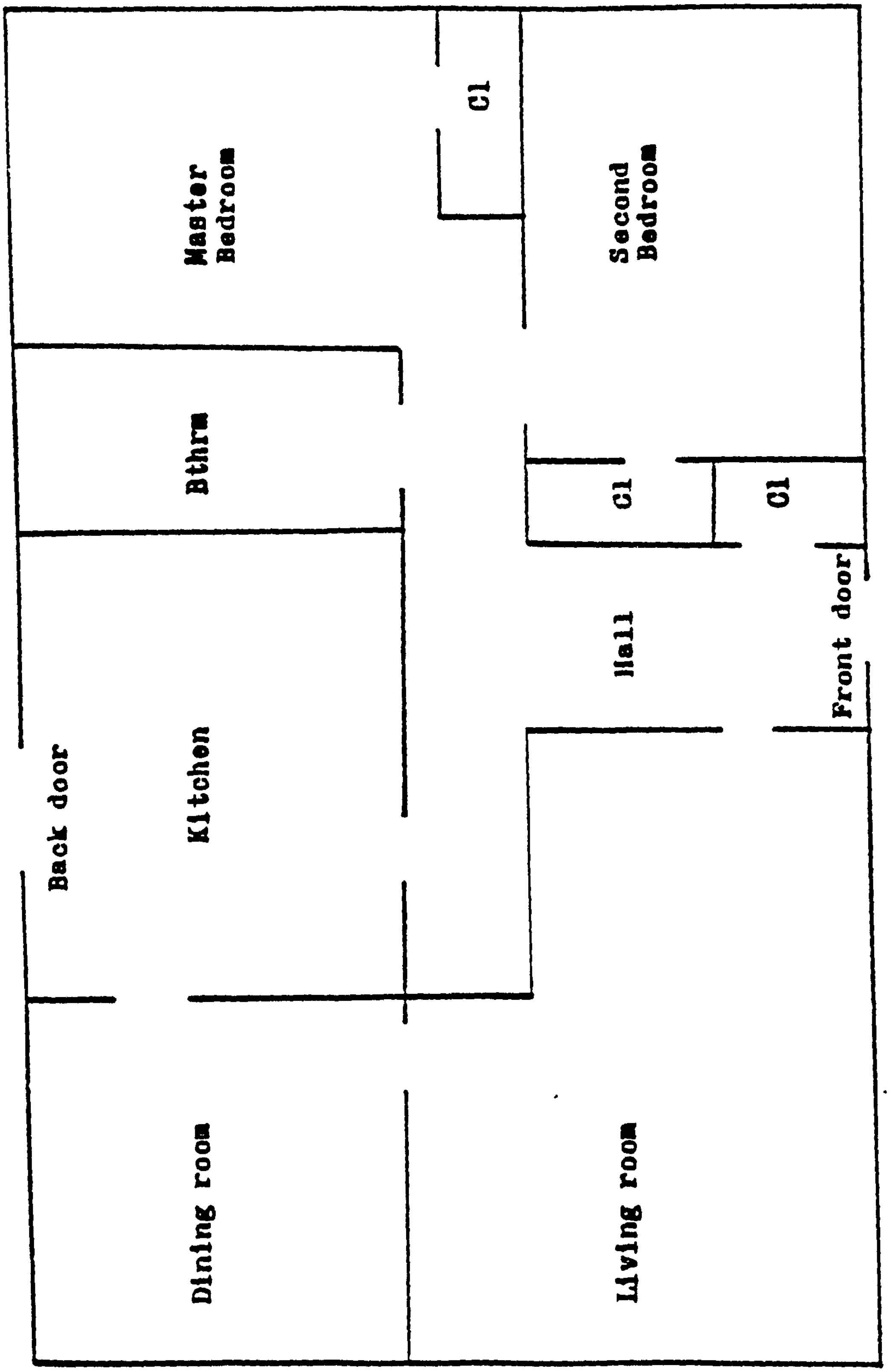

Figure 7. Typical House Plan: Version B.

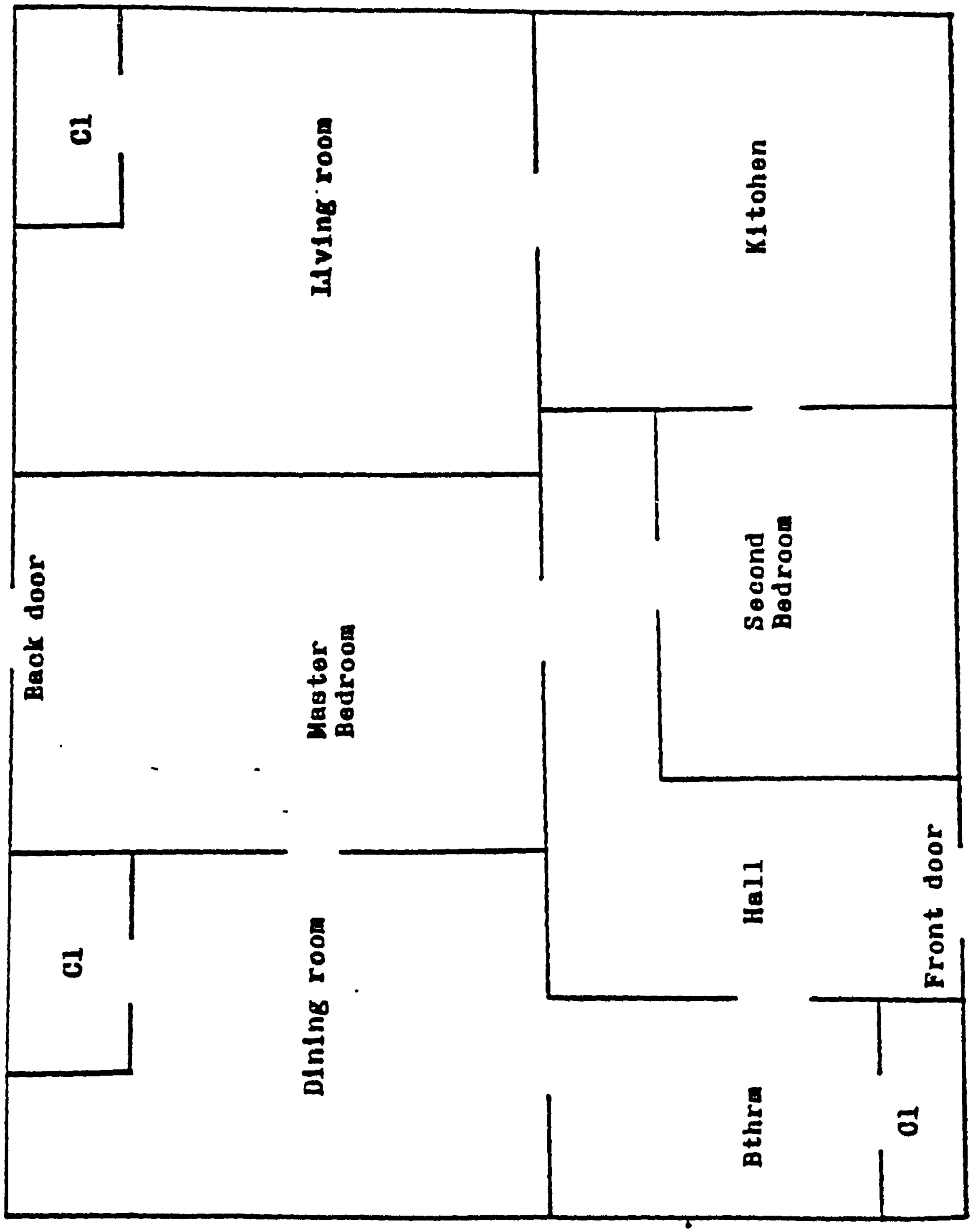

Figure 8. Atypical House Plan: Version A.

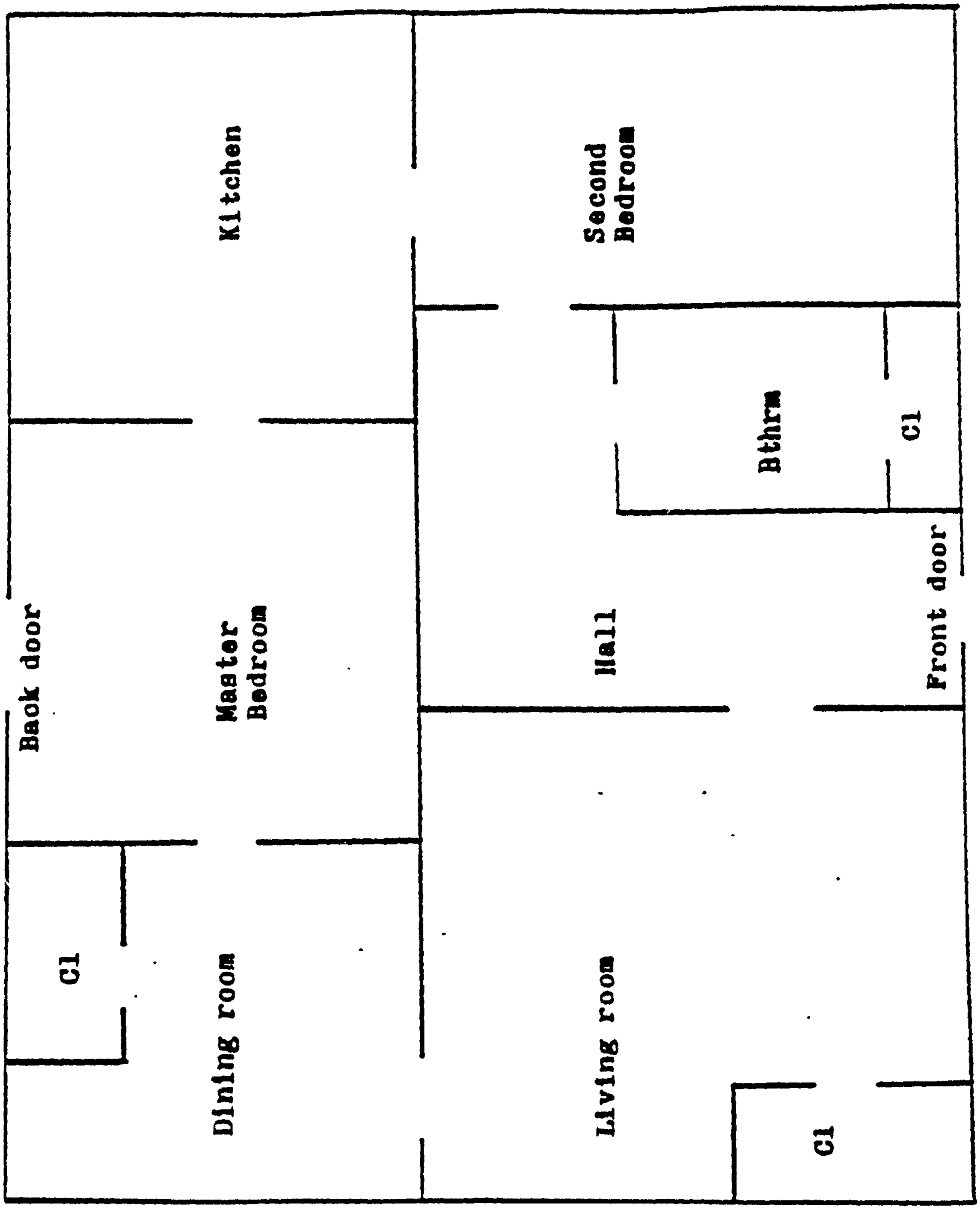

Figure 9. Atypical House Plan: Version B.