ARE ALL SOURCES EQUAL? THE ROLES OF AGING AND THE FRONTAL LOBES ON MULTIPLE TYPES OF SOURCE MEMORY USING A REPEATED-MEASURES DESIGN

by

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A Dissertation Submitted to the Faculty of the

DEPARTMENT OF PSYCHOLOGY

In Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

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entitled Are All Sources Equal? The Roles of Aging and the Frontal Lobes on Multiple Types of Source Memory Using a Repeated-Measures Design and recommend that it be accepted as fulfilling the dissertation requirement for the

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ACKNOWLEDGEMENTS

This dissertation and graduate career would not have been possible without the support of many wonderful people. I thank my entire family, especially my wife Kerrie for providing unwavering support. Without her love, encouragement, and companionship these last few years would not have been as enjoyable or complete. Cora and Autumn have been a constant source of joy and inspiration for which I am grateful. Input and suggestions from my peers, especially Patrick S. R. Davidson and Kelly S. Giovanello, as well as Maria Marquine, Courtney Dirksen, Emily Skow, Lauren Kong, and Craig McFarland has been invaluable. I am grateful to Maurice Hershenson for taking a chance and giving me a start in graduate school. Mieke Verfaellie and Margaret Keane sparked my interest in the cognitive neuropsychology of memory, which I appreciate. Two research assistants, Heather Montierth and Casey Catlin provided very useful assistance in testing participants, and in entering and checking experimental data. Barbara Bendlin, Jasmeet Pannu, and Jonathan Forster provided programming templates and help with DMDX. Financial support for this research came from the Department of Psychology at the University of Arizona, the Amnesia and Cognition Unit at the University of Arizona, the Event-Related Potential Lab at the University of Arizona, a grant from National Institute on Aging to Cyma Van Petten and Elizabeth L. Glisky, a grant from the Social and Behavioral Sciences Research Institute at the University of Arizona, and grants from the Graduate and Professional Student Council at the University of Arizona.

I would also like to thank my advisor, Elizabeth L. Glisky, for her patience, understanding, guidance, encouragement, and friendship. Her enthusiastic tutelage has made my journey through the doctoral program a successful and enjoyable one.

Thank you to the faculty in the Department of Psychology at the University of Arizona, including Cyma Van Petten, Lee Ryan, Steven Rapcsak, and Al Kaszniak. They have been exceptional teachers who were very supportive as I learned about psychology, cognitive neuroscience, and aging.

DEDICATION

This dissertation is dedicated to the memory of Constance J. Bedard. A wonderful woman whose limitless love and heartfelt compassion has had a profound influence on the man I have become.

TABLE OF CONTENTS

TABLE OF CONTENTS – *Continued*

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This paper reports a series of experiments designed to compare memory for multiple kinds of source information in young and older adults. The older adults in these studies were classified as having well or poorly functioning frontal lobes. In EXPERIMENTS 1-3, three different sources that provided independent cues to item information were examined using a repeated-measures design. In particular, participants' memory for voice source information, spatial source information, and temporal source information was tested in separate blocks. The results indicated that the performance of both young and older adults depended upon the type of source tested: Voice source memory was superior to spatial source and temporal source memory, which did not differ. There was also an age effect that was mediated by frontal functioning. Only the low frontal older adults showed impairments in source memory. High frontal older adults were equivalent to young. In EXPERIMENT 4, sources that provided redundant cues to item information were investigated. Voice sources and spatial sources were perfectly matched during encoding such that Voice A always came from Location 1 and Voice B always came from Location 2. When sources provided redundant information in this manner, young and high frontal older adults improved their spatial source memory by making use of redundant voice information, whereas the low frontal older adults not only performed more poorly than both young and high frontal older adults, but were unable to benefit from the redundancy. No differences in item memory were found. The findings were interpreted in terms of the executive and working memory functions involved in the integration of various contextual elements of an experience with its content.

CHAPTER 1

INTRODUCTION

When people talk conversationally about memory, they are often referring to what memory researchers call episodic memory, or memories that are linked with a specific spatiotemporal context (e.g., Tulving, 1983). Examples of episodic memories include memory for last night's dinner or memory for one's college graduation, events that occurred in a specific place and time. When recalling an episode from the past, one may remember not only the content of the event but also information about its context, where and when it occurred. It is possible, however, that memories for content and context are separable, such that one might retain memory for the content without its context, and vice versa. A related distinction has been made between item (or fact) memory and source memory with item memory referring to a word, object or fact to be remembered and source memory referring to where, when or from whom information was acquired. In this case too, one might retain memory for the fact without being able to remember how that fact was acquired. Traditionally, studies of episodic memory have focused on memory for the content or item. Fewer studies have examined memory for the contextual details or source.

Source Memory and the Frontal Lobes

Some of the earliest experiments on source memory were conducted with neuropsychological populations. For example in a series of experiments with patients suffering from frontal lobe damage, Janowsky, Shimamura, and Squire (1989) examined memory for recently learned facts and memory for where and when those facts had been learned. The results of these experiments indicated that although patients with frontal lobe damage could remember the facts as well as normal control participants, they had difficulty remembering where and when they had learned those facts. Schacter, Harbluk, and McLachlan (1984) investigated source memory in individuals suffering from amnesia. In this study, the experimenters presented the patients with fictional facts. When later queried, some patients could recall the facts but could not remember whether they had learned the "facts" during the experiment or outside of the experiment. Interestingly, the amnesic patients who had difficulty remembering the source were those who, in addition to their amnesia, also showed deficits on tasks dependent on the frontal lobes.

A number of studies have also found disproportionate deficits in context or source memory compared to content or item memory in older adults. For example, Janowsky et al. (1989) found that older adults, like frontal patients, although unimpaired in memory for recently learned facts, had trouble remembering where or when the facts were acquired. This age deficit in memory for contextual detail coupled with the lack of or a minimal age effect in item or content memory has been reported in a number of studies (e.g., Ferguson, Hashtroudi, & Johnson, 1992, experiments 1 & 2; Kausler & Puckett, 1981; McIntyre & Craik, 1987; Park, Puglisi, & Lutz, 1982).

A number of investigations with normally aging older adults have supported a role for the frontal lobes in source memory. In these experiments, as in previous studies with older adults, memory for contextual information has been found to be disproportionately impaired compared to memory for content, and this effect is exaggerated in older adults with reduced frontal lobe function (e.g., Craik, Morris, Morris, Loewen, 1990; Glisky, Polster, & Routhieaux, 1995; Glisky, Rubin, & Davidson, 2001). For example, Glisky and colleagues (1995) classified older adults based on a battery of neuropsychological tests thought to index frontal lobe and medial temporal lobe function. A "high" classification on the frontal factor predicted enhanced performance on a source memory task, but had no relation to performance on an item memory task, whereas a "high" classification on the medial temporal factor score was associated with enhanced performance on the item memory task, but had no relation to performance on the source memory task.

Additionally, neuroimaging results have provided evidence that the frontal lobes are involved in memory for contextual information in normal young adults (e.g., Hayes, Ryan, Schnyer, & Nadel, 2004; Nyberg, McIntosh, Cabeza, Habib, Houle, & Tulving, 1996; Senkfor & Van Petten, 1998; Van Petten, Senkfor, & Newberg, 2000; for a review, see Fletcher & Henson, 2001) and in older adults (e.g., Trott, Friedman, Ritter, & Fabiani, 1997; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999). Thus, findings from a variety of populations and methodologies converge on the conclusion that the frontal lobes play a role in source memory. The specific role of the frontal lobes, however, is still open to debate.

Multiple Kinds of Source Information

Most studies of source memory have investigated a single aspect of context or source, although a range of sources have been investigated, including temporal context (e.g., Huppert & Piercy, 1976; 1978; Milner,1971, as cited in Johnson, 1993; Meudell, Mayes, Ostergaard, & Pickering, 1985; Squire, 1982; Squire, Nadel, & Slater, 1981), spatial location (e.g., Light & Zelinski, 1983; Park et al., 1982; Smith & Milner, 1981; 1984), person or identity (e.g., Dodd & Bradshaw, 1980), perceptual features of a stimulus (e.g., Kausler & Puckett, 1981, McIntyre & Craik, 1987), emotional aspects of an episode (e.g., Davidson, McFarland, & Glisky, in press; May, Rahhal, Berry, & Leighton, 2005), cognitive operations performed during encoding (e.g., Davachi, Mitchell, & Wagner, 2003; Johnson, De Leonardis, Hashtroudi, & Ferguson, 1995), and whether something was perceived or imagined (e.g., Johnson, Foley, & Leach, 1988; Johnson, Kounious, & Reeder, 1994). A few studies have investigated more than one kind of source memory but have not compared the sources directly (e.g., Glisky et al., 2001; Marsh, Hicks, & Cook, 2004; May et al., 2005; Rahhal, May, & Hasher, 2002).

A limited number of investigations have compared memory across different types of source using a within-subjects design (e.g., Hayes et al., 2004; Kogure, Hatta, Kawakami, Kawaguchi, & Makino, 2001; Kopelman, Stanhope, & Kingsley, 1997; Meiser & Bröder, 2002; Parkin, Walter, & Hunkin, 1995; Siedlecki, Salthouse, & Berish, 2005; Thaiss & Petrides, 2003). In one such investigation, Siedlecki et al. (2005) were interested in the effects of age on source memory. In this study, participants completed four different source memory tasks: One task tested participants' memory for the color of words from the study phase. One task tested memory for the spatial locations of pictures that had been rated during study. Another task examined participants' memory for whether an action was performed, watched, or imagined. The fourth task required participants to remember whether a statement was true or false. Of interest here are the patterns of performance on the different source memory tasks. Source memory performance levels ranged from .47 for the spatial source memory task to .85 for the "True/False" task. Performance on each task was negatively correlated with age, but to different degrees. In addition to these results, Siedlecki et al. reported that the median correlation among the four source memory tasks was .25 and that these four tasks, when modeled for convergent validity, were significantly related to an overall source memory construct. These results thus support the notion that source memory likely involves a general processing component as well as different processes for each kind of source.

Multiple kinds of source memory have also been tested in neuroimaging studies. For instance, Hayes et al. (2004) tested memory for spatial and temporal source information using functional Magnetic Resonance Imaging (fMRI). Using measures of two-alternative, forced choice recognition for spatial and temporal source memory, Hayes et al. found that temporal source memory was poorer than spatial source memory in terms of recognition and reaction time. In addition, performance for both forms of source memory was significantly worse than item memory. The imaging results identified regions of the brain that distinguished source memory (both spatial and temporal) from item memory – multiple frontal regions extending into motor regions and the left posterior parietal lobe – and other regions that distinguished between the two kinds of source memory, namely greater activation in the right parahippocampal gyrus, right posterior parietal lobe, and bilateral fusiform gyrus for spatial than temporal source memory. In another imaging study, Dobbins, Foley, Schacter, and Wagner (2002) compared memory for cognitive operations performed on studied words with a measure of temporal source information and found that participants performed significantly worse on the temporal source task. In addition to these behavioral results, Dobbins et al. found that a region in the left hippocampal axis exhibited greater activation for successful cognitive operation trials than for successful temporal source trials. Taken together, these patterns of activations suggest that although there are regions of the brain that are involved in many different kinds of source memory, there are other regions that are specific to the type of source information being tested.

Other neuroimaging studies of source memory have also provided evidence that source memory consists of multiple processes. In investigations using event-related potentials (ERPs) to study memory for items and their sources, Senkfor and Van Petten (1998) and Van Petten et al. (2000) reported a frontal positivity or what the authors termed a "prefrontal effect" (Van Petten et al., 2000, p. 560) that was associated with source memory. As this effect was found in two studies and with different materials and sources, the authors argued that it represented a general processing component that might apply to multiple source memory tasks. However, although this frontal positivity was observed in both source paradigms, its onset varied across studies, suggesting processing differences related to the specific source memory task. In the 2000 paper, in which memory for drawings and their spatial locations was examined, the onset of the frontal effect was considerably sooner than that reported in the 1998 paper where memory for words and the voices that spoke the words was examined. One possible explanation of this difference is that identification of drawings and their locations occurs more rapidly than the identification of words and the voices that spoke them. Thus, there could be differences in the time course of source memory processing that depend upon the type of materials that are being processed and/or the task being completed.

These results agree with others in the literature that have tested multiple kinds of source memory in between-participant designs. Indeed, many (e.g., Rahhal et al., 2002; May et al., 2005), but not all (e.g., Fan, Snodgrass, & Bilder, 2003), of these between-participant studies also found that performance varied as a function of the type of source information tested. Although these studies have been informative, experiments that use a repeated-measures design would provide more direct evidence as to whether source memory is a unitary cognitive construct.

In much of the literature, source memory has been treated as if it is unitary. However, although there may be processes in common in the encoding and retrieval of different kinds of source, it seems likely that there may also be processes that differ depending on the nature of the particular source. The present research project investigated the similarities and differences across three different kinds of source memory: perceptual, spatial and temporal.

Source Memory and Aging

Different kinds of source memory may be differentially affected by variables such as age. For example, in their 1996 study, Chalfonte and Johnson examined two types of source memory: one perceptual and one spatial. The perceptual conditions involved memory for the color of items that had been presented during study, while the spatial conditions involved memory for the locations within a grid where studied items had been presented. The results of these experiments showed that older adults, relative to younger adults, had disproportionate impairments in memory for location, but not color. Parkin et al. (1995) evaluated older and younger adults' memories for spatial and temporal source information. They found that older adults performed significantly worse than younger adults on temporal source memory but were as good as younger adults on a measure of spatial source memory. Even though both studies tested memory for spatial location, the tasks were different, possibly explaining the discrepant findings. In fact, Parkin et al. claimed that different sets of results such as these are directly related to the spatial tasks employed (p. 309 – 310).

To muddy the waters a bit more, some studies have shown age effects under some experimental conditions, but not others. For example, Glisky et al. (2001), when testing memory for perceptual and spatial source information, found memory deficits for both types of source information in a subgroup of older adults characterized by low frontal function, under an item-orienting encoding condition. These deficits could be eliminated, however, with encoding instructions that required people to integrate the item and source. Schacter, Kaszniak, Kihlstrom, and Valdiserri (1991), in a paradigm in which two people read facts at encoding that were either blocked by reader or in a random sequence, found that older adults exhibited impaired memory for personal identity only in the blocked, but not in the random condition. These results suggest that age-related decline in source memory performance might depend not only on the kind of source information but also on other task and subject variables.

The Current Project

The current project examined the relation between frontal lobe functioning in older adults and performance on various kinds of source memory tests. Although some studies (e.g., Fabiani & Friedman, 1997; Glisky et al., 1995, 2001; Parkin et al., 1995) have found a relation between the frontal lobes and source memory, others (e.g., Johnson et al., 1995) have found that source memory, like item memory depends on medial temporal lobe function. A possible reason for these discrepant findings may be that source and item memory tasks share processes or components to a greater or lesser extent, depending upon the situation, the methods or the materials (Johnson et al., 1993). Nonetheless, the bulk of the evidence points to the frontal lobes as playing some role in source memory performance. To try to reduce cross-experimental differences, the present studies equated methods, materials and test formats as closely as possible across all source and item memory tasks. Three kinds of source memory were tested in a repeated-measures design: voice, space and time. Participants were young adults and older adults characterized according to their performance on a group of neuropsychological tests designed to measure frontal function. This design thus allowed comparison between young and old adults, and also a comparison within the older adult group among “high” and “low” frontal performers.

The present project also addressed whether source memory is best represented as a unitary cognitive concept, or whether it may be comprised of different processes depending on the type of source. Based on the evidence sited above, it was hypothesized that source memory may require a general, frontally-based process for all source memory tasks but separate processes that are specific to the type of source being tested. If different kinds of source require different processes, then one might expect different performance levels across the three kinds of source memory tasks. In addition, if there is a general frontally-based process common to all source tests, then one would expect to see an effect of frontal lobe function across all source tasks.

Another issue tackled by this project involved the ability to use multiple kinds of source information. Although laboratory studies commonly test one aspect of source memory in isolation, source memory in the real world is multidimensional. It is possible, even likely, that any one aspect of source memory is not retrieved in a vacuum. In fact, explanations of good source memory performance include the idea that the episode is accessed and/or reconstructed at retrieval and that this retrieval processing may include information about various kinds of source. Little is known about whether people can make use of multiple kinds of source information to enhance their memory performance on item or source memory tasks. This project also addressed this issue. In particular, experiments explored the extent to which young and older adults could make use of overlapping or redundant information about source. For example, if Voice A always came from Location 1 and Voice B always came from Location 2, would people be equally able to identify voice and location?

Memory for Redundant Source Information

There are a limited number of studies that have investigated multiple sources with redundant information, and they are inconsistent with respect to the effects of aging. In one study, Ferguson et al. (1992, experiment 2), presented participants with words spoken by one of two confederates. Confederates were seated across from the participants and, in one condition, switched seats, while in the other condition they remained in the same seat (spatial location) throughout the study phase. During the test phase, participants were asked to identify which of two confederates had spoken each word. This allowed the experimenters to compare performance when there was only one type of source information available (personal identity) to performance when two types of source information (personal identity and spatial location) could be used to remember the speaker. The results indicated that only younger adults benefited from having two cues to source. However, in another experiment they found that both the young and older adults benefited from redundant source information. Specifically, they were able to improve their memory for personal identity when it was confounded with spatial location (see also Johnson et al., 1995, Experiment 1). However, in a study conducted by Bayen and Murnane (1996) using personal identity and temporal information as the sources, a benefit for older adults, but not young adults was reported. Schacter et al. (1991) also used personal identity and temporal source information as the two kinds of source, but found that neither young nor older adults benefited from the redundant information. These studies have thus provided a confusing picture with respect to age differences in the use of more than one kind of source information.

In all of the above-mentioned studies, participants were asked only about the identity of the voice or speaker. They were not asked to identify the other piece of source information (e.g., place or time). A study by Rahhal et al. (2002), however, asked questions about two aspects of source information. In this study, statements were read by two voices (Experiment 1) or by two voices matched with photographs (Experiment 2).

In Experiment 1, participants were told that the statements from one source were always true, while those from the other source were always false. In Experiment 2, they were told that one source and his/her statement were evil, while the other was good. Unlike previous studies in which participants were only asked about the personal identity of the source, Rahhal et al. asked two kinds of questions: a) Who spoke the statement? and b) Was the statement true or false (Exp. 1) or Was the speaker evil or good (Exp. 2). When asked about personal identity, age-related deficits in source memory were found. However, when asked about the affective or conceptual source information (i.e., truth or goodness), no effects of age were found. These findings (see also May et al., 2005) suggest that source memory performance may also depend upon which aspect of source is queried.

In summary, whether young or older adults can make use of multiple cues to source is unclear from existing literature. There are, however, only six studies that have examined multiple sources that provide redundant information in aging, and they have used a variety of materials, methodologies, and test formats. It is therefore not surprising that there are inconsistencies. Possibly, as the Rahhal et al. (2002) and May et al. (2005) results indicate, source memory performance may depend, at least partially on the source question asked. The present project addressed the issue of multiple redundant sources, asking questions not only about the personal identity of the source but also about the other kind of contextual information that might have provided a cue to the source.

Current Goals

The current project examined aging, frontal lobe function, and multiple kinds of source memory that provide unique or redundant information within a repeated-measures design. Unlike most of the previous studies with redundant source cues, which asked only a single question about source, in these multiple cue experiments, questions were asked about each type of source presented. This allowed examination of the ability of participants to use memory for one kind of source information to increase memory for another kind of source information that they may find more difficult.

This project focused on three types of source: voice, space, and time. Sentences were spoken in either a male or female voice, came from a speaker located on either the left or right side of the room, or occurred early or late in a list. All of the experiments addressed the question of whether source memory is a unitary cognitive phenomenon. EXPERIMENTS 1 and 2 were exploratory studies examining different source memory test formats in order to create tests that were as similar as possible across the three kinds of source memory information. Both young and older adults were tested and the effects of age and frontal lobe function were examined in EXPERIMENTS 3 and 4. EXPERIMENT 4 was designed to determine the extent to which younger and older participants could take advantage of multiple cues to source information and capitalize on redundant information to improve source memory performance.

CHAPTER 2

EXPERIMENT 1

The goal of this experiment was to compare performance on multiple kinds of source in a within-participants design. Based on previous research it was hypothesized that performance in temporal source memory would be poorer than in voice source memory and spatial source memory (e.g., Hayes et al., 2004; Schacter et al., 1991; Thaiss & Petrides, 2003). Reasons for poor memory of temporal information remain unanswered. It is unlikely (see Block, 1985; Friedman, 1993) that time is stored and retrieved through the use of time tags or codes that represent stored temporal information (Church, 1984; Hasher & Zacks, 1979). If that were the case then temporal information might behave in a manner similar to that of perceptual and spatial information, which one might argue is stored directly with the other components of the episode. An alternative possibility suggested by Friedman (1993) is that temporal information is inferred at the time of retrieval on the basis of other stored information. If this were the case, then temporal source memory might take longer to retrieve than voice source memory or spatial source memory.

Method

Participants

Twenty-four younger adults (age range = 18 – 27, $M = 20.3$, $SD = 3.9$) from the undergraduate population at the University of Arizona served as participants in this study. Each young adult received credit toward a course requirement for his/her participation.

Materials

One hundred and sixty sentences were recorded by three speakers, one female and two males. The voices were selected to be as distinct as possible with no accents. The sentences were constructed to be neutral with regard to emotional content (e.g., "The children played with the toys."). The sentences were rated by two independent raters for emotional content on a scale from 1 – 5. Any sentence that was rated as emotional was replaced with a sentence rated as neutral. The sentences were grouped into five lists of 20, with lists equated for number of syllables. Each list also had two filler sentences at the beginning to control for primacy effects and two filler sentences at the end to control for recency effects, resulting in five lists each containing 24 sentences. Four lists served as the study lists for the three source memory conditions and one item memory condition and one list served as the distractors for the item test. Lists were rotated through conditions such that each was used equally often for the source conditions, the item condition, and as distractors for the item test. Order of the three source memory conditions was also counterbalanced across participants such that each source memory block occurred equally often in each position. The item memory block was always last. All sentences were presented by a Dell desktop computer using DMDX software (Forster & Forster, 2003).

Each of the recognition tests was two-alternative forced choice. For the voice source memory test, each of the 20 studied sentences was re-presented once in each voice. For the spatial source memory test, each of the 20 studied sentences was re-presented once from each side of the room. For the temporal source memory test, each of the 20 studied sentences was presented once paired with a temporally adjacent sentence in the studied order and once in the reverse order. For the item memory test, each of the studied sentences was presented with a new sentence.

Procedure

During the study phase of the experiment, participants were presented sentences auditorily one at a time and asked to rate the likelihood that the sentence would be heard on the radio. No mention was made of the subsequent memory test. Prior to the presentation of the study list, there were two practice sentences during which the speaker volume could be adjusted.

For the voice source memory study phase, half of the sentences were presented in the female voice, half were presented in a male voice. Sentences were heard through speakers located in the center of the room. Assignment of voice to sentence was counterbalanced across participants. For the spatial source memory study phase, half of the sentences were presented from the left side of the room, half from the right. Assignment of location to sentence was counterbalanced across participants. These sentences were spoken by the male voice not used in the voice source memory condition. For the temporal source memory study phase, the sentences were presented from the center speaker by the same male voice as in the spatial source memory condition. For the item study phase, all sentences were presented from the center of the room by the male voice used in the spatial source memory and temporal source memory conditions.

Following each study phase was a two-alternative forced choice (2AFC) test phase. For the voice source memory test, each of the studied sentences was presented in both the female and male voice used during the study phase. Participants were asked to press the appropriate key (F or M) to indicate whether the sentence had been studied in the female or male voice. For the spatial source memory test each of the studied sentences was presented from the left and right side of the room. Participants were asked to press the appropriate key (Q for left or P for right) to indicate whether the sentence had been heard from the right or left side. For the temporal source memory test, participants were presented with pairs of sentences with each pair being comprised of sentences that had been heard sequentially during the study phase. Each pair was presented twice, once in the studied order and once in the reverse order. Participants were asked to press the appropriate key (1 or 2) to indicate whether the first or second test pairing was the same order as the study phase. The item memory test was also 2AFC, with each studied sentence being paired with a novel sentence. Participants were asked to press the appropriate key (1 or 2) to indicate whether the first or second sentence was heard during the study phase. For all test conditions, the presentation of stimuli was randomized with the correct response being one key for half of the test items, and the other key for the other half of test items.

Results

Item Memory

For the item test, proportion correct ranged from .77 to 1.00, with a mean = .96 and standard deviation = .05, indicating that the participants had little trouble recognizing the sentences under these conditions.

Table 1

Proportion Correct and Standard Deviations for the Three Source Memory Conditions in EXPERIMENT 1

Condition	Mean	Standard Deviation
VSM	.66	.15
SSM	.61	.13
TSM	.52	.11

Source Memory

Mean proportion correct on the voice source memory, spatial source memory, and temporal source memory tasks are presented in Table 1. Proportion correct was analyzed with a one-way repeated-measures analysis of variance (ANOVA), comparing voice source memory, spatial source memory, and temporal source memory. This analysis indicated a main effect of source memory type, F (2, 21) = 19.12, $p < .001$. Following this analysis, paired t-tests revealed that the only difference was an advantage for voice source memory compared to temporal source memory, t (23) = 4.90, $p < .001$.

Mean reaction times and standard deviations for the voice source memory, spatial source memory, and temporal source memory conditions are presented in Table 2. Reaction times were analyzed with a one-way repeated-measures analysis of variance (ANOVA), comparing voice source memory, spatial source memory, and temporal source memory. This analysis indicated a main effect of source memory type, F (2, 21) = 22.67, $p < .001$. Following this analysis, paired t-tests were conducted to further investigate this effect. These analyses revealed that the temporal source memory latencies were significantly longer than those for voice source memory, t (23) = -3.68, $p < .05$, or spatial source memory, t (23) = -3.64, $p < .05$, which did not differ, t (23) = -.61, $p > .05$.

Table 2

Reaction Time Means and Standard Deviations for the Three Source Memory Conditions in EXPERIMENT 1

Condition	Mean	Standard Deviation
VSM	980.74	425.88
SSM	1033.33	485.72
TSM	1581.64	701.32

Discussion

The results of this first experiment indicated that voice source memory and spatial source memory were statistically equivalent. In addition, performance in the temporal source memory condition was found to be poorer than in the voice source memory condition. There was no difference, however, between spatial source memory and temporal source memory in terms of proportion correct. However, spatial source memory was significantly different from chance, t (23) = 2.78, p <.05, whereas temporal source memory was not, t (23) = 1.02, p >.05. The lack of difference between these two conditions might be due to a floor effect in the temporal source memory condition.

Poor performance in the temporal source memory condition may be attributable to the different way in which time information is retrieved. As noted above, some temporal memory theorists posit that memory for time is accomplished by inferential processing (e.g., Block, 1985; Friedman, 1993). If no time tag is directly encoded during the study phase, one may have to infer when an event occurred by relying on other encoded information. The longer reaction times that were observed for the temporal source decisions are consistent with this view. However, it may also be that poorer performance in the temporal source memory condition was attributable to differences in the test formats for the three source memory conditions. For the voice source memory and spatial source memory tests, the participant was required to recognize the correct item-source pairing from the study phase. It was not possible to use this recognition format in the temporal source memory condition. The temporal source memory test required a judgment concerning the order of two studied items. Thus two studied sentences were presented at test, whereas for the voice and spatial source memory tests only one studied sentence was presented. Second, the voice and spatial source memory tasks represented distinct choices, male/female or left/right, whereas the temporal source memory task asked the participants to make order judgments of items that were presented sequentially during encoding. Thus the choices might have been more confusable. Research indicates that, in most instances, the greater the differences between alternatives in a source memory task, the better the performance (e.g., Gruppuso, Lindsay, & Kelley, 1997). So in EXPERIMENT 2, the temporal source memory judgments were made more distinct by presenting two studied items that had been separated by several intervening items during encoding.

CHAPTER 3

EXPERIMENT 2

EXPERIMENT 2 modified the temporal source memory test by increasing the lag between targets to 10 intervening items. It was expected that the longer lag would elevate performance in the temporal source memory condition. Previous research (e.g., Hacker, 1980) has indicated that increasing lags between studied items increases memory performance associated with those items. EXPERIMENT 2 tested both young and older adults. The other aspects of EXPERIMENT 2 were identical to EXPERIMENT 1.

The predictions of EXPERIMENT 2 were similar to those in EXPERIMENT 1, although it was expected that the more distinct choices in the temporal source memory test might lead to better performance on that task. In addition, it was expected that older adults would show poorer source memory performance than young adults on all tasks.

Method

Participants

Twenty younger adults (age range = 18 – 29, *M* = 19.5, *SD* = 4.3) from the undergraduate population at the University of Arizona served as participants in this study. Each young adult received credit toward a course requirement for his/her participation.

Ten older adults were selected from a pool of healthy, community-dwelling older adults, all of whom were over the age of 65. All older adults received monetary compensation for their participation.

Materials

The materials were the same as those used in EXPERIMENT 1 with the following exception: each test item in the temporal source memory test was comprised of two sentences that had been separated by ten intervening items during encoding. For example, item four was paired with item fourteen and presented in that order, as well as in the reverse order. In this way, each of the 20 studied sentences was presented twice at test, once paired with a sentence in the studied order and once in the reverse order.

Procedure

The procedure for EXPERIMENT 2 was identical to that of EXPERIMENT 1.

Results

Item memory

For the item test, proportion correct for the young adults ranged from .80 to 1.00, with a mean = .96 and standard deviation = .04, while those for older adults ranged from .75 to .95, with a mean = .93 and standard deviation = .07, resulting in a non-significant age difference, t (18) = .82, p >.05. This suggests that any memory effects found in the source memory conditions were not due to memory for the items themselves.

Source Memory

Mean proportion correct and standard deviations by group for the voice source memory, spatial source memory, and temporal source memory conditions are presented in Table 3. Proportion correct was analyzed with a repeated-measures ANOVA, with source memory test type as a within-participants variable and group as a between-participants variable. This analysis indicated a main effect of age, F (1, 18) = 6.02, p < .05, and source memory type, F (2, 36) = 8.42, $p < .05$. Paired comparisons indicated that voice source memory was superior to spatial source memory, t (19) = 3.07, $p < .05$, and temporal source memory, t (19) = 4.17, $p < .05$, which did not differ from one another, t (19) = .44, $p > .05$. There was no interaction.

Table 3

Proportion Correct and Standard Deviations for the Three Source Memory Conditions in EXPERIMENT 2

	Condition		
Group	VSM	SSM	TSM
Young	.67 (.13)	.60 (.13)	.62 (.18)
Older	.61 (.15)	.57 (.18)	.54 (.10)

Discussion

As in EXPERIMENT 1, EXPERIMENT 2 showed no difference between spatial source memory and temporal source memory. In EXPERIMENT 2, however, performance in the temporal source memory condition for the young was significantly above chance, t (9) = 5.28, $p < .05$ suggesting that the lack of a difference was not due to a floor effect. Also replicating EXPERIMENT 1, EXPERIMENT 2 found that voice source memory was significantly better than temporal source memory. In EXPERIMENT 2, however, voice source memory was also superior to spatial source memory. There may be a number of reasons why spatial source memory and temporal source memory are inferior to voice source memory performance. Voice or identity information may be better integrated with a spoken sentence or more adaptive in some sense than either the location of the speaker or the temporal order of the sentences. The sources may also differ in processing demands or depend on different systems, and the tests may still not be exactly matched for difficulty. The present experiments, however, do not test these different explanations.

In EXPERIMENT 2, equality across testing formats for the three source memory conditions still remained an issue. The relative temporal order judgment is conceptually different and potentially more difficult than the other two kinds of recognition judgments. Therefore, EXPERIMENT 3 was designed to equate as closely as possible the source memory testing formats across the three sources.

Low performance levels in the source memory conditions were also a concern in EXPERIMENT 2, particularly in the older adults. Such low levels might obscure any differences that exist between groups or among source memory conditions. Similarly, since the design of future experiments includes testing older adults who are expected to display impoverished source memory ability secondary to poor frontal lobe functioning, higher levels of performance on the source memory tasks were needed.

CHAPTER 4

EXPERIMENT 3

Concern over design issues of EXPERIMENTS 1 and 2 were addressed in EXPERIMENT 3. To compare performance on different types of source memory within-participants, it is important to have source memory paradigms that are equal except for the kind of source in question. In EXPERIMENTS 1 and 2, the temporal source memory testing format differed from those of voice source memory and spatial source memory. In the temporal source memory conditions, participants were always presented with two different sentences, both of which were studied, and asked to make a relative judgment concerning the occurrence of these items. In the voice source memory and spatial source memory conditions, participants were exposed only to one studied sentence, which was presented in the two sources during the testing phase. Additionally in the first two experiments, unlike in the temporal source memory condition, the voice source memory and spatial source memory conditions re-presented the original item-source pairings for the purposes of recognition, whereas this was not the case in the temporal source memory condition. Finally, limitations in the design of the temporal source memory condition dictated that only 10 test observations could be made, while in the voice source memory and spatial source memory conditions, 20 test observations were made.

Because of these design differences, EXPERIMENT 3 included modifications to the study and test phases of the experiment. During the temporal source memory study phase, participants were presented with half of the list, heard a series of chimes, and then heard the second half of the list. The temporal source memory test question was changed as well. In EXPERIMENT 3, the temporal source memory judgment required participants to indicate if the item was presented before or after the chimes.

In addition, EXPERIMENT 3 included modifications on the formats for all three source memory tests. In this experiment, all three source tests involved a visual presentation of a single studied item accompanied by a two-alternative forced choice decision.

To address the issue of low performance in the source memory conditions, two further adjustments were made to the study phases of EXPERIMENT 3. First, the participants were given intentional study instructions. During the study phase of each block, the participants were specifically informed as to the nature of the upcoming memory test. Second, each study list was presented twice.

As in the previous two experiments, it was hypothesized that performance on the three source memory tests would not be equivalent. For EXPERIMENT 3, it was expected that spatial source memory performance would be equal to that of temporal source memory with voice source memory better than both. A main effect of aging was again predicted. In addition to this main effect, a frontal lobe effect was also posited. Research from this laboratory (Glisky et al., 1995; 2001) indicates when older adults are characterized as high or low according to ability on tests that tap frontal lobe functioning, an effect of this characterization is found on source memory performance such that low frontal lobe older adults are impaired relative to high frontal lobe older adults. Therefore, it was also hypothesized that the expected aging effect would be mediated by frontal lobe functioning.

Method

Participants

Twenty-four younger adults (age range = 18 – 33, *M* = 21.1, *SD* = 3.9) from the undergraduate population at the University of Arizona served as participants in this study. Each young adult received credit toward a course requirement for his/her participation.

Twenty-four older adults (age range = 67 – 86, *M* = 76, *SD* = 5.1) were selected from the same pool as in EXPERIMENT 2. All had completed neuropsychological testing within two years of experimental testing. The older adults were selected for this study on the basis of their performance on tests of frontal lobe and medial temporal lobe functioning (see Glisky et al., 2001 for more details). Half of the participants were above average on frontal lobe function and half were below average, while half of the participants were above average on medial temporal lobe function and half were below average. The high and low frontal lobe subgroups were matched on measures of age, education and medial temporal lobe function. Table 4 shows demographic variables and composite neuropsychological measures by neuropsychological subgroup. All of the older adults received monetary compensation for their participation.

Table 4

Characteristics of Older Adults by Neuropsychological Group for EXPERIMENT 3

	FL Function	
Group	High	Low
n	12	12
Age (in years)	75.80	76.10
Education (years)	14.76	14.33
MMSE (/30)	28.71	28.39
FL score	.68	-.65
MTL score	.05	-.08

Materials

The same sentences that were used in the first two experiments were used to create the lists for EXPERIMENT 3. Five lists of 26 sentences were created. Each list contained 20 targets, four buffers and two practice sentences. These five lists served as the study lists for the three source memory conditions and one item memory condition. The five lists were rotated such that each was used equally often for the source conditions, the item condition, and as distractors for the item test. Order of the three source memory conditions was also counterbalanced across participants such that each source memory block occurred equally often in each position. The item memory block was always last.

Procedure

The procedure was the same as that used in EXPERIMENTS 1 and 2, with the following exceptions:

During the study phase of the experiment, participants were told of the upcoming memory test and, specifically, what aspects of the study episode would be tested. For instance, during the study phase of the voice source memory condition, participants were told that their memory for which voice spoke the sentence would be tested. For the voice source memory and spatial source memory conditions, the participants were presented with each study list twice, in different random orders, before moving on to the test phase. For the temporal source memory condition, the participants were presented with each study list twice. During each of these presentations, the sentences within each half of the list were in different random orders. That is, sentences that were heard before the chimes during presentation one were heard before the chimes during presentation two.

Following each study phase was a 2AFC test phase, presented visually. For each source condition, the appropriate test question appeared at the top the computer screen. Below the question was a single studied item accompanied by the appropriate two choices. For the voice source memory test, the question “Which voice spoke this sentence?” was accompanied by a studied sentence and the choices “F” or “M” to indicate whether the sentence had been presented in the female or male voice. For the spatial source memory test, the question “From which side was this sentence heard?” was accompanied by a studied sentence and the choices “Q” or “P” to indicate whether the sentence had been presented from the left or right side, respectively. For the temporal source memory test, the question “Was this sentence herd before or after the chimes?” was accompanied by a studied sentence and the choices “A” or “B” to indicate whether the sentence had been heard after or before the chimes. The item memory test was also

2AFC, presented visually. Below the test question, a studied sentence was presented with a novel sentence. Participants were asked to press the appropriate key (1 or 2) to indicate whether the first or second sentence was heard during the study phase.

Results

Item memory

For the item test, proportion correct for the young adults ranged from .85 to 1.00, with a mean = .98 and standard deviation = .06, while those for older adults ranged from .75 to 1.00, with a mean = .96 and standard deviation = .08. There were no differences based on age, t (46) = 1.21, $p > .05$, suggesting that any memory effects found in the source memory conditions were not due to memory for the items themselves.

Item memory proportion correct was compared between older adults characterized as high or low on the frontal lobe factor score. Results of this analysis revealed no difference in item memory based on frontal lobe functioning, t (22) = .43, $p > .05$. The medial temporal lobe factor score used in this experiment has previously predicted item memory performance (Glisky et al. 1995). However, in the current experiment, analysis of item memory scores revealed no differences between older adults characterized as high or low on the medial temporal lobe factor, t (22) = .43, $p > .05$. Performance in all groups, however, was essentially on the ceiling.

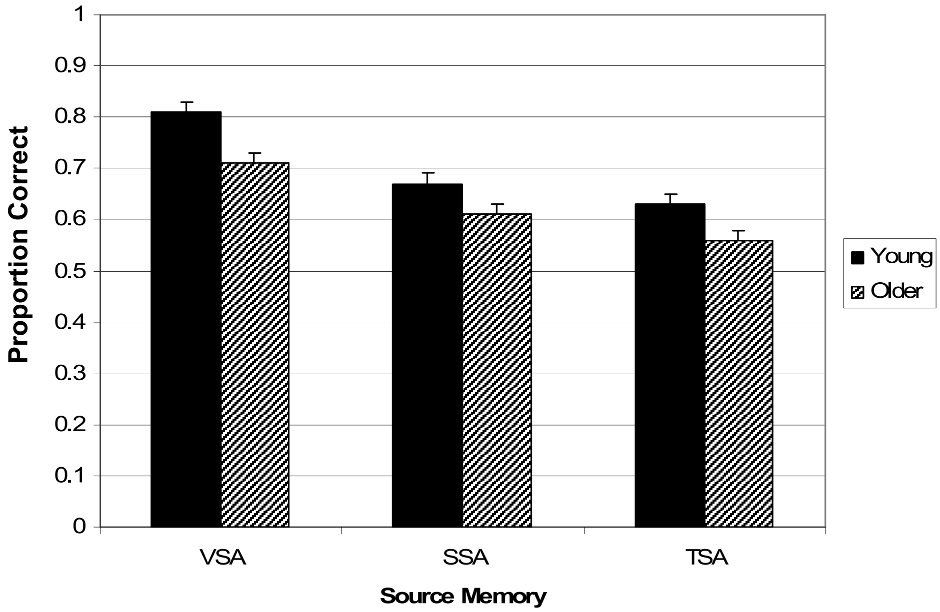

Figure 1. Source memory proportion correct as a function of age group for EXPERIMENT 3

Source Memory

Mean proportion correct and standard errors by age group for the voice source memory, spatial source memory, and temporal source memory conditions are depicted in Figure 1. Proportion correct was analyzed with a repeated-measures ANOVA, with source memory test type as a within-participants variable and group as a between-participants variable. This analysis indicated a main effect of source memory type, F (2, 92) = 31.26, $p < .001$. Paired comparisons indicated that voice source memory was superior to spatial source memory, t (47) = 5.58, $p <.05$, and temporal source memory, t (47) = 7.73, $p <.05$. The difference between spatial and temporal source memory just failed to reach significance, t (47) = 1.99, $p >.05$. There was also a main effect of age, F (1, 46) = 8.71, $p < .005$, indicating that younger adults outperformed older adults on all types of source memory. There was no significant interaction. Performance in all three source memory conditions was above chance (all *t*s > 2.25, *p*s < .05).

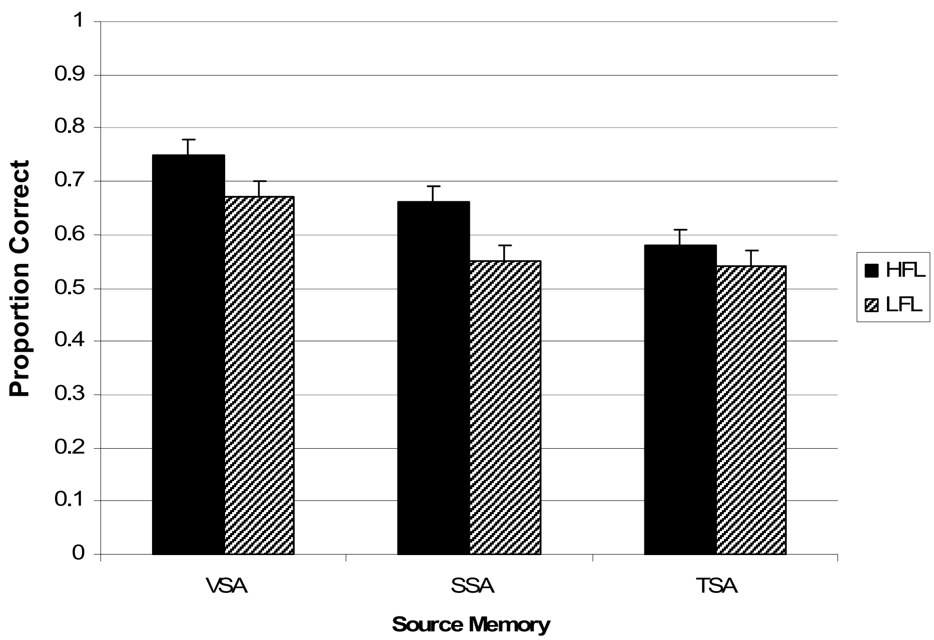

Figure 2. Source memory proportion correct as a function of frontal lobe factor score for Experiment 3

The results of the older adults split by frontal lobe functioning are presented in Figure 2. A repeated-measures ANOVA, with source memory test type as a within-participants variable and frontal lobe factor as a between-participants variable, found a main effect of source memory type, $F\ (2, 40) = 18.53$, $p < .001$. There was also a main effect of the frontal lobe factor, $F\ (1, 20) = 5.28$, $p < .05$, indicating that high frontal lobe older adults outperformed low frontal lobe older adults. The interaction was not significant.

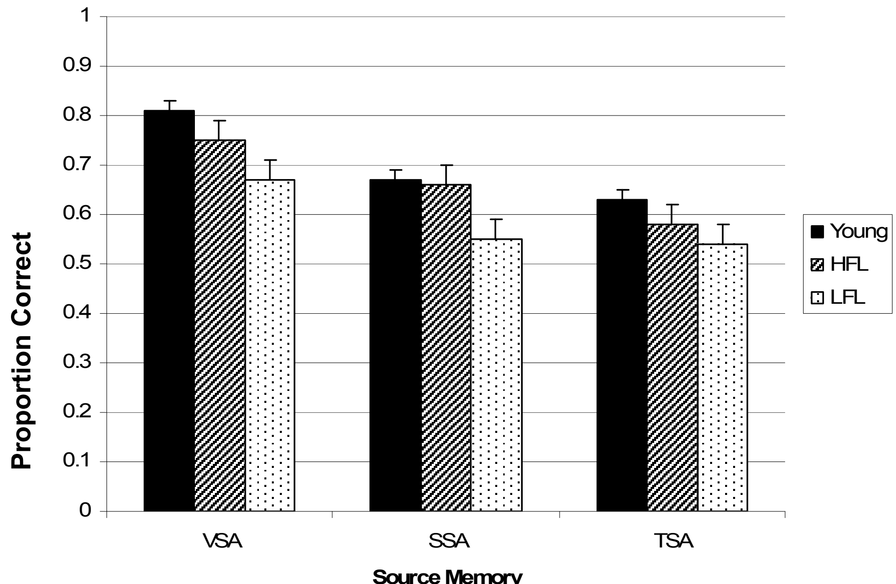

Figure 3. Source memory proportion correct for young and old by frontal lobe factor score for EXPERIMENT 3

The performance of younger adults as compared to older adults characterized by frontal lobe functioning is shown in Figure 3. To investigate these performances, a repeated-measures ANOVA with source memory test type as the within-participants variable and group as the between-participants variable was conducted. This analysis indicated a main effect of source memory type, F (2, 90) = 13.45, $p < .001$. There was also a main effect of group, F (2, 45) = 19.02, $p < .05$. To further define this group effect, *t*-tests were conducted. The results showed that there were no differences between the high frontal lobe older adults and the young, t (34) = 1.27, $p > .05$ for voice, t (34) = .07, $p > .05$ for space, t (34) = 1.26, $p > .05$ for time. The low frontal lobe older adults, however, were significantly worse than the young on all three source memory tasks, t (34) = 2.86, $p < .05$ for voice, t (34) = 2.48, $p < .05$ for space, t (34) = 2.39, $p < .05$ for time. There was no significant interaction.

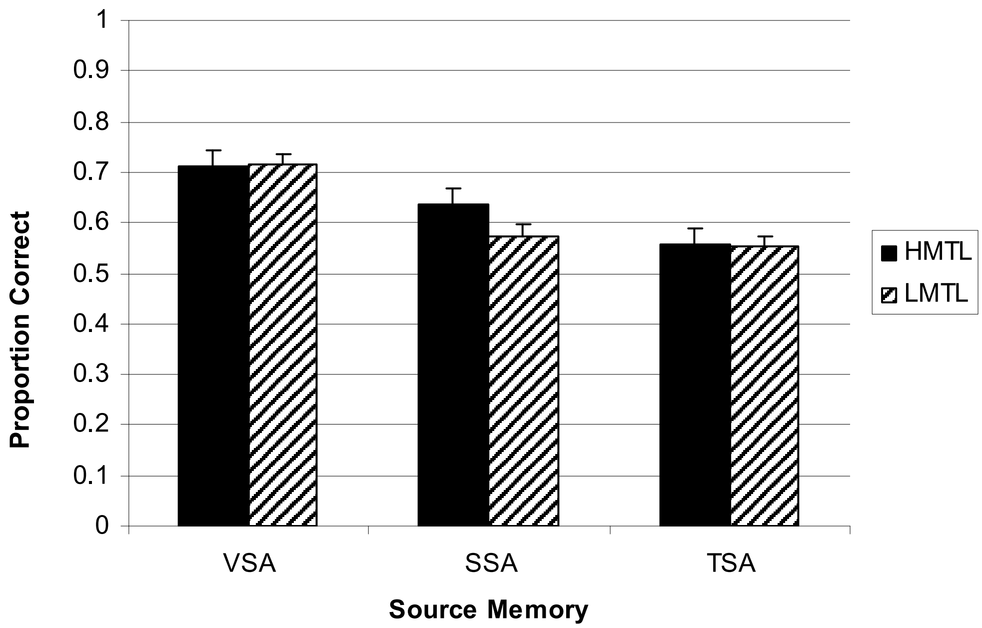

Figure 4. Source memory proportion correct for old by medial temporal lobe factor score for Experiment 3

The performance of older adults characterized by medial temporal lobe functioning is shown in Figure 4. To evaluate the effect of the medial temporal lobe factor on source memory, a repeated-measures ANOVA was conducted with source memory type as the within-participants factor and medial temporal lobe classification as the between-participants factor. This analysis showed a significant main effect of source memory type, $F(2, 44) = 17.75$, $p < .001$. Paired comparisons indicated that voice source memory was superior to spatial source memory, $t(23) = 3.91$, $p < .05$, and temporal source memory, $t(23) = 5.62$, $p < .05$, which did not differ from one another, $t(23) = 1.97$, $p > .05$. There was no main effect of group nor was there a significant interaction.

Table 5 presents the reaction time data for the young and older adults in experiment 3. These data were analyzed with a repeated-measures ANOVA with source memory type as the within-participants factor and group as the between-participants factor. The results showed a main effect of group, $F(1, 45) = 61.91$, $p < .05$, indicating that the young adults were faster to respond than were the older adults. The effect of source memory type was not significant, nor was the interaction.

Table 5

Source Memory Mean Reaction Times and Standard Deviations for the Young and Older Adults in EXPERIMENT 3

Group	VSA	SSA	TSA
Young	2687.67 (999.86)	2788.27 (1012.38)	3000.62 (1103.21)
Old	3973.88 (862.06)	4402.72 (1107.55)	4027.68 (1375.42)

Table 6 shows the correlations among the measures of source memory for the young adults and older adults split by neuropsychological subgroup. There were no significant correlations among the measures for any group (all *p*s >.05).

Table 6
Correlation Values Among Source Memory Measures for the Young and Older Adults by Neuropsychological Function in EXPERIMENT 3

		Function			
Measure	Young	High FL	Low FL	High MTL	Low MTL
VSA - SSA	.12	.09	.18	.16	.15
VSA - TSA	.18	-.01	.06	-.02	.22
SSA - TSA	.21	.07	.15	.16	.20

Discussion

The results of EXPERIMENT 3 agree with those of EXPERIMENT 2 in showing an age effect in source, but not item memory. Item memory, however, was once again on the ceiling in both young and old. These results are consistent with previous research (e.g., Craik et al., 1990; Glisky et al., 1995; 2001) in supporting a role for the frontal lobes in source memory in older adults. Performance on all the source memory tasks was related to the frontal lobe factor score, with only the low frontal group showing significant impairment compared to young. Poorer performance on tests of source memory therefore seems not to be an inevitable result of aging, but rather tied to frontal lobe processing ability. The effect of frontal lobe function on all of the source memory tasks used here also supports the idea of a general processing component in source memory that is involved in several different kinds of source memory tasks.

There was also no significant correlation between the medial temporal lobe factor scores and any type of source memory. Although others (Henkel, Johnson, & De Leonrdis, 1998: Mather, Johnson, & De Leonardis, 1999) have found correlations between measures of medial temporal lobe function and measures of source memory, research from this laboratory (Glisky et al., 1995; 2001) has not found such relationships. It is possible that differences in materials and methods account for the inconsistent findings in the literature. In the Glisky et al. studies, as in the experiments reported here, source and item memory tasks are independent, allowing one to answer source memory questions without accessing the item memory. In other source memory studies, such as those reported in Henkel et al. (1998), source memory tasks are conducted concurrently with item memory tasks. Under such circumstances, medial temporal lobe function might play a greater role as it has been associated with item memory (e. g., Glisky et al., 1995).

The results of EXPERIMENT 3 agree with those of EXPERIMENTS 1 and 2 in suggesting that performance on different kinds of source tests may involve processing components specific to the type of source. As in EXPERIMENT 2, both young and older adults performed better on voice source memory than on spatial and temporal source memory, which did not differ. In this experiment, tests were closely equated so that differences between voice source memory and the other two source tests are unlikely to be attributable to test format. Reaction times for responding to the source memory questions also did not differ significantly across types of source, but the times were quite long and variable given the visual format of the test and therefore can probably not be meaningfully interpreted. If, in this paradigm, voice source memory is generally superior to spatial and temporal source memory, one might ask whether people would be able to use relevant voice information to improve their performance in the other two conditions. EXPERIMENT 4 addresses this question.

CHAPTER 5

EXPERIMENT 4

EXPERIMENT 4 addressed the question of whether people can use their good performance on voice source memory to boost performance on another kind of source memory. Spatial source memory was chosen as the second source in this experiment. Temporal source memory was not evaluated.

As noted in the INTRODUCTION, there is a paucity of aging research on source memory tasks that involve different sources providing redundant information about the same item. Some evidence indicates that performance with different sources providing redundant information is better when compared to a single source condition for both young and older adults (Ferguson et al., 1992, Experiment 3; Johnson et al., 1995, Experiment 1). Others (e.g., Bayen & Murnane, 1996; Schacter et al., 1991) have not found this effect. Differences in materials and methodologies might account for the conflicting outcomes. It is possible that frontal lobe functioning impacts the ability to benefit from redundant source information. Forming and remembering an integrated memory that associates multiple pieces of contextual information with its content probably involves processes dependent on frontal lobe integrity. It may therefore be that only those older adults with poor frontal lobe function are impaired in their ability to make flexible use of redundant cues.

EXPERIMENT 4 examined memory for voice source and spatial source information when these two sources provided redundant or overlapping information. In other words, voice and space were perfectly matched during the study phase such that

Voice A always came from Location 1 and Voice B always came from Location 2. As in EXPERIMENT 3, intentional study instructions were provided so that the participants were aware that their memory for both the sources would be tested. To be specific, all participants were asked test questions about voice source information and spatial source information. EXPERIMENT 4 used a repeated-measures design that included that same testing format as in EXPERIMENT 3, namely a two-alternative, forced choice recall procedure with the choices for voices being "Female or Male" and the choice for locations being "Left or Right". Therefore the tests were closely equated so that differences between voice source memory and spatial source memory could not be attributed to test format.

It was hypothesized that young adults and high frontal older adults would be able to make use of the voice information to improve their performance on spatial source memory. Specifically, both young and high frontal older adults should show equivalent levels of performance with voice and spatial source memory. Low frontal older adults, however, were expected to be unable to integrate the two sources of information and therefore be unable to improve their spatial source memory by using voice information. Their performance on the two source memory tasks should look much like that in EXPERIMENT 3 with voice source memory superior to spatial source memory. The low frontal older adults were also expected to perform worse in both source memory conditions compared to the young and the high frontal older adults. Additionally, it was hypothesized that voice source memory and spatial source memory performance would be correlated for young and high frontal older adults, but not for low frontal older adults. No differences in item memory were anticipated.

Method

Participants

Twenty-four younger adults (age range = 18 – 29, *M* = 19.17, *SD* = 2.29) from the undergraduate population at the University of Arizona served as participants in this study. Each young adult received credit toward a course requirement for his/her participation.

Thirty-two older adults (age range = 67 – 91, *M* = 77.38, *SD* = 6.81) were selected from the same pool as in EXPERIMENTS 2 and 3. All had completed neuropsychological testing within two years of experimental testing. The older adults were selected for this study on the basis of their performance on tests of frontal lobe functioning (see Glisky et al., 2001 for more details) with 16 of the participants being above average on frontal lobe function and 16 having scores that were below average. Table 7 shows demographic variables and composite neuropsychological measures by neuropsychological subgroup. The high and low frontal lobe subgroups were matched on measures of age, education and medial temporal lobe function. All of the older adults received monetary compensation for their participation.

Table 7

Characteristics of Older Adults by Neuropsychological Group for EXPERIMENT 4

	FL Function	
Group	High	Low
n	16	16
Age (in years)	76.87	77.89
Education (years)	16.31	16.50
MMSE (/30)	29.01	28.24
FL score	.53	-.52
MTL score	.22	.17

Materials

The same sentences that were used in the first three experiments were used to create the lists for EXPERIMENT 4. Three lists of 38 sentences were created. Each list contained 32 targets and six practice sentences. There were two study-test blocks: a source memory block followed by an item memory block. Within the source memory block, there was one study list and two tests lists. Each study list contained paired voice and spatial source information (i.e., Voice A consistently came from one part of space and Voice B consistently came from another part of space) to ensure that the two sources provided redundant information. Eight versions of each list were created to account for the pairing of the two levels of the two sources, the order of source tests within the source block, as well as the type of source information that was queried for each sentence. In the source memory condition, 16 studied items were randomly selected to serve as items for one kind of source test question (e.g., voice source memory), while the other 16 studied sentences served as items for the other source test question (e.g., spatial source memory). The three lists were rotated such that each was used equally often for the source conditions, the item condition, and as distractors for the item test.

A memory strategy questionnaire was designed to ascertain whether the redundant source information was used to answer the source memory test questions. There were four key questions on this questionnaire. The first asked whether the participant noticed the pairing of sources during the study phase of the source block. The second queried when the participant noticed the pairing of sources. The third asked if the participant used the knowledge that the sources were paired when answering the source memory test questions. The fourth asked how this knowledge was used.

Procedure

The procedure was the same as that used in EXPERIMENT 3 with the following exceptions: For the source memory block, there was only one study list, which was repeated once (in a different random order), followed by both voice source memory and spatial source memory test questions. Prior to the source memory study phase, participants were given intentional study instructions. That is, they were informed that they would hear sentences in different voices from different sides of the room and that they would receive a memory test for the voices and their location. The order of presentation of the sentences was random with respect to voice/space and no mention was made of the redundant nature of the source pairings. After the study phase, the participants completed the source test. Half of the items were tested with a question about voice (male/female) and half were tested with a question about place (left/right). The test questions were blocked by question type and the order was counterbalanced. The item memory study-test block followed and participants were then asked to fill out the memory strategy questionnaire.

Results

Item memory

For the item test, proportion correct for the young adults ranged from .88 to 1.00, with a mean = .95 and standard deviation = .04, while those for older adults ranged from .81 to 1.00, with a mean = .94 and standard deviation = .05. There were no differences as a function of age, t (54) = 1.50, $p > .05$. This ceiling level of performance for both groups suggests that any memory effects found in the source memory conditions were not due to memory for the items themselves.

Source Memory

Mean proportion correct and standard errors by age group for the voice and spatial source memory conditions are depicted in Figure 5. Proportion correct was analyzed with a repeated-measures ANOVA, with source memory test type as a within-participants variable and group as a between-participants variable. This analysis resulted in a main effect of source memory type, F (1, 54) = 5.80, $p < .05$, indicating that overall performance in the voice source memory conditions was superior to that in the spatial source memory conditions. There was also a main effect of age, F (1, 54) = 16.69, $p <$ .05, indicating that younger adults outperformed older adults. The interaction was not significant. However, planned comparisons revealed that the young adults performed equivalently on voice source memory and spatial source memory, t (23) = .25, $p >.05$, whereas older adults performed better on voice source than spatial source memory, t (31)

= 4.33, *p* <.05. Note also that the performance of the younger adults in both source memory conditions (.83 and 82 for voice source memory and spatial source memory respectively) was roughly equivalent to the voice source memory condition in EXPERIMENT 3 (.81).

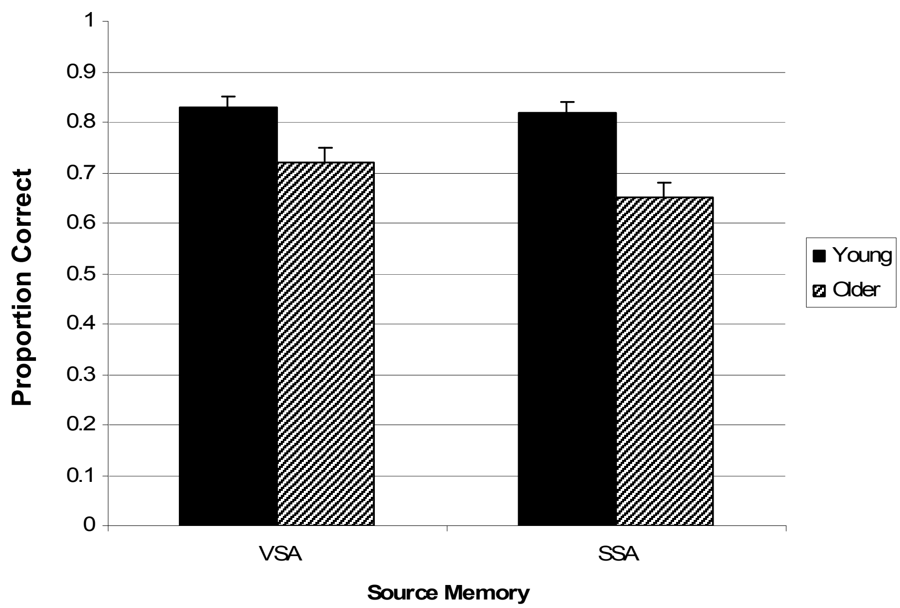

Figure 5. Source memory proportion correct as a function of age group for EXPERIMENT 4

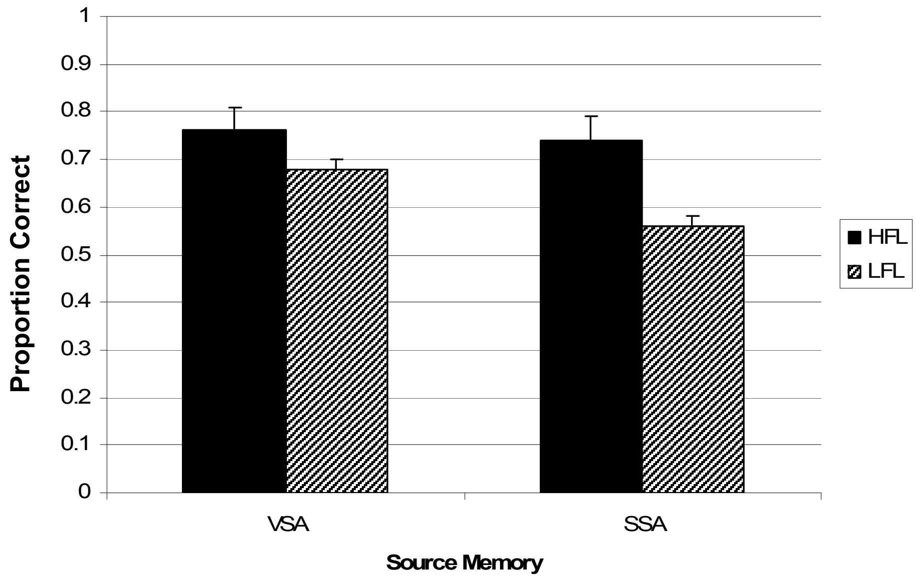

Figure 6. Source memory proportion correct as a function of frontal lobe factor score for EXPERIMENT 4

The results of the older adults split by frontal lobe functioning are presented in Figure 6. A repeated-measures ANOVA, with source memory test type as a within-participants variable and frontal lobe factor as a between-participants variable, found a main effect of source memory type, F (1, 30) = 25.06, $p < .05$, reflecting poorer performance in the spatial source memory condition. There was also a main effect of the frontal lobe factor, F (1, 30) = 6.82, $p < .05$, indicating that high frontal lobe older adults outperf ormed low frontal lobe older adults. There was a significant interaction, F (1, 30) = 11.49, $p < .05$. Post-hoc tests revealed that the difference between voice and spatial source memory conditions was not significant for the high frontal older adults, t (15) = 1.53, $p > .05$, whereas low frontal older adults performed better in the voice than the spatial source memory condition, t (15) = 4.95, $p < .05$. Additionally, the high frontal older adults outperformed the low on both source memory tasks, t (30) = 3.47, $p < .05$ for the voice task, and t (30) = 3.53, $p < .05$ for the spatial task. Note here also that the performance of the high frontal older adults on both source memory tasks (.75 and .73 for voice source memory and spatial source memory respectively) was approximately equivalent to the voice source memory condition in EXPERIMENT 3 (.75). Comparisons of performance of high and low frontal older adults in EXPERIMENTS 3 and 4 can be seen in Table 8.

Table 8

Proportion Correct and Standard Deviations for the Older Adults' Source Memory Performance in EXPERIMENTS 3 and 4

	High Frontal		Low Frontal	
Experiment	VSM	SSM	VSM	SSM
Three	.75 (.15)	.67 (.14)	.69 (.11)	.55 (.10)
Four	.75 (.17)	.73 (.15)	.68 (.10)	.56 (.07)

The performance of younger adults as compared to older adults characterized by frontal lobe functioning is shown in Figure 7. To investigate these performances, a repeated-measures ANOVA with source memory test type as the within-participants variable and group as the between-participants variable was conducted. This analysis indicated a main effect of source memory type, $F\ (1, 53) = 9.94$, $p < .05$, indicating that performance in the voice was better than the spatial source memory condition. There was also a main effect of group, $F\ (2, 53) = 12.90$, $p < .05$. Paired comparisons showed that there were no differences between the high frontal lobe older adults and the young $t\ (38) = .96$, $p > .05$, and the young were superior to the low frontal older adults, $t\ (38) = 5.84$, $p < .05$. As previously reported, the high frontal older adults were also superior to the low frontal older adults. In addition to these main effects, there was a significant interaction, $F\ (2, 53) = 4.77$, $p < .05$, reflecting that both the young adults and the high frontal older adults performed equivalently on voice and spatial source memory, $t\ (23) = .25$, $p > .05$

for the young, and t (15) = 1.53, $p > .05$ for the high frontal older group, whereas the low frontals performed more poorly on the spatial than the voice task, t (15) = 4.95, $p < .05$.

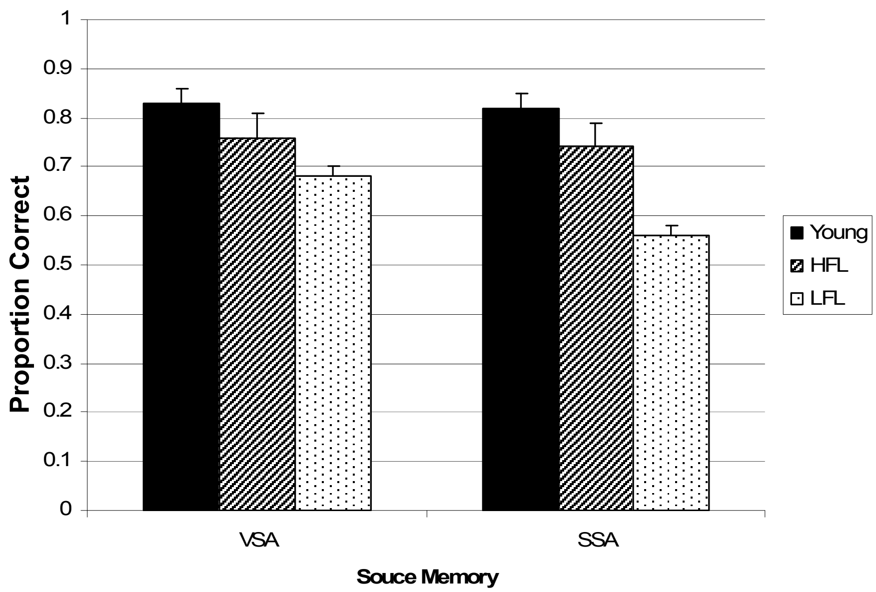

Figure 7. Source memory proportion correct for young and old by frontal lobe factor score for EXPERIMENT 4

The results of the older adults split by medial temporal lobe function are presented in Figure 8. To evaluate the effect of the medial temporal lobe factor on source memory, a repeated-measures ANOVA was conducted with source memory type as the within-participants factor and medial temporal lobe classification as the between-participants factor. This analysis showed a significant main effect of source memory type, F (1, 30) = 16.96, $p < .05$, indicating that voice source memory was superior to spatial source memory. There was no main effect of group nor was there a significant interaction.

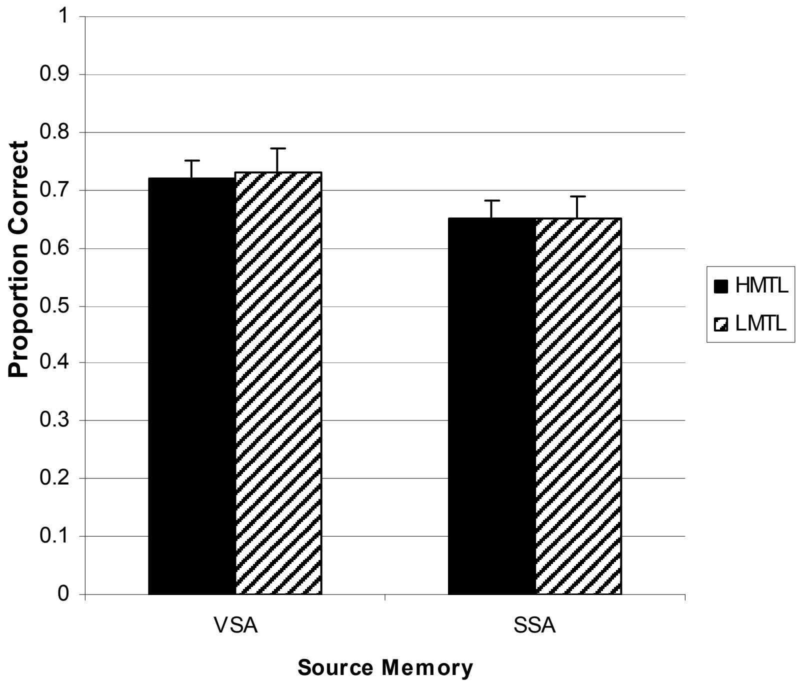

Figure 8. Source memory proportion correct for old by medial temporal lobe factor score for EXPERIMENT 4

Correlations

There was a significant correlation between the two measures of source memory for the young, $r = .44$, $p < .05$, and older adults, $r = .81$, $p < .05$. When split according to neuropsychological functioning, all subgroups of older adults showed correlated performance between voice and spatial source memory, $r = .94$, $p < .05$ and $r = .56$, $p < .05$, for the high and low frontal lobe groups respectively, and $r = .83$, $p < .05$ and $r = .66$, $p < .05$, for the high and low medial temporal lobe groups respectively.

Figure 9 shows scatterplots of source memory performance for young and older adults split by frontal lobe function. As can be seen in Figure 9, the young adults are tightly grouped at the upper end of both variables, which likely accounts for the lower correlation in this group. The very high correlation found for the high frontal older adults is being driven by an outlier. In fact, when this individual is removed from the analysis, the correlation for the high frontal older adults decreases, $r = .77$, $p < .05$.

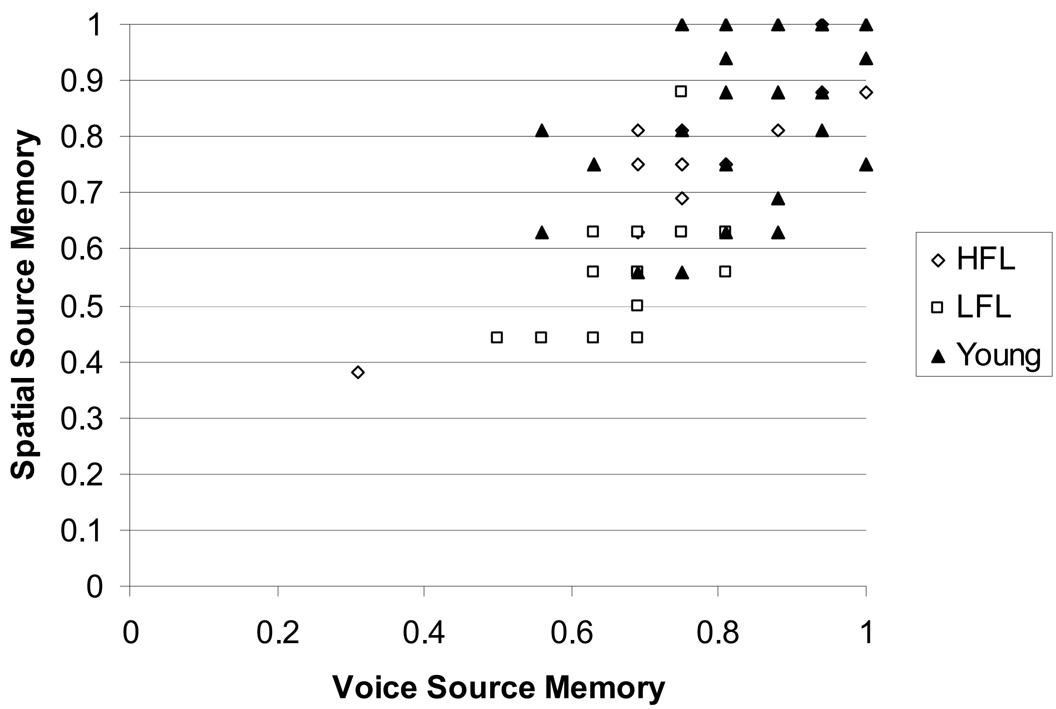

Figure 9. Scatterplot of source memory scores for young and older adults split by frontal lobe function in EXPERIMENT 4

Questionnaire

The results of the questionnaire for the young are clear. All 24 noticed that the voice and location provided redundant information about the sentence. Twenty-two of the 24 noticed the redundancy during the first six practice sentences. For the other two, they reported noticing it within the first half of the study list. All 24 reported using the information concerning the redundancy to answer the source memory test questions. One of the 24 reported relying solely on space information to answer all of the source test questions. Two of the 24 reported relying solely on voice information to answer all of the source test questions. The other 21 reported using both kinds of source information to answer both kinds of test questions.

The results of the questionnaire for the older adults indicate all 32 noticed that the voice and location provided redundant information about the sentence. Twenty eight of the 32 noticed the redundancy during the first six practice sentences. For the other 4, they reported noticing it within the first half of the study list. Twenty three of the 32 reported using the information concerning the redundancy to answer the source memory test questions. Of these 23, 6 reported relying solely on voice information to answer all of the source test questions, while 1 reported relying solely on space information to answer all of the source test questions. The other 16 reported using both kinds of source information to answer both kinds of test questions.

When split by frontal lobe function, the results of the questionnaire revealed all 16 of the high frontal older adults noticed that the voice and location provided redundant information about the sentence. Fourteen of the 16 noticed the redundancy during the first six practice sentences. For the other 2, they reported noticing it within the first half of the study list. Fourteen of the 16 reported using the information concerning the redundancy to answer the source memory test questions. Of these 14, 4 reported relying solely on voice information to answer all of the source test questions, while none reported relying solely on space information to answer the source test questions. The other 10 reported using both kinds of source information to answer both source memory test questions.

All 16 of the low frontal older adults noticed that the voice and location provided redundant information about the sentence. Fourteen of the 16 noticed the redundancy during the first six practice sentences. For the other 2, they reported noticing it within the first half of the study list. Nine of the 16 reported using the information concerning the redundancy to answer the source memory test questions. Of these 9, 2 reported relying solely on voice information to answer all of the source test questions, while 1 reported relying solely on space information to answer all of the source test questions. The other 6 reported using both kinds of source information to answer both kinds of test questions. A chi-square analysis of contingency, $\chi^2_{(1)} = 3.86$, $p < .05$, indicated that FL function did influence whether or not a redundant strategy was used to answer the source memory test questions such that high frontal older adults were more likely to use a redundant strategy.

For the low frontal older adults a repeated-measures ANOVA, with source memory test type as a within-participants variable and strategy of using or not using redundant source information as a between-participants variable was conducted. The results, shown in Table 9, indicated a main effect of source memory type, $F(1, 14) = 25.45$, $p < .05$, reflecting poorer performance in the spatial source memory condition. There was no main effect of the strategy type, $F(1, 14) = 1.27$, $p > .05$, nor was there a significant interaction, $F(1, 14) = 1.05$, $p > .05$. Correlational analyses among the two measures of source memory and whether the participant reported using a redundant strategy when answering source memory questions revealed no significant relationships among the variables ($r = .06$, $p > .05$ between voice source memory and reported strategy use; $r = .10$, $p > .05$ between spatial source memory and reported strategy use).

Table 9

Proportion Correct and Standard Deviations for the Low Frontal Older Adults' Source Memory Performance by Strategy Use in EXPERIMENTS 4

	Condition	
Redundant-Based Strategy	VSM	SSM
Yes	.70 (.08)	.60 (.13)
No	.67 (.09)	.53 (.07)

Discussion

The results of EXPERIMENT 4 agree with those of EXPERIMENTS 2 and 3 in showing an age effect in source, but not item memory, indicating that young adults outperformed older adults on tests of source memory. Performance on item memory was, however, on the ceiling in all groups.

Under conditions where two different sources provided redundant information about the item, young adults were able to answer questions equally regarding either source. Older adults, as a whole, however, were better able to answer questions about voice than space. These findings are, in some ways, consistent with those of May et al. (2005) and Rahhal et al. (2002) who found that older adults were better at reporting one type of source (emotional/conceptual) than another (personal identity) despite the fact that the two sources provided redundant information. The present findings expand these ideas by suggesting that individual differences in frontal lobe function contribute to an older adult's ability to make use of more than one source at a time.

The analysis of older adults grouped according to the frontal lobe factor score revealed main effects of source memory and frontal lobe function such that voice source memory was better than spatial source memory and high frontal older adults performed better than low frontal older adults, but effects were qualified by a significant interaction. The nature of this interaction suggests that one's ability to benefit from redundant source information depends on good frontal lobe functioning. Whereas the high frontal older adults performed equally well on the voice and spatial source memory tasks, the low frontal older adults performed more poorly on the spatial source memory task, indicating that they were unable to use voice cues to help answer source memory questions about spatial location.

Although the mechanism behind this high frontal function advantage is unclear, previous research in this laboratory (Glisky et al., 2001) provides evidence for a role of the frontal lobes in source memory during encoding. It is possible that frontal lobes are involved in initiating the encoding of contextual information and integrating these contextual details with the item information to form an integrated episodic memory trace. If this were the case, people with poor frontal function might have trouble with source memory tasks in general, that is, with integrating an item with its source as was found in EXPERIMENTS 3 and 4, but might also have difficulty integrating information from two sources even though the sources are closely linked experimentally. Additionally, it is possible that the frontal lobes are involved in selecting an appropriate strategy or using a desired strategy to successfully answer source memory questions.

Unlike in EXPERIMENT 3, significant correlations between the measures of source memory were found for young and older adults in EXPERIMENT 4 and for both subgroups of older adults classified by frontal lobe functioning. The fact that correlations between the measures of source memory were significant for all groups in EXPERIMENT 4 supports the idea that when information from two sources is redundant, people engage similar processes or access both kinds of information no matter what the source question.

Nevertheless, older adults with low frontal lobe function seemed unable to capitalize on the redundant relation between the sources even though they were aware of it. Although all of the low frontal older adults reported noticing the redundancy, only 9 of these 16 participants reported using that knowledge during the source memory test. Although use of this strategy did not significantly improve performance, there was a non-significant advantage indicating that those who reported using the strategy were able somewhat to improve performance on the spatial source memory task (see Table 9). This finding suggests that strategy selection or use might also be an issue for some low frontal older adults.

The main results of EXPERIMENT 4 show that younger adults and high frontal older adults were able to improve their spatial source memory when voice could be used as a cue to space. Additionally, the source memory performance levels of the young and high frontal older adults suggested that the redundant information selectively bolstered spatial source memory. The task in this experiment likely placed a high demand on executive function and processing resources. During encoding, for example, participants knew that they needed to remember multiple pieces of information, although their attention was focused on the item in order to successfully complete the study task. Similarly, during retrieval, participants were required to recall multiple pieces of information that might or might not have been well bound in an episodic memory trace. Various components of the memory then had to be compared to other pieces of information, checked for accuracy and verified before a decision could be made. All of these processes would strain working memory and other executive control processes, making the task difficult for the low frontal older adult group. This explanation is consistent with a recent report linking the frontal lobe factor used here to working memory ability (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2006).

CHAPTER 6

GENERAL DISCUSSION

The series of experiments reported here utilized a repeated-measures design to test the source memory abilities of young adults and older adults characterized by frontal lobe function. The results clearly demonstrate that different kinds of source memory tasks involve different processes in both young and older adults, although there may be processes in common as well.

Why is there an Advantage for Voice Source Memory?

One interesting finding concerns the superiority of voice source memory compared to spatial and temporal source memory. One explanation for this pattern of results has to do with the natures of the items and sources. In these experiments, the items were always sentences heard during the study phase. Memory for verbal items might be more easily associated with a verbally-based source than with a visuospatial or temporal source. Sentences spoken from different locations may be a rather uncommon experience for many people, and therefore difficult to integrate. Also as noted earlier, memory for temporal information may involve a kind of inferential processing not needed in the case of voice. Another possibility is that the relevance of the source to an item affects the likelihood of integration. In cases where source information is more relevant or more related to the item information, the pairing of these pieces of information might be enhanced. For the types of sources used here, voices would seem to be the most relevant for verbal items such as sentences. This suggests that different conditions might result in a different pattern of results. For example, if objects served as the items, one might expect that source memory performance in the spatial condition would be best, both because objects in locations are common in one's experience, and also because the location of an object may be a particularly relevant piece of information.

In addition, the purpose or goal of a study episode, whether subject-generated or experimenter-imposed, might affect the extent to which item and source information become integrated. If a participant believes that the identity of the speaker is a particularly important aspect of an experience, or if instructions or orienting tasks suggest this importance, then voice information might be particularly well-encoded. It is possible that the orienting task used in the present experiments promoted such integration in the case of voice information. Because participants were asked to rate the likelihood that the sentence would be *heard* on the radio, the participants might have used qualities of the voices such as diction, inflection, and speech rate in order to make this rating. Under these conditions, the voices may have received greater attention and processing during encoding than locations or list positions, despite the fact that in EXPERIMENTS 3 and 4, instructions indicated that memory for space and time would be tested.

Finally, it is possible that voices were more discriminable or distinctive than the other kinds of sources tested here. Although an attempt was made to equate the source memory tasks in all aspects, it remains a possibility that the voice source decision was the easiest one to make. Perhaps the differences between the female and male voices were greater than those between the sides of the room or positions within the study list. Although the sources were chosen to be maximally different, no psychophysical measurements were made, nor were sources rated for distinctiveness. Johnson and colleagues (1995) have demonstrated that source decisions are easier when the two sources are most distinctive. Future studies might use less discriminable voices (e.g., two female voices) to assess whether the same differences found here would still emerge or perhaps consider ways in which the discriminability of different source alternatives might be measured and equated.

Is Source Memory Unitary?

Source memory is often referred to as a unitary cognitive ability. If source memory is unitary, then correlations among the results on the different source memory tasks for the same individuals would be expected. This was not the case in EXPERIMENTS 1 – 3 where non-redundant source information was provided. In EXPERIMENT 4, however, performance on the different source memory tasks was correlated. These patterns of correlations suggest that, under standard non-redundant testing conditions, different source memory tasks are recruiting different processes. These results, along with the general finding that source memory performance levels vary depending on the type of source tested suggest that source memory performance is influenced by processing components that are specific to the type of source in question.

Other results, however, support the notion that, in addition to these specific processing components, source memory involves a general processor. For the older adults, all types of source memory were found to be influenced by frontal lobe function, under both redundant and non-redundant testing conditions. This suggests that a general executive process, subserved by the frontal lobes, may be involved in all kinds of source memory tasks. Nevertheless, the results as a whole suggest that source memory is not unitary, but rather is composed of processes specific to each source along with a general process that applies to all source memory tasks.

Can Redundant Information be used to Improve Source Memory?

Another issue addressed by this project was whether people could benefit from having multiple sources that provided redundant information. This was tested by pairing voice and spatial source information in EXPERIMENT 4. The results indicated that young and high frontal older adults benefited from such redundancy, but low frontal older adults did not.

The benefit of redundant sources in this study was observed specifically in performance on the spatial source memory task. Voice source memory was roughly equivalent in EXPERIMENTS 3 and 4, whereas spatial source memory improved in EXPERIMENT 4 for young and high frontal older adults. The benefit from redundant cues was thus selective for the spatial task. Interestingly, having an additional cue (i.e., space) did not improve voice memory, consistent with the notion that the two sources were indeed linked, and that participants in this paradigm were already using the information from the voices effectively.

Previous research with multiple sources and redundancy (e.g., Ferguson et al., 1992) has generally found that young but not older adults can capitalize on the redundancy to improve their source memory. Most of these studies (e.g., Johnson et al., 1995; Schacter et al., 1991), however, probed participants' memory for personal identification or voice only and have concluded that older adults' source memory is not helped by redundancy. EXPERIMENT 4 also found that memory for personal identification (i.e., voice) was not improved by the addition of spatial cues, although spatial memory was helped by the voice cue. As others have shown (e.g., Rahhal et al., 2002; May et al., 2005), when there are multiple, redundant pieces of source information for the same item, performance may vary depending on the type of source questions asked.

The Frontal Lobes and Multiple Kinds of Source Information

The results of EXPERIMENTS 3 and 4 found that young adults outperformed older adults on measures of source memory, replicating previous findings in the literature (e.g., Ferguson et al., 1992; Glisky et al, 1995; 2001; McIntyre & Craik, 1987; Schacter et al., 1991). In the current experiments, as in previous ones from this laboratory (Glisky et al, 1995; 2001), this age effect was mediated by a frontal lobe effect, pointing to a role for the frontal lobes in source memory. Although previous investigations of source memory have suggested a role for the frontal lobes, this is the first study that has examined the role of the frontal lobes with multiple kinds of sources, using a repeated-measures design. In EXPERIMENT 3, where three kinds of source information were tested independently, a main effect of frontal lobe function, which failed to interact with type of source memory, was found. These results suggest that the frontal lobes support processing required by all three source memory tasks. Such processing likely involves both encoding and retrieval. For example, during encoding, information about various aspects of the experience must be attended to and integrated into a multi-component memory trace and stored in anticipation of the upcoming memory task. During retrieval, search processes have to be initiated and the various components of the memory retrieved, integrated, and evaluated. All of these processes require frontal executive processes and working memory, the kinds of processes tapped by the Glisky fontal lobe factor (Glisky et al., 1995).

The frontal lobes were also found to influence source memory performance when two sources provided redundant information regarding the item. Although the mechanism responsible for the ability to benefit from redundant source information is unknown, the results of EXPERIMENT 4 indicate that it is related to frontal lobe function. The older adults with poor frontal lobe function did not benefit, although they were aware of the redundancy. In an experiment similar to EXPERIMENT 4, Ferguson et al.(1992, Experiment 2) also paired an identity source and a spatial source while testing young and older adults. As in the current EXPERIMENT 4, Ferguson and colleagues found that young adults outperformed older adults when the two sources provided redundant information. In the current experiment, however, it was found that this age effect was primarily attributable to the poorer performance of the low frontal older adults. Ferguson and colleagues attributed the lack of a benefit from redundancy in source memory for the older adults to their not being able to utilize multiple, distinct cues to the same information. The results from the present series of experiments are consistent with this view but suggest further that this inability to use multiple cues is not a characteristic of older adults in general, but rather of those who have poorly functioning frontal lobes.

There may be many processes involved in processing and capitalizing on redundant cues in addition to those engaged by a single source. For example, during encoding the two redundant sources need to be linked to each other as well as to the item.

Supplemental processing requirements for redundant sources could also be present during retrieval. When asked to determine which source was associated with a particular item, participants may need to retrieve both sources and the link between them, maintain them together in an active state, and make a decision based on the combination of retrieved attributes. The active maintenance of verbal and visuospatial pieces of information, the manipulation of this information, and the selection of a response based upon this information are all processes associated with working memory and the kinds of executive processes tapped by the Glisky fontal lobe factor (Glisky et al., 1995). In EXPERIMENT 4, the low frontal older adults exhibited poor performance on the spatial source memory tasks, and were unable to capitalize on redundant source information, despite the fact that they were aware of the redundancy. In fact, 9 of the 16 low frontal participants reported trying to use this knowledge in answering the source memory test questions. Although they apparently employed this strategy, these 9 were still unable to make effective use of the redundancy during source memory questioning. It may be that the ability to link the two sources in working memory was impaired in the low frontal group or that the link between the two sources was weaker in this group.

Item Memory

All participants in all experiments performed excellently on tests of item memory. The experiments were designed to result in superior item memory performance, thus indicating that any deficiencies in source memory were not attributable to difficulty in remembering the item.

Medial Temporal Lobe Function and Measures of Memory

Although the medial temporal lobe factor (Glisky et al., 1995) has previously predicted item memory performance in older adults (Glisky et al., 1995), it did not do so here. This is likely because item memory performance was on the ceiling, making it difficult to detect any differences due to medial temporal lobe function. There has been some suggestion that source memory and medial temporal lobe function are related (e.g., Henkel et al., 1998; Johnson et al., 1993). For example, Henkel et al. found that, under certain conditions, performance on source memory tasks was correlated with performance on traditional tests of item or fact memory and with medial temporal lobe function. In the present set of experiments, however, source memory performance failed to show any sensitivity to medial temporal lobe function.

Some of the findings from this series of experiments replicate previous ones reported in the source memory and aging literature. However, there are two major new contributions of this project. First, the patterns of performance for young and older adults' source memory, when tested within-participants, were found to vary depending on factors such as the type of source tested, the presence of redundant cues, and the status of frontal lobe function. These results suggest that source memory is not unitary and that performance on different kinds of source tests might involve a general frontal/executive process as well as processing components specific to the type of source tested. Second, young adults and older adults with highly functioning frontal lobes can benefit from redundant source cues to boost performance with certain kinds of source information, but those with poor frontal function may not be able to do so. This indicates that the ability to use redundant cues to improve source memory does not necessarily decline with age, but is related to frontal lobe functioning. Whether these patterns of results hold in other paradigms or with other materials are open questions that await answers.

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