

**MEMORY FOR ASSOCIATIVE INFORMATION  
IN YOUNGER AND OLDER ADULTS**

by

**Alan D. Castel**

A thesis submitted in conformity with the requirements  
for the degree of Doctor of Philosophy  
Graduate Department of Psychology  
University of Toronto

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**Department of Psychology, University of Toronto**

**Ph.D. 2004**

**Abstract**

The present series of experiments examined how aging and divided attention influence memory for item and associative information in a variety of contexts. Previous research has suggested that one reason for older adults' poorer episodic memory is an impairment in processing and retaining associative information. To examine this, older adults, younger adults, and younger adults under various divided attention conditions studied unrelated word pairs for a later recognition memory test of both single words and different combinations of word pairs (Experiments 1-3). Both older and younger divided attention adults performed less well than the full attention group, with the deficit in associative information being greater than the deficit in item information. In addition, a differentially greater associative impairment was found for the older adults, as shown by their heightened tendency to make false alarm responses to re-paired (conjunction) distracters. These findings are interpreted in a dual-process model of recognition memory, in which older adults rely more on familiarity rather than recollection when processing associative information.

The ability to remember other types of associative information was further examined by using cued recall tests of associative memory that varied in terms of the degree of specificity. In these experiments (Experiments 4-6), participants studied items

that were paired with either related or unrelated units of information, as well as specific numerical information (either quantity or price information). Although older adults had the greatest difficulty remembering specific arbitrary associations, this impairment was reduced when associations were made meaningful (as a result of expertise) or contained a certain degree of schematic support. These results are discussed in terms of how prior knowledge and evaluative processing can influence associative memory, and suggest that a framework of associative memory that emphasizes different levels of associative specificity is necessary to interpret how older adults access associative information. The overall pattern of results imply that observations of age-related differences in memory for associative information depend on differences in available attentional resources, grain size (degree of precision) analyses at both encoding and retrieval, schematic support, and the meaningfulness and specificity of the association.

## **Acknowledgements**

I would like to express my sincere thanks to my advisor Fergus Craik for his expertise, guidance and generosity throughout my graduate training. I would also like to thank Jay Pratt for his constant support and advice, and Lynn Hasher for her insight and guidance. I appreciate the helpful comments and suggestions from Rose Zacks and Nicole Anderson. I am also very grateful to the many members of the laboratory and department that made this research possible and enjoyable. Finally, I would like to especially thank my family and friends, who have provided continuous support and encouragement.

## Table of Contents

<b>Abstract</b>	ii
<b>Acknowledgements</b>	iv
<b>Table of Contents</b>	v
<b>List of Tables</b>	viii
<b>List of Figures</b>	ix
<b>List of Appendices</b>	x
<b>Chapter 1: Introduction</b> .....	1
A Review of Memory and Aging Research.....	1
Distinctions between Item and Associative Memory.....	3
Previous Examinations of Associative Memory Impairments.....	6
Reduced Resources and Memory for Associations.....	9
Overview of Current Research.....	11
<b>Chapter 2: Divided Attention and Memory for Associative Information</b> .....	13
Introduction.....	13
<u>Experiment 1</u> .....	15
Experiment 1A.....	15
Method.....	15
Results and Discussion.....	19
Experiment 1B.....	27
Method.....	28
Results and Discussion.....	28

<u>Experiment 2</u> .....	31
Experiment 2A.....	31
Method.....	33
Results and Discussion.....	34
Experiment 2B.....	36
Method.....	37
Results and Discussion.....	37
<u>Experiment 3</u> .....	39
Method.....	42
Results and Discussion.....	44
General Discussion and Summary.....	48
<b>Chapter 3: Binding and Memory for Numerical Information</b> .....	55
Introduction.....	55
<u>Experiment 4</u> .....	59
Method.....	60
Results and Discussion.....	62
<u>Experiment 5</u> .....	66
Method.....	67
Results and Discussion.....	69
<u>Experiment 6</u> .....	73
Method.....	76
Results and Discussion.....	78
General Discussion and Summary.....	81

<b>Chapter 4: General Discussion, Theoretical Contributions, and Implications</b> ...	84
General Summary.....	84
Mechanisms of Associative Memory in Older Adults.....	85
Memory for Gist and Specific Information in Older Adults.....	90
Prior Knowledge, Expertise and Memory for Associations.....	94
Grain Size, Associative Memory, and Aging.....	97
Situating Levels of Associative Memory (SLAM) Framework .....	99
Summary and Conclusions.....	106
<b>References</b> .....	109
<b>Tables</b> .....	128
<b>Figures</b> .....	131
<b>Appendices</b> .....	145

## List of Tables

<b>Table</b>		<b>Page</b>
<b>2.1</b>	Mean Proportion of “Old” Responses in the Word Pair and Item Recognition Test for Experiments 1A and 1B	128
<b>2.2</b>	Mean Proportion of “Old” Responses in the Word Pair Recognition Test for Experiments 2A and 2B	129
<b>2.3</b>	Mean Proportion of “Old” Responses in the Word Pair Recognition Test for Experiment 3	130



## List of Figures

<b>Figure</b>		<b>Page</b>
2.1	Memory Performance (Word Pairs) in Experiment 1A	131
2.2	Memory Performance (Single Words) in Experiment 1A	132
2.3	Discriminability Analysis for Experiment 1A	133
2.4	Memory Performance (Word Pairs) in Experiment 2A	134
2.5	Discriminability Analysis for Experiment 2B	135
2.6	Memory Performance (Word Pairs) in Experiment 3	136
2.7	Discriminability Analysis for Experiment 3	137
2.8	Discriminability as a Function of Corrected Hit Rate for Experiments 1-3	138
3.1	Schematic Outline of Experiment 4	139
3.2	Correct Recall for Numbers and Objects in Experiment 4	140
3.3	Correct Recall of Prices in Experiment 5	141
3.4	Deviation of Incorrect Responses in Experiment 5	142
3.5	Correct Recall of Prices in Experiment 6	143
3.6	Correct Value Category Recall in Experiment 6	144

## **List of Appendices**

<b>Appendix</b>	<b>Page</b>
3.1 Phrases used in Experiment 4	145
3.2 Examples of Items and Prices used in Experiments 5 and 6	146

## **Chapter ONE: GENERAL INTRODUCTION**

There is substantial evidence that aging is accompanied by a variety of changes in memory and related cognitive functioning, with certain kinds of memory showing little or no impairment, while other kinds of memory show much larger impairments (Kester, Benjamin, Castel, & Craik, 2002; Anderson & Craik, 2000; Balota, Dolan, & Duchek, 2000; Zacks, Hasher, & Li, 2000; Park, Lautenschlager, Hedden et al., 1996). Previous research that has examined age differences in memory for associative information has typically found that younger adults outperform older adults in a variety of tasks that involve cued recall and recognition tests of association memory (Kausler, 1994). Early work on associative memory impairments in older adults focused on the production deficiency hypothesis which proposes that older adults' associative memory is impaired because they do not produce potentially effective strategies or mediators between two items relative to younger adults (Kausler, 1994), but more recent research has shown that strategy production accounts for very little of the age-related differences that are evident in associative memory performance (Dunlosky & Hertzog, 1998a).

A reduced resource model of cognitive aging suggests that one reason for older adults' poorer overall episodic memory is an age-related reduction in available attentional resources, which leads to reduced efficiency both at encoding and retrieval (Craik, 1982; Rabinowitz, Craik, & Ackerman, 1982; Craik, 2002; see also Park, Smith, Dudley, & Lafronza, 1988). Chalfonte and Johnson (1996) have suggested that part of older adults' impaired memory performance stems from their reduced efficiency in binding information in working memory into a more coherent complex memory. Similarly, Naveh-Benjamin (2000, 2001) has proposed an associative deficit hypothesis that states

that older adults have poorer overall episodic memory because of a deficiency in creating and retrieving links between single units of information. Furthermore, an age-related decrement in memory for context or the source of information is well established (McIntyre & Craik, 1987; Schacter, Kaszniak, Kihlstrom & Valdiserri, 1991; Spencer & Raz, 1995), suggesting that the binding process may be impaired in old age.

The research presented here examines how item and associative information is remembered by younger and older adults, and how situations of reduced cognitive resources influence the binding process and associative memory. In a series of experiments, different types of associative memory were examined in the context of current theories of cognitive psychology, cognitive aging and cognitive neuropsychology, in order to develop a better understanding of how associative information is encoded and later retrieved, and how this process changes as a function of age. One goal was to test a reduced resource model of cognitive aging by comparing younger adults under situations of divided attention (DA) to older adults under full attention (FA) in terms of memory for associations. A second goal was to determine the factors that influence associative binding, and how these factors can have beneficial or detrimental effects for older adults' memory performance in both laboratory-based tasks and more naturalistic tests of associative memory. In order to address these issues, the theoretical and experimental framework for the current research will be described, followed by a series of experimental investigations of associative memory, as well as a thorough discussion of how the current findings supplement and advance the understand of aging and associative memory.

### Dissociations between Item and Associative Memory

The distinction between item information and associative information has a long history in psychology, and has been treated extensively in both theoretical and empirical studies of human memory (Anderson & Bower, 1973; Hockley, 1992; Hockley & Cristi, 1996; Humphreys, 1976; Murdock, 1982, 1993). Items are typically well-integrated stimuli such as words, letters, numbers and pictures, whereas associative information refers variously to the formation of new items by binding features together, to the links among several items, or to the integration of an event with its source or context of occurrence. The distinction between item and associative memory has been supported by many recent findings. Grunlund and Ratcliffe (1989) have shown that the retrieval of item and associative information have different time courses, and Hockley (1991, 1992; see also Murdock & Hockley, 1989) has demonstrated that item and associative information differ in their rate of forgetting or susceptibility to interference from intervening items. Although memory for item and associative information has been studied in many laboratory-based settings using materials that can be experimentally controlled and manipulated (e.g. word pairs, objects and their spatial locations, faces and facial features), extending this to more everyday associative memory challenges (e.g. remembering the name and occupation of a recently introduced person, remembering an item that was recently purchased and the price of the item, or the dose and frequency of certain medication) is especially critical for older adults.

Although the actual mechanisms involved in forming associative memories are still unknown, the binding process presumably involves the connection of two units or items of information in order to form a new cohesive form that is represented in terms of

associative information. Formal mathematical models have been proposed to account for item and associative memory, with an attempt to conceptualize how information is represented in a quantitative sense. Murdock's TODAM model (Theory of Distributed Associative Memory) uses vectors to explain serial recall and recognition, while SAM (Search of Associative Memory, Raajmakers & Shiffrin, 1981) uses an interconnected feature set (or image) and focuses on modeling free recall and recognition by emphasizing critical properties of a dual-store model of memory. Although many mathematical models attempt to explain associative memory in a precise quantitative manner, the actual mechanisms that give rise to associative memory have not been thoroughly defined, and little attempt has been made to apply these models to situations of divided attention or aging.

At the neuropsychological level, the actual mechanisms of integration or binding that result in the formation of associative information is also poorly understood, although there is considerable evidence that suggests that the hippocampal system is involved in the binding process. In general, the processing of relational information and the binding of items to form associative ensembles have been found to be specifically compromised in amnesic patients in a variety of tasks and settings (Cohen et al., 1999; Eichenbaum, 1999; Ryan et al., 2000; Giovanello, Verfaellie, & Keane, 2003), implying that the hippocampus is critically involved in the formation and maintenance of the relational representations of items. Kroll, Knight, Metcalfe, Wolf, and Tulving (1996) found that patients with left hippocampal damage made more false alarms to recombined verbal stimuli, and that damage to either side of the hippocampus resulted in more conjunction errors in the recognition of face drawings (i.e. errors to stimuli that consisted of

previously studied but recombined features). This result suggests that the hippocampus is a critical component of the neural system that is involved in the appropriate binding of memory components. Rubin et al. (1999) found that neuropsychological tests sensitive to frontal lobe function predicted false alarm rates to information that varied in terms of the degree of associative information for healthy older adults. Furthermore, a standardized memory scale that was sensitive to medial temporal/diencephalic function predicted the pattern of false alarms for healthy older adults in an associative recognition memory paradigm, suggesting that both frontal and medial temporal structures are important in operations that require identifying previously encountered associative information. Using functional magnetic resonance imaging (fMRI), Mitchell et al. (2000) found reductions in hippocampal and frontal lobe activity in older adults in tasks that required binding information in working memory, while Sperling et al. (2002) showed significantly less activation in both superior and inferior prefrontal cortices, as well as less activation in the hippocampal formation in an association encoding task, and that the pattern of fMRI activation during the encoding of novel associations was differentially altered in the early stages of Alzheimer's disease compared with normal aging. Consistent with these findings, it has been suggested that successful binding involves conscious attentional processes mediated by the frontal lobes (West, 1996), as well as more automatic processes mediated by medial-temporal structures (Moscovitch, 2000; Moscovitch & Winocur, 1992). If conscious attentional processing is a prerequisite for binding, then an impairment of such processing should lead to inefficient binding and poor formation of associations.

### Previous Examinations of Associative Memory Impairments

The idea that the impaired encoding and retrieval of associative information leads to a reduction in overall memory performance has been examined in a variety of tasks. It has been suggested that at least some false memories are caused by binding failures, such that components of presented information are inappropriately or incorrectly recombined to form episodes that have not happened (Kroll et al., 1996). These impairments can be studied by presenting information that consists of a number of features at encoding, and then testing the ability to reject information at test that consists of rearranged or recombined features (known as “conjunction” items). The errors that arise from the inappropriate combination of processed information are known as *memory conjunction errors*, and these errors can occur when one encounters faces, pictures, sentences or word pairs (Reinitz, Verfaellie, & Milberg, 1996). Reinitz, Lammers and Cochran (1992) found that participants would often claim to have seen a new stimulus if it had been constructed from parts of previously studied stimuli. For both faces and two-syllable nonsense words, participants made more false alarm responses to conjunction stimuli that were constructed entirely from parts of previously studied stimuli than they did to both partially and completely new stimuli. Reinitz, Morrissey and Demb (1994) found that participants under divided attention were more susceptible to the false claim that conjunction faces were previously seen during an encoding phase, further supporting the notion that attention is needed to encode relational or associative information about features. Similarly, Naveh-Benjamin (2000) showed that normal aging is characterized by a diminished ability to discriminate between correctly and incorrectly re-paired items in a recognition memory test, leading to the suggestion of an “associative deficit



hypothesis” (ADH) as a partial explanation for age-related differences in associative episodic memory.

The associative memory deficit observed in older adults is not limited simply to recognition memory tests. Kahana et al. (2000) found that older adults displayed less temporal proximity of words recalled in a free recall task, relative to younger adults. Temporal proximity was measured by examining how many items were recalled in associated groups (i.e. words that were presented in close serial proximity) relative to recalling single words, without recalling the words that were presented immediately before or after the word in question. This allows for a measure of how well items were bound together at encoding, and older adults showed a greater tendency to recall isolated words rather than groups of words that were presented consecutively (i.e. one after the other) in the study list. This suggests that an associative deficit may be an important contributor to older adults’ impairment in free recall.

There is also a good deal of evidence that suggests that older adults encode more gist-based information, which refers to a highly abstracted and semantic-rich representation of the past, relative to more specific verbatim memory, which is memory for the exact sensory inputs of a given situation in the past. Fuzzy-trace theory, which contrasts the reliance on gist versus verbatim memory, (Brainerd & Reyna, 1990, 1992, 2002) has been examined from an aging perspective, and has led to the observation that the ability to retain verbatim information deteriorates more quickly than the ability to retain gist information as a function of old age (e.g. Schacter, Koutstaal, Johnson, Gross & Angell, 1997; Titcomb & Reyna, 1995; Tun, Wingfield, Rosen & Blanchard, 1998). Research from the false memory literature has also shown selective age-related deficits in

processing and remembering verbatim versus gist information. In the standard Deese/Roediger/McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), older adults are more likely to false alarm to the critical semantic associate (a highly-related member of the semantic class which makes up the study list but was actually not presented at study), than younger adults in both recognition (Norman & Schacter, 1997; Koustaal & Schacter, 1997; Balota et al., 1999) and recall (Kensington & Schacter, 1999; Norman & Schacter, 1997; Tun et al., 1998) tasks. Explanations of this result emphasize either age-related improvements in gist memory or age-related declines in verbatim memory, but this finding suggests that in some situations older adults may actually bind together related units of information at encoding, eventually leading to incorrectly claim that a certain highly related word appeared on a previous study list.

Another way to describe the manner in which item and associative recognition occurs is based on a dual-process model that is used to account for feature and conjunction errors (e.g. Jones, Jacoby, & Gellis, 2001; Jones & Jacoby, 2001). Feature errors refer to incorrectly identifying an item as old because it shares one or more features with a previously studied item, whereas conjunction errors refer to incorrectly identifying an item as old because it is composed of several previously studied features, although these features were never originally paired together during the study phase. According to this dual-process model of recognition, dissociations between old item recognition and feature and conjunction errors support the familiarity-recollection account of recognition memory. Specifically, the ability to recognize previously studied word pairs is based on the processes of familiarity and recollection working in concert,

whereas feature and conjunction errors are based on familiarity in the absence of recollection.

Several sources of evidence suggest that recollective processes are more impaired in old age than familiarity processes (see Light, Prull, LaVoie, & Healy, 2000, for a review). Jones and Jacoby (2001) point out that several manipulations have been shown to affect hit rates but not feature and conjunction error rates after subtracting out the baseline false alarm rates to new words. Interestingly, two of these variables are divided attention at study (Reinitz et al., 1994), and normal aging (Rubin, Van Petten, Glisky, & Newberg, 1999, but also see Kroll et al. 1996). In general, Jacoby, Jennings, and Hay (1996) have shown using the process dissociation procedure that divided attention and aging influence controlled processes such as recollection, while more automatic processes such as familiarity are not affected to the same degree.

#### Reduced Resources and Memory for Associations

One prominent view regarding cognitive aging is that normal aging is accompanied by a reduction in attentional resources ( Craik, 1983; Craik & Byrd, 1982; Craik & Simon, 1980), so it should follow that older adults are less able to bind features together, to form new associations, and to integrate items with their contexts of occurrence. Craik, Govoni, Naveh-Benjamin and Anderson (1996) showed that division of attention at the time of encoding greatly reduced subsequent cued recall for unrelated noun pairs (i.e., the first noun served as the cue for the second) and this reduction may be attributed to a failure to establish an adequate associative linkage between the component items. Park et al. (1988) showed substantial divided attention effects in older adults -

much greater than those observed by younger adults - during encoding, but these age differences were greatly reduced during retrieval under divided attention. Further experiments have shown deficits in memory for contextual information when young adults performed under conditions of divided attention (Troyer & Craik, 2000; Troyer, Winocur, Craik & Moscovitch, 2000). It seems that division of attention and aging have similar effects on memory performance, and these similarities may stem from a reduction in available attentional resources in both cases (Craik 1982, 1983; Rabinowitz, Craik, & Ackerman, 1982). Neuroimaging studies have supported this observation, with both normal aging and division of attention in young adults being associated with similar reductions in left prefrontal cortex activity during encoding (Cabeza et al., 1997; Grady et al., 1995; Anderson et al., 2000; Iidaka, Anderson, Kapur, Cabeza & Craik, 2000; Shallice et al., 1994) supporting a reduced resource model of cognitive aging.

However, there is also evidence that questions the equivalence of aging and divided attention. In a recent series of experiments, Naveh-Benjamin, Guez, Givati and Marom (2001; see also Naveh-Benjamin, 2001, Naveh-Benjamin & Guez, 2002, Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003) found different patterns of impairment between older adults and younger adults working under conditions of divided attention. Specifically, these researchers showed that whereas older adults exhibited a differentially greater decrement (relative to their younger counterparts) in associative information relative to item information, division of attention in younger adults resulted in equivalent deficits in item and associative information. This result was consistently found using a variety of unrelated materials and encoding variables, as well as under various laboratory-based testing conditions (recognition, cued recall, and free recall). In general,

these results are in line with Naveh-Benjamin's (2000) suggestion that aging is particularly detrimental to memory for associative information and suggest that there are distinct differences between aging and division of attention in young adults. One major purpose of the present study was to explore the similarities and differences between divided attention in younger adults and healthy aging in greater detail, especially in terms of memory for associative information.

### Research Overview

If one source for age-related impairments is a reduction in available processing resources, then it may be possible to simulate cognitive aging by testing younger adults under situations of divided attention. The first three experiments examine this issue, using several different types of tasks at encoding and/or retrieval in an associative recognition paradigm. Given that word pair recognition is a fairly controlled laboratory-based associative memory measure, it is also important to examine age-related differences in associative memory by using more naturalistic material and a greater variety of memory tasks. The next series of experiments extends the examination of the binding process to situations that involve memory for specific numerical information (quantity information bound to items), and situations in which numerical information has some semantic value (prices paired with grocery items). Although previous research has shown that older adults display large impairments in memory for associative information (relative to item information), the present series of studies examines this in the context of a model of cognitive aging (by examining reductions in available processing resources in younger adults under divided attention), and in terms of situations in which the binding process is

reinforced or enriched via expertise and reliance on prior knowledge or schematic support. A better understanding of cognitive aging can be achieved by a complete examination of how different types of associative information are processed by younger and older adults (who likely rely on different strategies than younger adults), leading to similarities and differences in terms of memory performance.

In summary, the present set of studies seeks to examine how aging and divided attention lead to memory impairments in terms of the encoding and retrieval of item, context and associative information, and how the ability to bind information into coherent units is influenced by a number of different factors that change over the adult life span. Given that associative information is important to remember reliably in many contexts (in both laboratory memory tests and more naturalistic memory-challenging tasks), it is important to assess how aging influences the ability to remember associative information in a variety of tasks and situations. This series of experiments examines aging and associative memory performance on tests that involve learning and remembering new and somewhat arbitrary associations, such as word pairs, as well as associative memory tests that incorporate some degree of knowledge and prior experience, such as remembering prices of recently studied grocery items. It is likely that the age-related differences observed in many episodic memory studies are affected both by changes in the ability to efficiently encode and retrieve associative information and by differences in materials and modes of presentation and testing.

## **CHAPTER TWO: DIVIDED ATTENTION AND MEMORY FOR ASSOCIATIVE INFORMATION**

### **Experiment 1A**

Is it the case that aging has a differentially greater negative effect on associative information than on item information, whereas division of attention in younger adults equally affects both types of information to the same degree? To examine these issue three groups of participants [younger adults under full attention, younger adults under divided attention (DA), and older adults under full attention (FA)] were presented with unrelated word pairs during an encoding phase, and were then given two recognition tests. Participants were presented with four types of word pairs during the recognition tests: old word pairs, word pairs containing two previously presented words but that were never presented together as a pair (conjunction pairs), word pairs with one old word and one new word (item pairs), and word pairs that contained two new words (new pairs). Participants who participated in the divided attention condition also engaged in a secondary digit-monitoring task during the encoding phase only. In the word pair recognition test, participants were asked to identify old word pairs that they had previously seen during the encoding phase. The pattern of "old" responses for the old and conjunction word pairs for the three groups of participants was of primary interest. If older adults and younger adults under divided attention conditions had difficulty processing the association between the two words during encoding, then they should show a higher number of old responses (false alarms) to conjunction word pairs, and a lower number of old responses (hits) to old word pairs, relative to the younger full attention participants. Thus, if both older adults and younger adults under divided

attention encoded the words (i.e. the single units of information), but had greater difficulty remembering the associations, then both groups should show a similar pattern of results. However, if older adults have particular difficulty encoding and retrieving associative information, which is over and above what a “general” processing resource deficit would predict (as suggested by Naveh-Benjamin, 2000; 2001), they should be less able than divided attention younger adults to discriminate between old (original) and conjunction (recombined) word pairs.

To test for the retention of item information under conditions similar to those used for associative information, participants were given a similar recognition test (consisting of the same four types of word pairs as those used in the associative memory test), but in this case participants decided whether they had previously seen the second word in a presented pair during the encoding phase. In this item test, therefore, both old pairs and conjunction pairs were potential hits, as the second word had occurred previously. In contrast, only old pairs were potential hits for the associative test; all other test types were potential false alarms. If pairs presented during encoding are represented as A-B and C-D, and if words not presented at study are represented as X, Y and Z, then the four types of test pairs may be represented as A-B (old), A-D (conjunction), A-X (item), and Y-Z (new). For the associative test only A-B test pairs should be judged "old" whereas for the item test both A-B and A-D pairs should be judged "old".

A further benefit of this design in the case of item information is that the effects of context on the recognition of items can be examined. Both A-B pairs (old) and A-D pairs (conjunction) include old items (B and D), but recognition of B may be superior given that it is presented in the same pair context (A-B) at test as at encoding. Such a



result would be in line with previous findings in this paradigm (Humphreys, 1976, 1978; Light & Carter-Sobell, 1970; Tulving & Thomson, 1973; but see also Koutstaal, 2003), and the extent of the superiority of A-B over A-D would provide a measure of the extent to which participants use context information to enhance recognition performance. If younger adults bind items to their contexts (at encoding) more successfully than either older adults or young adults under divided attention, it would be expected that the superior recognition of B over D would be greatest for younger adults working under full attention conditions. This allows for an examination of the effects of aging and divided attention on possible differences between recognition of context (i.e., Old vs. Conjunction pairs in the case of pair recognition) and utilization of context (i.e., Old vs. Conjunction pairs in the case of item recognition). Furthermore, we were interested in examining the effect of the overall similarity of lures on pair recognition; for example, would participants be more likely to make false alarms as the test pairs went from new (Y-Z) to item (A-X) to conjunction (A-D) pairs, and would any such trend differ for younger and older adults?

## **Method**

### Participants

In total, 64 undergraduate students from the University of Toronto (52 women and 12 men, mean age = 21.3 years, mean number of years of education = 13.8) volunteered to participate and received course credit for their participation. Participants were randomly assigned to participate in either the full or divided attention condition, such that 32 students participated in each condition. Thirty-two older adults (19 women

and 13 men, mean age=70.3 years, mean number of years of education = 14.3) also participated in the study, and were paid \$10 for their participation. The older adults tested in this experiment and in Experiment 2 were high functioning and in good health; they lived in the community and made their own way to the laboratory to participate.

### Materials

The words presented in the encoding task were 260 two-syllable common concrete nouns that were randomly paired to form 130 word pairs (e.g. A-B or C-D). Each participant was presented with 130 word pairs during the encoding phase. The word pairs were visually presented in a completely randomized order (separately for each participant) in the centre of a 17-inch IBM computer screen. Each pair was presented for 4 seconds, with a 500 ms gap between presentations. In each of two recognition tests, 80 word pairs were presented in a randomized order. The word pairs in the recognition tests consisted of previously seen, old word pairs (A-B or C-D), recombined pairs that contained two words that were previously seen, but not together (A-D), pairs that contained one previously seen word in the first position and one new word in the second position (A-X) and word pairs that contained two new words (Y-Z). Each word had an equal likelihood of appearing in each of the four types of word pair, such that four different types of trials were constructed with the word being rotated through each of the four types of word pairs. In all cases, if an old word appeared at test, it was presented in the same pair position (first or second word in the pair) as it was in the encoding phase. Twenty of each of the four types of word pairs were presented in a random order of 80 word pairs, and the presented word pair disappeared from the screen either after the

participant made a response, or after four seconds had elapsed. The experiment was programmed using Mel2 (Schneider, 1990), and each participant was tested individually.

The digit-monitoring task consisted of an auditory presentation of single digits ranging from 0 to 9 in a random order. Twelve hundred digits were spoken by a female voice and recorded on a tape recorder at a rate of one digit every 1.5 seconds, producing a thirty minute long recording. The participant's task was to monitor the series of digits for targets defined as "three successive odd digits" (e.g. 391, 951, 737 etc.) and to report the targets to the experimenter. The digits occurred in a random order, with the following constraints: The recording included 80 target sequences, defined as three consecutive odd digits. The first 60 targets were unique, and the last 20 targets were repeated from the beginning of the recording. The lags between target sequences ranged from 6 to 19 digits, with a mean lag of 12.5 digits.

### Procedure

Younger participants were randomly assigned either to the full attention condition or to the divided attention condition. Older adults performed the memory task under full attention conditions only. Before the encoding task, participants were given instructions regarding the experiment. They were told that they would be presented with word pairs, and were asked to try to remember the words, as well as how they were paired with one another, for a later memory test.

In the divided attention condition, the digit monitoring task was described to the participants. The participants were instructed to listen to the recording of digits, and to identify sequences that contained three consecutive odd digits (e.g. 573) by repeating the target sequences aloud so that the experimenter could record their responses. Before the

encoding phase began, participants practiced the digit-monitoring task until they correctly identified two consecutive target sequences. Participants performed the digit-monitoring task during the encoding phase only, and not during the recognition tests.

After the encoding phase, participants were given two recognition tests in counterbalanced order. Each test consisted of 80 word pairs, as described above in the Materials section. In one test, participants were asked if they had seen the presented word pair during the encoding phase (the WORD PAIR recognition test). That is, participants should answer "yes" only if the same words had occurred in the same order as members of a pair in the initial presentation. A second test involved determining if they had seen the SECOND word in the presented word pair during the encoding phase (the SINGLE WORD recognition test). In the word pair recognition test, participants were told they would be presented with a word pair, and they should read the word pair aloud and then decide if they had seen the entire word pair during the encoding phase. Participants were instructed to press the "z" key on the keyboard (labeled "yes") if they had previously seen the word pair in the encoding phase, or the "n" key on the keyboard (labeled "no") if they had not seen the word pair in the encoding phase. In the single word recognition test, participants were told that a series of word pairs would be presented, and that they should read each word pair aloud. This time, however, they were asked to decide if they had seen the SECOND word in the pair during the initial encoding phase. That is, they should respond "yes" if the second word had appeared anywhere in the original encoding list, regardless of its original pairing. Again, participants were instructed to press the "z" key on the keyboard (labeled "yes") if they had previously seen the second word during the encoding phase, or the "n" key on the keyboard (labeled "no")

if they had not seen the word during the encoding phase. These two recognition tests were presented in counterbalanced order, and none of the words in the word pair recognition test appeared in the single word recognition test. In each test, participants had up to four seconds to make a response, and the next trial began either after a response was made, or after the four seconds had elapsed.

### **Results and Discussion**

The results for the word pair recognition test and for the single word recognition tests are displayed in Table 1. In both cases, the proportions of “old” responses to each of the four types of word pairs are shown in Table 2.1. In Figures 2.1 and 2.2 (for word pair and single word tests respectively), false alarms to new word pairs (Y-Z) were subtracted from the proportions of old responses to the three other types of word pair, in order to take into account the possibility of differing response bias for the three groups (see Jones & Jacoby, 2001 for a similar procedure). The data presented in Figures 2.1 and 2.2 are referred to as corrected recognition scores. Performance on the digit-monitoring task for participants in the divided attention condition was measured in terms of the proportion of target sequences correctly identified. The mean number of target sequences to which the participants were exposed was 18.3, and the mean proportion of correctly identified sequences was .81 ( $SD = .15$ ).

[Insert Table 2.1, Figures 2.1 and 2.2 about here]

#### Word pair recognition

In the word pair recognition test, old responses to previously seen word pairs were considered hits, whereas old responses to the three other types of word pairs (conjunction, item, and new word pairs) constitute three types of false alarms. Table 2.1

shows that the distribution of old responses to the four types of word pairs followed a similar pattern to that observed in other studies using a similar paradigm (Reinitz et al., 1994; Kroll et al., 1996; Rubin et al., 1999). Table 2.1 shows that both older adults and younger adults under divided attention conditions during encoding (young-DA) were more likely to make false alarms to conjunction word pairs, relative to full attention younger adults. However, it also appears that older adults made more false alarms to the conjunction word pairs than did the young-DA group, suggesting differences in performance between these two groups.

The corrected recognition scores plotted in Figure 2.1 show that the older adult group still made more false alarms than the other two groups, despite the subtraction of "new" false alarms. It is not surprising that the young full attention group made the fewest false alarms, yet had the highest hit rate on old (A-B) pairs. A 3 (group) x 3 (word pair type) analysis of variance (ANOVA) was conducted on the data shown in Figure 2.1, and found a significant main effect for word pair type,  $F(2, 186) = 190.1, MSE = .018, p < .0001$ , and group,  $F(2, 93) = 12.4, MSE = .047, p < .0001$ . The interaction was also significant,  $F(4, 186) = 20.1, MSE = .018, p < .0001$ . To compare the gradient of responses for older adults and the young-DA group, a 2 (group) by 3 (word pair type) analysis was conducted. A significant main effect was found for word pair type,  $F(2, 124) = 67.6, MSE = .019, p < .0001$ , and group,  $F(1, 62) = 19.1, MSE = .060, p < .001$ , as well as a significant interaction between word pair type and group,  $F(2, 124) = 7.98, MSE = .019, p < .01$ . To examine the use of associative information in recognition performance, a further 2 (group: old and young-DA) x 2 (word pair type: old-new and conjunction-new) ANOVA was carried out in order to see if an interaction was present.

There were significant main effects of word pair type,  $F(1, 62) = 40.33$ ,  $MSE = .020$ ,  $p < .0001$ , and group,  $F(1, 62) = 21.85$ ,  $MSE = .059$ ,  $p < .0001$ , as well as a just-significant interaction between word pair type and group,  $F(1, 62) = 3.97$ ,  $MSE = .020$ ,  $p = .05$ .

These findings support the conclusion that younger adults whose attention was divided at encoding and older adults showed a different pattern of results on this test of associative information, and support the conclusion that older adults are particularly susceptible to errors in associative recognition, but it should be noted that older participants had a greater tendency to respond positively to both old and conjunction pairs.

### Single word recognition

In the single word recognition test, old responses to word pairs in which the second word had been previously presented were considered hits (old word pairs and conjunction word pairs), whereas old responses to the two other types of word pairs (item and new word pairs) constituted two types of false alarms. The results from the single word recognition test were again analyzed by taking into account the different false alarm rates to the new words for the three groups of participants. False alarms to new word pairs were subtracted from the proportion of old responses to the three other types of word pairs, and the results are plotted in Figure 2.2. A 3 (group) x 3 (word pair type) ANOVA was conducted, and significant main effects were found for word pair type,  $F(2, 186) = 211.97$ ,  $MSE = .016$ ,  $p < .0001$ , and group,  $F(2, 93) = 11.83$ ,  $MSE = .068$ ,  $p < .001$ . The interaction was also significant  $F(4, 186) = 17.39$ ,  $MSE = .016$ ,  $p < .0001$ . In order to compare the performance of older adults and the young-DA group on the two types of word pairs that constituted hits, a 2 (group: older adults and young-DA) by 2 (word pair type: conjunction and old) ANOVA was conducted. In this case, the main

effect of word pair type was significant,  $F(1, 62) = 6.98$ ,  $MSE = .091$ ,  $p < .05$ , as was the effect for group,  $F(1, 62) = 17.82$ ,  $MSE = .068$ ,  $p < .001$ , but there was no significant interaction ( $F < 1$ ). This result shows that older adults performed somewhat better than the divided attention group, and that both groups used context information to some degree, but there was no differential benefit for either group. In contrast, the young adults who encoded the pairs under full attention showed a marked improvement in hit rates from conjunction to old. To further illustrate this result, a measure of the utilization of context information was derived by subtracting the probability of responding “old” to a word in a conjunction pair (context absent) from the probability of responding “old” to a word in an old word pair (context present). This measure led to a “context utilization score” of .15 for the full attention group, .05 for the divided attention group, and .03 for the older adults. These scores were entered in a one-way ANOVA with the context utilization score as the dependent measure, and a significant between groups effects was found,  $F(2, 95) = 5.21$ ,  $MSE = .013$ ,  $p < .01$ . Follow-up post hoc tests (least significant difference) revealed that the older adults and the divided attention group did not differ significantly from one another ( $p > .50$ ), but both groups differed from the full attention group ( $p < .05$ ).

Previous researchers have suggested various reasons for the beneficial effects on recognition of maintaining the original pairing. The encoding specificity hypothesis put forward by Tulving and Thomson (1973) suggests that a word is encoded with a specific nuance of meaning when it is presented in the context of a paired word (e.g. whisky – WATER) and that the word is less likely to be recognized at test if the paired word is changed (e.g. lake – WATER), essentially because its subtle meaning has been changed.



This type of explanation was also offered by Light and Carter-Sobell (1970). Humphreys (1976, 1978) took a different approach, suggesting that recognition of the second word in a pair depends on two types of information, item and relational, and that the benefit of the relational information is lost if the word is presented in a new pairing at test. The present finding that neither older adults nor young-DA adults showed much benefit of A-B over A-D test presentations can thus be construed either as their inability to use relational information or as their relative indifference to changes in the subtle encoded meaning of the second word. This processing inefficiency on the part of the older and young-DA participants is presumably attributable partly to poorer encoding of the second word in its specific context, and partly to less efficient use of contextual and relational information at the time of retrieval. In this instance, division of attention and aging have the same effects.

#### Discriminability Analysis

With respect to the question of whether the increasing similarity of lures to targets (Y-Z vs. A-X vs. A-D) would have differential effects on the groups' liability to make false alarm responses, Figure 2.3 shows the difference scores for word pair recognition between Old pairs and New, Item, and Conjunction pairs, respectively. That is, Figure 2.3 plots the three groups' ability to discriminate presented word pairs (A-B) from three types of lures, of increasing similarity to presented pairs (i.e., Y-Z, A-X, and A-D respectively). Figure 2.3 shows that the ability to discriminate targets from lures declined for all three groups from New to Conjunction pairs; it also shows (in line with the previous discussion) that the older adults and the young-DA group discriminated less well than the young full attention group. Of greatest interest, the figure shows that the

decline in discriminability for the young-DA group was parallel to that of the young full attention group, but that the decline for the older adults was steeper. Increasing similarity of lures had a larger negative effect on discriminability for older adults than for either group of younger adults. This observation was demonstrated by the results of a 3 (groups) x 3 (word pair type) ANOVA on the data shown in Figure 2.3. The effect of group was significant,  $F(2, 94) = 27.6$ ,  $MSE = .11$ ,  $p < .0001$ , as was the effect of word pair type,  $F(2, 188) = 78.05$ ,  $MSE = .13$ ,  $p < .0001$ . The interaction between group and pair type was also significant,  $F(4, 188) = 6.84$ ,  $MSE = .13$ ,  $p < .0001$ . Subsequent 2 x 3 ANOVAS involving pairs of groups (young and young-DA, old and young-DA, young and old) revealed a significant interaction between group and word pair for the young-DA and old comparison,  $F(1, 124) = 7.51$ ,  $MSE = .012$ ,  $p < .001$ , and for the comparison between the full attention younger group and the older group,  $F(1, 124) = 53.7$ ,  $MSE = .011$ ,  $p < .0001$ , but not for the comparison between both younger groups,  $F < 1$ .

[Insert Figure 2.3 about here]

### Comparing Item and Associative Deficits

The experiment yielded various possible measures of memory for item information. In order to determine how well participants could recognize previously studied single words, one can measure the ability to discriminate old words (e.g. D in the A-D pair) from new items (e.g. Z in the Y-Z pair). It would also be possible to use the B item in the A-B pair, but it has been shown that the context provided by the A item influences the response for the B item. Thus, perhaps the most representative measure of item memory is the subtraction of new pairs (Y-Z) from conjunction pairs (A-D) in the single word recognition test. That is, “yes” responses to Y-Z pairs were treated as false

alarms, and correct “yes” responses to A-D pairs were taken to measure hit rates. It is possible to take old pairs (A-B) as a measure of hit rate, but Figure 2.2 makes it clear that only the younger adults working under full attention profited significantly from the reinstatement of the original pair context in the A-B condition. It is also possible to take A-X pairs as a measure of false alarms, but given the older adults’ high false alarm rate on such pairs (.30), we concluded that this measure would yield a misleadingly low estimate of item information for the older adults. The measure of the deficit in item information from the level achieved by the younger adult group was thus given by the differences between full attention young adults on the one hand, and older adults and the younger-DA group on the other hand. The scores represent the difference between the two groups, relative to the younger full attention group. These differences are depicted in the Conjunction minus New condition of Figure 2.2, and were -.01 and .21 for the older adults and young-DA adults respectively.

The measure of associative information was taken to be the difference between Old and Conjunction word pairs in the word pair recognition test. For other contrasts (e.g., between Old pairs, A-B, and New pairs, Y-Z) the decision could be made on the basis of item information. That is, the participant was asked to judge if that exact word pair had been seen in the presentation list, and so could respond “no” if he or she detected one or more completely new items. The measure of the deficit in associative information relative to the young full attention group is thus depicted by the differences between the young full attention group and the other two groups for the Old minus Conjunction condition shown in Figure 2.3. These differences were .24 for the older adults and .34 for the young-DA adults.

To obtain distributions of deficit scores for the older adults and young-DA adults, each person's score for item information and associative information was subtracted from the mean of the young adults' (full attention) scores for the relevant condition. A 2 by 2 ANOVA on these difference scores showed a significant effect of type of information,  $F(1, 62) = 65.86$ ,  $MSE = .018$ ,  $p < .0001$ , a significant effect of group,  $F(1, 62) = 14.92$ ,  $MSE = .058$ ,  $p < .0001$ , and, most importantly in terms of theoretical interest, a significant interaction between group and type of information,  $F(1, 62) = 5.96$ ,  $MSE = .018$ ,  $p < .05$ . That is, both groups showed a greater deficit in associative information than in item information, and the two groups differed in the amount of deficit shown. The observation of a relatively greater deficit in associative information in the group of older adults is in line with the previous work reported by Naveh-Benjamin (2001, Naveh-Benjamin et al., 2002), in which older adults show a relatively greater deficit in associative information compared to the young-DA group. The present results differ from those of Naveh-Benjamin and colleagues, however, in that the young-DA group also showed a greater deficit in associative than in item information (.34 vs. .21, respectively). This difference was statistically reliable,  $t(31) = 4.66$ ,  $p < .001$ . The present findings thus differ from those of Naveh-Benjamin and his colleagues in that *both* divided attention and aging were associated with greater deficits in associative than in item information, but the two sets of findings agree that aging is associated with a differentially greater negative effect on the recognition of associative information.

## Experiment 1B

The results from Experiment 1A show that there are some interesting similarities and differences between older adults and younger adults who studied word pairs under divided attention. However, there are two important issues to address before definitive conclusions can be drawn. First, if divided attention mimics aging because both cases involve a reduction in processing resources relative to young adults, it may be important to bear in mind that attention was divided at encoding only in Experiment 1A, whereas processing resources are supposedly reduced at all times in older adults – during both encoding and retrieval. Thus, in order to serve as an accurate model of aging, it may be more appropriate to have the divided attention group engage in the secondary task both at encoding and at retrieval. Second, it is evident from the memory performance of the divided attention group that the secondary task used in Experiment 1A was very demanding, resulting in much poorer memory performance overall relative to the older adults. It would be preferable to have the young-DA and older adult groups performing equivalently to rule out the possibility of differential effects on item and associative information simply as a function of performance level. To address this issue, we chose an easier divided attention task (identifying the digit “9” in a string of auditorily presented random digits) that participants performed during both encoding *and* retrieval. Pilot testing showed that this task should yield performance levels close to those shown by older adults in Experiment 1A. Other than these two modifications, the paradigm was exactly the same as that used in Experiment 1A.

## **Method**

### Participants

Thirty-two undergraduate students from the University of Toronto (27 women and 5 men, mean age = 20.1 years, mean number of years of education = 14.1) volunteered to participate and received course credit for their participation. All participants were in the divided attention condition - the only condition in the present study.

### Materials & Procedure

The materials and procedure were identical to those used in Experiment 1A; the only exception was the modified secondary task, which participants performed both at encoding and retrieval. The digit-monitoring task consisted of an auditory presentation of single digits ranging from 0 to 9 in a random order. Twelve hundred digits were spoken by a female voice and recorded on a tape recorder at a rate of one digit every 1.5 seconds, producing a thirty minute long recording. The participant's task was to monitor the series of digits for targets, defined as the digit "9", and to report the digit's occurrence by repeating it aloud. Digits occurred in a random order, and the lags between target digits ranged from 2 to 16 digits, with a mean lag of 7.2 digits. The experimenter monitored performance on the task.

## **Results and Discussion**

The results for the word pair recognition test and for the single word recognition tests are shown in Table 2.1 under the heading Experiment 1B. The corrected recognition scores are displayed in Figures 2.1 and 2.2, for word pair and single word tests respectively, in order to allow for a direct comparison to the groups in Experiment 1A.

Performance on the digit-monitoring task was measured in terms of the proportion of target digits correctly identified. The mean number of targets to which the participants were exposed in total was 58.7 (encoding and recognition), and the mean proportion of correctly identified targets was .94 during the encoding phase, .85 during the word pair recognition test, and .84 during the single word recognition test.

### Word pair recognition

The main contrast of interest is between the present young-DA group and the older adults from Experiment 1A. Therefore, a 2 (group) by 3 (word pair type) ANOVA was carried out on the corrected recognition scores shown in Figure 2.1. This analysis revealed an effect of word pair type,  $F(2, 124) = 143.40$ ,  $MSE = .20$ ,  $p < .001$ , no main effect of group,  $F(1, 62) = 2.22$ ,  $MSE = .25$ ,  $p > .05$ , but a significant interaction,  $F(2, 124) = 4.99$ ,  $MSE = .20$ ,  $p < .01$ . This last effect reflects the fact that hit rates were approximately equivalent between the groups, but that the older participants made more false alarms. A further analysis between the same groups but including only the ‘old minus new’ and ‘conjunction minus new’ scores showed a significant main effect for word pair type,  $F(1, 62) = 117.14$ ,  $MSE = .23$ ,  $p < .0001$ , but not for group,  $F < 1.6$ ,  $MSE = .060$ ,  $p > .05$ . Of greatest interest in terms of the purpose of this study, the interaction was significant,  $F(1, 62) = 8.77$ ,  $MSE = .023$ ,  $p < .01$ , indicating that the older adults were more likely to generate false alarms to the conjunction word pairs.

### Single word recognition

Again, the pattern of data shown in Table 2.1 for the present divided attention group was similar to that of the previous divided attention group, but showed much

higher levels of performance. In order to compare how the present divided attention group performed relative to the older adults from Experiment 1A, a 2 (group) x 3 (word pair types) ANOVA was conducted using the corrected recognition scores shown in Figure 2.2. In this case, there was a significant main effect of word pair type,  $F(2, 124) = 126.16$ ,  $MSE = .019$ ,  $p < .0001$ , but no main effect of group,  $F < 1$ , and no significant interaction,  $F < 1$ . Since there is no main effect of group, it appears that the choice of a less demanding secondary task successfully brought the memory performance of the divided attention group to a more suitable and comparable level to that of the older adults, relative to the overall poor performance of the divided attention group in Experiment 1A.

In terms of the context utilization score that was mentioned previously (derived by subtracting “old” responses to conjunction pairs from “old” responses to old pairs in the single word recognition test), the divided attention group in the present study displayed a score of .09. This score suggests that the context provided by the first word (in old word pairs) was somewhat useful when the participants were attempting to recognize the second word, and this score was greater than those shown by both the divided attention group and the older adults in Experiment 1A, likely due to the less demanding secondary task in the present experiment. When deficits in performance were measured relative to the levels shown by the young full attention group in Experiment 1A, these values were .03 for item recognition and .09 for associative recognition. The greater drop in associative information was only marginally significant,  $t(31) = 1.87$ ,  $p = .07$ , although it was in the same direction as the results from Experiment 1A. Both deficits were small, again due to the much easier secondary task.



### Discriminability Analysis

With respect to the question of whether the increasing similarity of lures (Y-Z vs. A-X vs. A-D) would have differential effects on the groups' liability to make false alarm responses, Figure 2.3 shows the difference scores for word pair recognition between Old pairs and New, Item, and Conjunction pairs, respectively. It is evident from this figure that the decline in discriminability for the DA group in the present study is parallel to that of the young full attention group and to that of the divided attention group from Experiment 1A, but again the decline for older adults is steeper. Of greatest interest is the comparison between the divided attention group from the present study and the older adults from Experiment 1A. A 2 (group) x 3 (word pairs type) ANOVA showed a significant main effect for word pair type,  $F(2, 124) = 62.25$ ,  $MSE = .012$ ,  $p < .0001$ , but only a marginal effect for group,  $F(1, 62) = 3.0$ ,  $MSE = .014$ ,  $p = .08$ . Of most importance, the interaction between group and word pair type was significant,  $F(2, 124) = 5.86$ ,  $MSE = .012$ ,  $p < .01$ . Thus, as shown in the previous study, increasing similarity of lures had a larger negative effect on discriminability for older adults than for younger adults working under divided attention conditions.

### **Experiment 2A**

Experiment 1 showed that there were not only similarities between the effects of aging and divided attention on memory for item and associative information, but also some marked differences between the two variables. In the first category, both aging and divided attention reduced performance relative to the levels shown by younger adults, and both groups showed a reduced benefit associated with context reinstatement (A-B vs.

A-D pairs) in the item recognition paradigm. In contrast, whereas the effect of divided attention was primarily seen as a reduction in hit rates with relatively small increases in false alarm rates, the effects of aging was seen most dramatically in the older group's greatly increased false alarm rates in pair recognition, especially when lures were most similar to targets (see Table 2.1, and Figures 2.1 and 2.3). Secondly, when pair recognition scores were plotted as the ability to discriminate between distracter pairs and targets (Figure 2.3), the divided attention groups' functions were parallel to the function associated with the young full attention group, but the older adults' function was steeper, reflecting their particular difficulty in discriminating A-D from A-B pairs. Finally, the analyses of deficits in item and associative information relative to the young full attention group found that the older adults showed differentially greater deficits in associative than in item information. These findings are in line with the evidence presented by Naveh-Benjamin and colleagues (2001, 2002) and with the associative deficit hypothesis of aging (Naveh-Benjamin, 2000). However, the findings are not in line with the suggestions by Craik (1982, 1983, Craik & Byrd, 1982) that the effects of aging can be mimicked in all respects by division of attention. It was therefore considered important to replicate the main findings of Experiment 1 by using a slightly different design before formulating a changed or an amended position.

In Experiment 2A we tested young adults only, and used a within-subject design. Each person participated in three consecutive blocks: (a) full attention at both encoding and recognition, (b) divided attention at encoding and full attention at recognition, and (c) divided attention at both encoding and recognition. Given that the main results of interest from Experiment 1 concerned associative information, participants were given only the

word pair recognition test in each block. We also introduced a secondary task that was slightly less demanding than the one used in Experiment 1A, but slightly more demanding than the one used in Experiment 1B. The task in the present study involved identifying *two* consecutive odd digits from a continuous auditory stream of digits. To round out the design, we tested a group of older adults and an additional group of younger adults working under full attention conditions in all three blocks; the design and results are presented as Experiment 2B.

## **Method**

### Participants

Twenty-seven undergraduate students from the University of Toronto (19 women and 8 men, mean age = 19.3 years, mean number of years of education = 14.2) volunteered to participate and received course credit for their participation. All volunteers participated in each of the three blocks.

### Materials

The materials were identical to those used in Experiment 1A, except for the use of a modified secondary task. Study and recognition lists were somewhat shorter than in Experiment 1A, and only the associative recognition test was given after each study phase.

The modified digit-monitoring task consisted of an auditory presentation of single digits ranging from 0 to 9 in a random order. Twelve hundred digits were spoken by a female voice and recorded on a tape recorder at a rate of one digit every 1.5 seconds, producing a thirty minute long recording. The participant's task was to monitor the series of digits for targets, to listen for the presence of two consecutive odd digits, and to report

the presence of these digits to the experimenter by repeating them aloud. The digits occurred in a random order, and the lags between target digit sequences ranged from 4 to 15 digits, with a mean lag of 9.6 digits.

### Procedure & Design

The procedure was similar to that used in the previous experiments, except for the within-subject design, the modified secondary task, and slightly shorter list lengths for each block. The order of the blocks was counterbalanced across participants such that each block occurred in each of the three positions an equal number of times. Each study phase consisted of 45 original word pairs (none of the words were repeated in a subsequent study phase for the participant), and each recognition test consisted of 60 word pairs (15 of each type: old, conjunction, item, and new). Participants were given instructions regarding the study and the presence or absence of the secondary task prior to the beginning of each block.

### **Results and Discussion**

The results of the word pair recognition test for each condition are displayed in Table 2.2 (under the heading Experiment 2A). The corrected recognition scores are displayed in Figure 2.4. Performance on the digit-monitoring task was measured in terms of the proportion of target sequences correctly identified. The mean number of target sequences to which the participants were exposed in each block was 7.8 during encoding, and 8.9 during recognition. The mean proportion of correctly identified sequences was .81 for divided attention at encoding only, .85 during the encoding phase of the divided attention at encoding and recognition condition, and .55 during the recognition phase of

this last-named condition. The finding of poorer secondary task performance at retrieval than at encoding is consistent with results from other studies (e.g. Craik et al., 1996).

[Insert Table 2.2 and Figure 2.4 about here]

### Word Pair Recognition

The corrected recognition scores are shown in Figure 2.4. The pattern of results replicated the pattern for the corresponding conditions in Experiment 1A; that is, the participants in the full attention condition made few false alarms on the Item-New and the Conjunction-New conditions, and achieved a substantial hit rate on the Old-New condition. The two young-DA conditions yielded almost identical results, so dividing attention at retrieval as well as at encoding made very little difference. Both DA conditions showed substantially lower hit rates than the full attention condition, however, but very little increase in false alarm rates. These observations were demonstrated by the results of a 3 (attention conditions) by 3 (word pair type) ANOVA on the data shown in Figure 2.4. The analysis yielded significant effects of attention condition,  $F(2, 78) = 6.52$ ,  $MSE = .033$ ,  $p < .01$ , of word pair type,  $F(2, 156) = 177.77$ ,  $MSE = .026$ ,  $p < .001$ , and of the interaction,  $F(4, 156) = 17.37$ ,  $MSE = .026$ ,  $p < .001$ . A similar analysis carried out to compare the two divided attention conditions yielded a significant effect of word pair type,  $F(2, 104) = 59.09$ ,  $MSE = .025$ ,  $p < .001$ , but no main effect of condition, and no interaction (both  $F_s < 1$ ).

### Discriminability Analysis

In order to examine whether the increasing similarity of lures (Y-Z vs. A-X vs. A-D) had differential effects on false alarm responses in the various conditions, Figure 2.5 shows the difference scores for word pair recognition between Old pairs and New, Item,

and Conjunction pairs, respectively. This analysis allowed for a comparison of the pattern of results with the groups tested in the previous experiments; the main point to observe in Figure 2.5 is that all three conditions in Experiment 2A show parallel effects with respect to word pair type. A 3 (condition) by 3 (word pair type) ANOVA showed a significant main effect of word pair type,  $F(2, 156) = 42.82$ ,  $MSE = .008$ ,  $p < .0001$ , and for condition,  $F(2, 78) = 21.20$ ,  $MSE = .18$ ,  $p < .0001$ . Of greatest importance, the interaction between condition and word pair type was not significant,  $F(4, 156) < 1$  (and note that these analyses only included the conditions from Experiment 2A). As in Experiment 1 then, the effect of divided attention was to reduce discriminability, but not differentially as a function of word pair type. The next comparison of interest was how older adults performed in terms of discriminability. In order to provide a group of older adults who participated under similar conditions, Experiment 2B was conducted, and the relevant discriminability analysis is presented in the following results section.

[Insert Figure 2.5 about here]

### **Experiment 2B**

To provide an appropriate comparison with the divided attention conditions (i.e. a within-subject design) of Experiment 2A, a group of older adults was tested in a similar design to that of Experiment 2A, but under full-attention conditions. Furthermore, an additional group of young adults was tested under the same full-attention conditions. Specifically, both the younger adults and the older adults in the present experiment participated in three identical blocks (each block consisted of encoding under full attention, and an associative recognition test under full attention), in order to compare their performance with that of the participants in Experiment 2A.

## Method

### Participants

Twenty undergraduate students from the University of Toronto (15 women and 5 men, mean age = 22.7 years, mean number of years of education = 16.0) volunteered to participate and received course credit for their participation. Twenty older adults (8 women and 12 men, mean age = 71.2 years, mean number of years of education = 14.6) also participated in the study, and were paid \$10 for their participation. The older adults tested in this experiment were high functioning and in good health; they lived in the community and made their own way to the laboratory to participate.

### Materials & Procedure

The materials and procedure were identical to those used in Experiment 2A, with the exception that each block was completed under full attention for both the younger and the older adults. All participants were tested on all three blocks.

## Results and Discussion

The results for word pair recognition performance for both groups are displayed in Table 2.2 (under the heading Experiment 2B). The corrected recognition scores are shown in Figure 2.4. Since the purpose of including these two groups was to compare their performance to that of the divided attention conditions in Experiment 2A, specific ANOVAs were carried out. In order to compare performance between the divided attention at both encoding and recognition condition from Experiment 2A to the older adults in the present study, a 2 (group) by 3 (word pair type corrected scores) ANOVA was conducted. There were significant main effects of word pair type,  $F(2, 104) = 122.6$ ,

$MSE = .021$ ,  $p < .0001$ , and group,  $F(1, 502) = 33.47$ ,  $MSE = .031$ ,  $p < .0001$ , as well as a significant interaction between word pair type and group,  $F(2, 104) = 6.78$ ,  $MSE = .021$ ,  $p < .0001$ . From Figure 2.4, it may be seen that the interaction reflected similar false alarm rates between the groups for Item-New pairs, but greater probabilities of “old” responses in the older adult group for both Conjunction-New pairs (false alarms) and Old-New pairs (hits). A closer examination of memory for associative information involves comparing “old” responses to the old and conjunction word pairs. A 2 (group) by 2 (word pairs type, old and conjunction corrected recognition scores) ANOVA showed significant main effects for word pair type,  $F(1, 52) = 68.87$ ,  $MSE = .029$ ,  $p < .0001$ , and group,  $F(1, 52) = 33.22$ ,  $MSE = .038$ ,  $p < .0001$ , but no interaction ( $F < 1$ ).

#### Discriminability Analysis

As in the previous studies, difference scores for word pair recognition between Old pairs and New, Item, and Conjunction pairs are presented in Figure 2.5, and provide a measure of discriminability. The purpose of the present experiment was to see how older adults compared with the younger adults from Experiment 2A, especially in the condition in which attention was divided at both encoding and retrieval. A 2 (group: older adults and young DA/DA) by word pair type (Old minus New, Old minus Item, Old minus Conjunction) ANOVA showed a significant main effect of word pair type,  $F(2, 104) = 93.08$ ,  $MSE = .008$ ,  $p < .0001$ , and of group,  $F(1, 52) = 7.59$ ,  $MSE = .138$ ,  $p < .01$ . A significant interaction between group and word pair type was also present,  $F(2, 104) = 17.02$ ,  $MSE = .008$ ,  $p < .0001$ . Thus, as shown in Experiment 1, increasing similarity of lures had a larger negative effect on discriminability for older adults than for the younger adults whose attention was divided at both encoding and retrieval.



### Experiment 3

To recapitulate the argument and findings thus far, Experiments 1 and 2 addressed the associative deficit hypothesis regarding cognitive aging by comparing cognitive aging to reduced attentional resources in younger adults. To examine this, younger adults engaged in a divided attention task (monitoring a series of aurally presented digits and identifying target sequences) while studying word pairs for a later recognition memory test. Younger adults engaged in the divided attention task at either encoding only, or at both encoding and retrieval, although previous research (Craik et al., 1996) has shown that employing a divided attention task of this nature (e.g. odd digit task or target detection reaction time task) at retrieval leads to little or no effect on memory performance. Older adults also completed the same study-test session, but under full attention conditions. The encoding session was then followed by two recognition tests, designed to examine item and associative recognition memory. Participants were presented with four types of word pairs during the recognition tests: old word pairs, word pairs containing two previously presented words but that were never presented together as a pair (conjunction pairs), word pairs with one old word and one new word (item pairs), and word pairs that contained two new words (new pairs). The recognition tests allowed for an examination of how the three groups responded to material that was either the same, somewhat similar, or completely different than studied information. Relative to both full attention and divided attention younger adults, it was found that older adults had the greatest difficulty rejecting conjunction word pairs (as evidenced by a high false alarm rate), likely because the ability to reject conjunction word pairs relies on memory

for associative information and recollection (as opposed to familiarity). In general, although a reduction in attentional resources may be one factor that accompanies cognitive aging, older adults were especially impaired in terms of encoding and retrieval of associative information in a word pair recognition memory paradigm, possibly as a result of reliance on a general-level of familiarity as opposed to detailed “fine-grain” recollection.

The mechanism (or mechanisms) underlying these impairments still remains to be identified, but recent findings from neuropsychology and cognitive neuroimaging have provided some clues. For example, both normal aging and division of attention in young adults are associated with similar reductions in left prefrontal cortex activity (Cabeza et al., 1997; Grady et al., 1995; Iidaka, Anderson, Kapur, Cabeza & Craik, 2000; Shallice et al., 1994). The hippocampal formation is also likely to be involved in the encoding and retrieval of associative information, and evidence supporting this point comes from the studies by Kroll and colleagues (1996), and by Reinitz, Verfaellie and Milberg (1996), as well as from the theoretical analysis provided by Moscovitch and Winocur (1992; Moscovitch, 2000). However, it may be that whereas aging results in reduced efficiency of processing at the level of the hippocampal formation, younger adults under divided attention do not show this impairment (Naveh-Benjamin, 2001, Naveh-Benjamin et al., 2001). Thus, although frontal lobe functions may be taxed during divided attention, the hippocampus may not be involved in secondary task processing, thereby allowing younger adults to successfully process associative information in the memory task. Also, it may be necessary to employ a divided attention task that involves constant responding and monitoring (e.g. Pashler, 1996; Rohrer & Pashler, 2003) in order to observe memory

interference effects at retrieval as well as an impairment in memory for associative information.

In order to compare cognitive aging to situations of divided attention in younger adults, it is important to create divided attention conditions that simulate the memory impairments that older adults often experience at both encoding and retrieval. Experiment 3 examined this issue using a divided attention task that results in interference at both encoding and retrieval for younger adults, and involves processing verbal material that contains some associative processing component, in an attempt to simulate the associative deficit displayed by older adults in the previous experiments. To achieve this, two different divided attention tasks were employed in a blocked design that was almost identical to Experiments 1 and 2. In one block, participants engaged in an animacy judgment task in which they heard a continuous stream of words and were asked to make decisions about whether the words represented living or non-living objects (e.g. cow, respond “yes”, desk, respond “no”) at both study and test. In a second block, participants engaged in an associative comparison task in which they heard word pairs and had to decide which of the two words represented the larger object (e.g. penny-table, respond “table”), hereafter referred to as the “bigger/smaller” task. Given that previous research has shown that these kinds of verbal tasks result in memory interference effects at both encoding and retrieval and are thought to involve medial temporal lobe/hippocampus structures that are involved in binding (e.g. Fernandes & Moscovitch, 2000; 2002, see also Rohrer & Pashler, 2003), it seems appropriate to use a task of this nature in order to simulate cognitive aging, which is thought to involve binding impairments at both encoding and retrieval. Fernandes and Moscovitch (2000) have

found that using an animacy task leads to interference at both encoding and retrieval by competing for access to a word-specific representational system, and argue that this system is governed by the medial temporal lobe/hippocampal structures. According to their notion, divided attention tasks such as the digit monitoring task (which involve little competition for word-specific resources) are frontally-mediated, and do not require the recruitment of the hippocampus. Thus, in order to compare aging to divided attention, it may be necessary to employ a divided attention task that involves the hippocampal regions and competes with word-specific resources that are needed for the memory task.

In order to also attempt to mimic the associative deficit that is shown in old age, a divided attention task was developed that involved processing associative information. It was hypothesized that a task that required the active comparison of two items (i.e. comparing two words in the “bigger/smaller” task) would lead to reductions in the ability to encode and retrieve associative information in the memory task for the divided attention younger adults, and that this may mimic older adults’ impairments in processing associative information. Thus, this experiment included two divided attention conditions that might specifically interfere with the processing of associative information, and it was of primary interest to compare memory performance under these conditions to that of older adults.

## **Method**

### Participants

Twenty-seven undergraduate students from the University of Toronto (23 women and 4 men, mean age = 19.5 years, mean number of years of education = 14.0)

volunteered to participate and received course credit for their participation. All volunteers participated in each of the three blocks.

### Materials

The materials were identical to those used in Experiment 2A and 2B, with the exception being the two different secondary tasks. In one block, participants engaged in an animacy judgment task in which they heard a continuous stream of words and were required to make decisions about whether the words represented living or non-living things (e.g. cow, respond “yes”, desk, respond “no”) at both study and test. Half of the nouns represented living things while the other half represented non-living things, and the order of presentation was randomized. The words were high frequency common nouns and were spoken by a female voice and recorded on a tape recorder at a rate of one word every 4 seconds.

In a second block, participants engaged in an associative comparison task in which they heard word pairs and had to decide which of the two words represented a larger object (e.g. penny-table, respond “table”). The words were high frequency common nouns and were spoken by a female voice and recorded on a tape recorder at a rate of one word pair every 5 seconds. The words were paired with one another such that there was no ambiguity regarding the correct answers (i.e. which word represented a larger object), and such that the larger object was equally likely to be in the first or second position in the pair.

### Procedure & Design

The procedure was very similar to that used in Experiments 2A and 2B, except for two new secondary tasks. Participants were given instructions regarding the study and

the presence or absence of the secondary task prior to the beginning of each block. All participants completed three blocks: a) full attention at encoding and test, b) animacy judgments task at encoding and test, and c) associative comparison task at encoding and test. The order of the blocks was counterbalanced across participants such that each block occurred in each of the three positions an equal number of times. Each study phase consisted of 45 original word pairs (none of the words were repeated in a subsequent study phase for the participant), and each recognition test consisted of 60 word pairs (15 of each type: old, conjunction, item, and new).

### **Results and Discussion**

The results for word pair recognition performance for each of the three blocks are displayed in Table 2.3. The corrected recognition scores are shown in Figure 2.6. In order to compare performance in the two different divided attention conditions, the data from the divided attention conditions in Experiment 3 were entered into a 2 (divided attention condition) by 3 (word pair type corrected scores) ANOVA. There was a main effect of word pair type,  $F(2, 104) = 34.19$ ,  $MSE = .0227$ ,  $p < .001$ , but no main effect of condition,  $F(1, 52) = 1.31$ ,  $MSE = .0542$ ,  $p = .26$ . The interaction did not reach significance,  $F(2, 104) = 2.72$ ,  $MSE = .0227$ ,  $p = .11$ . This suggests that the two divided attention conditions had similar effects of memory performance.

[Insert Table 2.3 and Figure 2.6 about here]

Since the purpose of including these two new divided attention conditions was to compare the divided attention younger adults' performance to that of the older adults in Experiment 2 (especially in terms of conjunction errors), specific ANOVAs were carried out. First, in order to compare performance between the two divided attention conditions

to that of the older adults from Experiment 2B, a 3 (condition/group) by 3 (word pair type corrected scores) ANOVA was conducted. There were significant main effects of word pair type,  $F(2, 156) = 108.9$ ,  $MSE = .028$ ,  $p < .0001$ , and group,  $F(2, 78) = 19.17$ ,  $MSE = .043$ ,  $p < .0001$ , as well as a significant interaction between word pair type and group,  $F(4, 156) = 9.96$ ,  $MSE = .021$ ,  $p < .0001$ .

From Figure 2.6, it may be seen that the interaction reflects similar false alarm rates between the groups for Item-New pairs, but greater probabilities of “old” responses in the older adult group for both Conjunction-New pairs (false alarms) and Old-New pairs (hits). As in the previous analyses (in Experiment 1 and 2), one can obtain a closer examination of memory for associative information by comparing “old” responses to the old and conjunction word pairs. A 3 (group, DA-animacy, DA-bigger/smaller task, older adults) by 2 (word pairs type, old and conjunction corrected recognition scores) ANOVA showed significant main effects for word pair type,  $F(1,78) = 47.04$ ,  $MSE = .029$ ,  $p < .0001$ , and group,  $F(2, 78) = 25.69$ ,  $MSE = .041$ ,  $p < .0001$ , as well as a significant interaction,  $F(2, 78) = 5.30$ ,  $MSE = .029$ ,  $p < .01$ .

To follow up on the finding of a significant interaction, which may be driven by different performance by the older adults relative to both DA conditions, or simply to one of the two DA conditions, two follow-up 2 by 2 ANOVAs were conducted. A 2 (group, DA-animacy and older adults) by 2 (word pairs type, old and conjunction corrected recognition scores) ANOVA showed significant main effects for word pair type,  $F(1, 52) = 53.77$ ,  $MSE = .029$ ,  $p < .0001$ , and group,  $F(2, 78) = 30.26$ ,  $MSE = .042$ ,  $p < .0001$ , but the interaction was not significant,  $F(1, 52) = 1.86$ ,  $MSE = .029$ ,  $p = .18$ .

A 2 (group, DA-bigger/smaller task and older adults) by 2 (word pairs type, old and conjunction corrected recognition scores) ANOVA showed significant main effects for word pair type,  $F(1, 52) = 33.19$ ,  $MSE = .026$ ,  $p < .0001$ , and group,  $F(1, 52) = 55.87$ ,  $MSE = .033$ ,  $p < .0001$ , as well as a significant interaction,  $F(1, 52) = 11.85$ ,  $MSE = .026$ ,  $p = .001$ . These findings suggest that although the divided attention tasks were demanding, only the animacy task resulted in a similar trend of responses to that of the older adults, whereas the bigger/smaller task led to a differential greater memory interference effect relative to the older adults.

To assess the degree to which the divided attention tasks were demanding and how well participants monitored this information, the number of errors in each divided attention task (during study and test phase) was recorded. Errors were defined as either responding incorrectly to an item, or not providing a response at all to an item, and were grouped together since either type of error likely resulted from not paying sufficient attention to the divided attention task. In the animacy judgment task, participants made errors on 2.8 % of all trials during encoding, and 6.1 % during test, and this difference was significant,  $t(26) = 2.16$ ,  $p < .05$ . In the bigger/smaller task, participants made errors on 11.2 % of trials during encoding, and 18.8 % during test, and this difference was also significant,  $t(26) = 4.50$ ,  $p < .0001$ . Overall, participants made significantly more errors in the bigger/smaller task compared to the animacy judgment task,  $t(26) = 6.31$ ,  $p < .0001$ . These results show that overall, more errors were made during the test phase than the study phase (consistent with findings from Craik et al., 1996), and that the bigger/smaller task was more demanding than the animacy judgment task. This result supports the findings from the memory test, in which poorer overall memory



performance was observed in the bigger/smaller divided attention condition compared to the animacy judgment condition.

### Discriminability Analysis

As in the previous experiments, difference scores for word pair recognition between Old pairs and New, Item, and Conjunction pairs are presented in Figure 2.7, and provide a measure of discriminability. The purpose of the present experiment was to see how the two divided attention groups compared with the older adults from Experiment 2B, especially in terms of the ability to discriminate old word pairs from conjunction pairs, relative to other types of word pairs. To analyze the data from the present study (separately from that of the older adults from Experiment 2B), a 3 (condition: full attention, DA-animacy task, DA-bigger/smaller task) by 3 (word pair type, Old minus New, Old minus Item, Old minus Conjunction) ANOVA was conducted, and showed a significant main effect of word pair type,  $F(2, 156) = 43.78$ ,  $MSE = .011$ ,  $p < .0001$ , and of group,  $F(2, 78) = 42.81$ ,  $MSE = .14$ ,  $p < .0001$ , but there was no significant interaction,  $F < 1$ .

[Insert Figure 2.7 about here]

In order to compare the older adults from Experiment 2B to the two divided attention groups in the present experiment, a 3 (group: older adults, DA-animacy, DA-bigger/smaller task) by 3 (word pair type, Old minus New, Old minus Item, Old minus Conjunction) ANOVA was conducted, and showed a significant main effect of word pair type,  $F(2, 156) = 91.67$ ,  $MSE = .010$ ,  $p < .0001$ , and of group,  $F(2, 78) = 14.92$ ,  $MSE = .126$ ,  $p < .001$ , as well as a significant interaction,  $F(4, 156) = 7.12$ ,  $MSE = .010$ ,  $p < .001$ . This interaction suggests that (as shown in the previous studies), older adults

encountered a great deal of difficulty discriminating old word pairs from similar word pairs, relative to younger adults under various divided attention conditions. Thus, even when the divided attention task involves processing associative information to some degree, these younger adults working under conditions of divided attention are still relatively better than older adults at discriminating between old and conjunction word pairs.

### **General Discussion and Summary – Experiments 1-3**

The major goal of the initial set of experiments was to compare the effects of normal aging with those of divided attention in younger adults on memory for item and associative information. The results showed that older adults and divided attention younger adults performed very similarly on single word recognition tests tapping item information when the difficulty of the secondary task was adjusted to give comparable levels of performance. However, the two groups performed very differently relative to young full attention controls on word pair tests. In general, the young-DA groups showed substantial reductions in hit rates relative to young full attention groups, but very slight increases in false alarm rates relative to the full attention younger groups. In contrast, the two groups of older adults showed comparatively small reductions in hit rates relative to young adults, but a substantial increase in false alarm rates, especially on the recombined (A-D) distracter items. In summary, the salient characteristic of younger adults performing under divided attention conditions in this paradigm was a reduction in hit rates, whereas the salient characteristic of older adults was an increase in false alarms to similar distracters.

The deficit in item information relative to full attention younger adults was measured in the single word recognition test by taking the difference between the younger adults' score in the Conjunction minus New condition (see Figure 2.2) and the corresponding scores of the older adults and the young-DA adults. The corresponding deficit in associative information was taken from the word pair recognition test as the difference between the young adults' scores and the scores of the other groups on the Old minus Conjunction condition shown in Figures 2.3 and 2.5. As reported in the results sections, these comparisons showed that the deficit was greater in associative information than in item information, and that the deficit in associative information was greater for the older adults, relative to various groups of divided attention younger adults. These findings are in concert with those of Naveh-Benjamin (2001, Naveh-Benjamin & Guez, 2002), and provide further evidence for the associative deficit hypothesis. However, the present results differ from those of Naveh-Benjamin and his colleagues in that divided attention (like aging) had greater negative effects on associative information than on item information. According to the present findings, the associative deficit hypothesis is not uniquely relevant to aging. Speculatively, it may apply to all conditions involving a reduction in processing resources, although the associative deficit may be particularly marked in aging (e.g. Naveh-Benjamin, 2000, 2001).

Other findings that are worth noting include the observation in the single word paradigm that whereas younger adults working under full attention conditions showed an increase in hit rate (presumably due to reinstatement of original context) from Conjunction to Old pairs, neither older adults nor young-DA adults showed the same amount of increase (see Figure 2.2). In this instance the young-DA group showed the

same pattern of responding as the older adult group, but in the discriminability analyses shown in Figures 2.3, 2.5, and 2.7 the groups performed differently. Figures 2.3, 2.5 and 2.7 show strikingly similar patterns; discriminability decreased as the lures became more similar to the target pairs, and the decreases were sharper for older adults than for younger adults working under either full or divided attention. These latter two groups showed parallel decreases. The discriminability results thus again make the point that older adults differed from young-DA groups in their lessened ability to discriminate targets from similar lures in the associative recognition paradigm. In particular, older adults showed a greatly increased tendency to make false alarm responses to conjunction pairs.

One final analysis also demonstrated this difference between the young-DA groups and older adults. Figure 2.8 shows associative discriminability (defined as corrected Old minus corrected Conjunction scores in the word pair paradigm) plotted against corrected hit rate (Old minus New) for all nine groups or conditions examined in the study. Figure 2.8 shows that all nine younger groups or conditions (i.e. all of the younger participants in each of the full and divided attention conditions in all three experiments) were well fitted by one linear function ( $R^2 = 0.99$ ), but that the two older adult groups clearly deviated from the function. Since discriminability is calculated as hits minus false alarms, graphing discriminability against hits is essentially one way to show the relation between hits and false alarms in associative recognition. The fact that one linear function fits all of the conditions involving younger adults, including the divided attention conditions, means that “false alarm rates” (Conjunction minus New) remained relatively constant across all conditions despite large variations in hit rate. In

fact, corrected hit rates for the young conditions ranged from 0.23 to 0.82, whereas corrected false alarm rates range only from 0.03 to 0.16. The mean of the nine false alarm rates associated with young participants was 0.12 with a standard deviation of 0.03; the corresponding means for the two groups of older adults is 0.30, some six standard deviations above the younger participants' mean value. The theoretical implication of these results is that different levels of difficulty and different degrees of divided attention in younger adults resulted in large changes in hit rates but in comparatively small changes in false alarms, measured here as “old” responses to Conjunction pairs. In contrast, the groups of older adults in the present study made many more conjunction errors than did their younger counterparts.

[Insert Figure 2.8 about here]

Jacoby and collaborators (e.g. Jacoby et al., 1996; Jones & Jacoby, 2001; Jones et al., 2001) have argued that familiarity and recollection provide alternative bases for responding “old” in tests of recognition memory (see Yonelinas, 2002, for a recent review). Furthermore, in the context of a conjunction paradigm similar to the word pair conditions in the present study, Jones and Jacoby (2001) suggested that conjunction errors reflect familiarity in the absence of recollection, and that a decrease in hit rates without an alteration of false alarms (conjunction errors) can be interpreted as an effect on recollection but not on familiarity. In these terms, the young-DA groups in the present study fit the second pattern, and thus divided attention at encoding may be considered to reduce recollection but leave familiarity unaltered (see also Reinitz et al., 1994). It seems likely that aging also decreases recollection; in the present study the drops in corrected hit rates shown by the older groups relative to the relevant full-attention young control

groups were 0.09 in Experiment 1A and 0.22 in Experiment 2B. However, the more dramatic age-related difference was the increase in conjunction errors, 0.16 in Experiment 1A and 0.25 in Experiment 2B; in Jacoby's terms these age-related errors reflect an age-related increase in the dependence on familiarity, unopposed by the corrective influence of recollection. By this analysis divided attention and aging are similar in that both are associated with a decline in recollection, but that in addition aging is associated with a greater dependence on familiarity leading them to make more false alarms to distracter items that are very similar to target items.

The system that underlies these impairments remains to be identified, but recent findings from neuropsychology and cognitive neuroimaging have provided some useful insights. For example, both normal aging and division of attention in young adults are associated with similar reductions in left prefrontal cortex activity (Cabeza et al., 1997; Grady et al., 1995; Iidaka, Anderson, Kapur, Cabeza & Craik, 2000; Shallice et al., 1994). The hippocampal formation is also likely to be critically involved in the encoding and retrieval of associative or relational information (Cohen et al., 1999; Eichenbaum, 1999), and evidence supporting this point comes from the studies by Kroll and colleagues (1996), and by Reinitz, Verfaellie and Milberg (1996), as well as from the theoretical analysis provided by Moscovitch and Winocur (1992; Moscovitch, 2000). However, it may be that whereas aging results in reduced efficiency of processing at the level of the hippocampal formation, younger adults under divided attention do not show this impairment (Naveh-Benjamin, 2001, Naveh-Benjamin et al, 2001). Thus, although frontal lobe functions may be taxed during divided attention, the hippocampus may not be involved in certain secondary tasks that involve the monitoring of digits, (such as

those in both Experiment 1 and 2) and thus allows younger adults to successfully process associative information in the memory task. Further research that uses a secondary task that involves (and ensures) the processing and remembering of associative information (or involves the hippocampus in some greater capacity) may show that situations of divided attention are more similar to aging under these conditions.

In summary, how do the present results fit with Craik's (1982, 1983) claim that the effects of aging can be mimicked by having younger adults perform under divided attention conditions? It appears that aging and divided attention are similar in that both are associated with a reduction in available processing resources, which in turn is related to a decrease in recollection in memory tasks. The present results show that aging is associated with a second factor, however, that differentiates aging from divided attention—namely a greatly increased liability to make false alarm errors to similar distracters in the associative recognition paradigm. This age-related impairment presumably reflects some combination of an inefficiency in binding processes during encoding (e.g. Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000) and an unopposed reliance on familiarity at the time of retrieval (Jones & Jacoby, 2001). One possible account of the latter effect is that older adults fail to process distracter items sufficiently deeply during retrieval and thus respond “old” on the basis of relatively shallow information that is similar to that of target information, without accessing the deeper or more specific information (“recollection”) that would enable them to reject the distracters (see Jones & Jacoby, 2001 for a related discussion). The findings are thus partly but not entirely in line with those reported by Naveh-Benjamin (Naveh-Benjamin et al., 2001; Naveh-Benjamin & Guez, 2002), and the conclusion is that divided attention resembles

aging in some but not all respects. It seems likely, in fact, that a complete account of age-related memory loss will be multi-factorial, reflecting inefficiencies in various types of processing as well as a reduction in attentional resources.

These findings suggest that even when the divided attention task leads to similarity-based interference at both encoding and retrieval, younger adults working under divided attention conditions can still rely on recollective processes at retrieval, as opposed to older adults who make decisions based on familiarity in the absence of recollection (e.g. Jones & Jacoby, 2001; see Yonelinas, 2002, for a review). If this is indeed the case, it would be useful to examine age-related differences in memory for associative information by using other memory tasks or materials that reduce the likelihood of relying on familiarity, and emphasize the importance of efficient encoding and retrieval of salient associative information. Along these lines, in a source memory experiment by Rahhal, May, and Hasher (2002) it was shown that although older adults had difficulty remembering the voice (male or female) that spoke a statement of information, when older adults were told that the speaker's voice indicated whether the statement was true or false they displayed exceptional memory for the "truthfulness" of these statements. Thus, it may be that when an associative memory task involves binding arbitrary bits or units of information (e.g. voice with a statement, unrelated word pairs, or numbers with words), older adults display associative memory impairments. However, when the memory task involves more meaningful and naturalistic associative information, age-related differences are reduced or eliminated. This notion was examined in more detail in the next set of studies.



## **CHAPTER THREE: BINDING AND MEMORY FOR NUMERICAL INFORMATION**

The examination of memory for associative information using word pairs in an associative recognition paradigm allows for an examination of only one aspect of the binding process. Under these situations, it appears that older adults rely on familiarity when making associative recognition judgments, and this leads to a greater susceptibility to false alarms especially to conjunction word pair lures. Experiments 4-6 extend the examination of aging and associative memory to cued recall tests that involve both verbal and numerical information, and that reduce the role of familiarity-based processes (by using a cued recall test rather than recognition). Given that many different types of associations must be made in the everyday world, these experiments seek to examine how highly specific information is bound to item information, and whether older adults have difficulty binding somewhat arbitrary information (e.g. numbers to items), relative to more meaningful information (e.g. prices to grocery items). It is likely that older adults perform better on more naturalistic memory and decision making tests because they involve more realistic reliance on memory and reasoning (e.g. Rahhal, May, & Hasher, 2002; Tentori, Osherson, Hasher, & May, 2001). Thus, it may be possible to reduce impairments in the ability to remember associative information by using materials that lend themselves well to typical associative memory challenges that face both younger and older adults outside the laboratory.

Although there is a great deal of research showing older adults have difficulty remembering associative information that involves verbal material, very little research has addressed age-related differences in the ability to remember numerical information

that is bound to other items of information. One of the few studies that has examined this issue tested younger and older adults' ability to remember recently studied telephone numbers, and found large age differences for seven- and ten-digit phone numbers, but small age differences for three digit numbers (West & Crook, 1988). Although this study examined age-related differences in the ability to remember numerical information, it did not assess the ability to associate numerical information with other useful units of information. It is possible that phone numbers are difficult to remember because the grouping of numbers is largely arbitrary, making it difficult to encode the information in a meaningful manner. Naveh-Benjamin (2000) found that older adults showed a reduced deficit in associative memory when studying and recalling related word pairs (as opposed to unrelated word pairings), suggesting that arbitrary associations contribute to the associative deficit that is often displayed by older adults. Thus, when numerical information is presented in a random or arbitrary manner (such as a phone number), older adults have a great deal of difficulty remembering this information. Conversely, it may be possible that older adults would benefit from studying numerical information that is consistent with an already established form of knowledge or schema, such as prices that reflect the market value of an item. On the other hand, when information is inconsistent with prior knowledge, older adults might display poor memory because it is difficult to incorporate and organize the incoming information with prior knowledge.

One type of numerical information that is often encountered in the everyday world is information regarding quantity, such as how many eggs are called for in a recipe or how many seats are in a classroom. Binding the numerical information to the specific object and context is important for a full understanding of the situation or event and for

the effective use of this information. Experiment 4 examines how younger and older adults remember quantity information, by presenting short phrases that consist of a number, an object, and a location. The experiment also examines how memory for the number and item is affected when the item information (i.e. the object) is related (e.g. 72 dollars in the wallet) or unrelated (e.g. 53 nails in the bowl) to the source. In these cases, 72 and 53 refer to an arbitrary quantity, while “dollars” and “nails” refer to the objects that are paired with either related (“wallet”) or unrelated (“bowl”) sources. In the encoding phase, participants studied short phrases that consisted of a random two-digit number that represented quantity, paired with an item and source. In one condition, the item and source were related (high context) whereas in a second condition, the item and source were relatively unrelated (low context). Participants were then given a cued recall test, in which they were presented with the source, and asked to recall the associated item and number. In terms of recalling the item, it was expected that when the item and source are relatively related, age differences would be small compared to the condition in which the source is completely unrelated to the item. It was expected that older adults would have greater difficulty than younger adults in recalling the precise number, as this represents a situation in which arbitrary information is bound to items.

In summary, the following experiments examined how younger and older adults remembered verbal and numerical information, and how this information is bound to form a complex unit of information. The first experiment examines this by using phrases that consist of a number (quantity information), and an object and source (item information), such as “58 nails in the bowl”. If older adults have difficulty remembering numerical information in general, then they should have a specific impairment in the

ability to recall the quantity information, relative to the object when presented with the source. The next two experiments examine how older adults remember numerical information that is presented in a more familiar and meaningful context (prices of grocery items), in which the price information is either consistent or inconsistent with an already established form of knowledge or schema, such as prices that either reflect the market value of an item or are inconsistent with previous knowledge regarding this item. If older adults can make use of prior knowledge regarding price information (“prior knowledge” can also be referred to as “schematic support” in the context of assisting memory performance, as described by Craik and Bosman, 1992), then older adults might be able to better remember market value prices, but not precise prices that are inconsistent with prior knowledge. Furthermore, older adults might be able to remember the general association between an item and its price (such as remembering whether the price was consistent or inconsistent with its market value price), but have more difficulty recalling the precise price. The following three experiments attempt to show that older adults perform well when environmental and schematic support is present, and when expertise and prior experience can mediate associative memory performance. One possibility is that different types of associative information can be organized in a hierarchical fashion (e.g. Craik, 2002), with older adults showing impairments when specific arbitrary and abstract associations are involved, but that age-differences are minimal when more generalized semantic information and prior knowledge contribute to the binding process.

### Experiment 4

In order to examine how information specificity and memory for associative information interact with age (as shown in the schematic representation in Figure 3.1), participants studied phases that consisted of a number (quantity information), an object, and a location (e.g. 85 rocks in the lake), and were later given a cued recall test for the information (what was in the lake and how many?). The objects and locations were either related (54 doctors in a hospital), or unrelated (96 nails in a bowl), and the numbers were random two-digit numbers. In the related condition, it was hypothesized that there would be small or negligible age differences for object recall, but much larger age differences for number/quantity recall, since this represents more arbitrary and specific associative memory. In the unrelated condition, it was hypothesized that there would be similar age-related differences for both object and number/quantity recall since in both cases arbitrary associations must be made and recalled at a later time. This type of finding would suggest that memory for specific information (precise numerical/quantity information, unrelated object-location information) is impaired in older adults, relative to less specific and more general information (related object-location information). This finding would be in line with previous work that has shown that when semantically related information is used to examine associative memory, older adults show a minimal impairment (e.g. Naveh-Benjamin, 2000; see also Light, 1992).

[Insert Figure 3.1 about here]

In order to examine whether this type of effect (age-related differences in memory for arbitrary and specific associative information) could be influenced by expertise in a certain domain, a group of older retired accountants and bookkeepers were also included

in the study. Previous research has shown that knowledge in a particular domain can facilitate memory performance for domain-relevant information, such as chess position (Chase & Simon, 1973), bridge hands (Engle & Bukstel, 1978), dance steps (Allard & Starkes, 1991), maps (Gilhooly, Wood, Kinnear, & Green, 1988), music (Meinz & Salthouse, 1998), aviation information (Morrow et al., 1994, 2001) and baseball-related information (Hambrick & Engle, 2002). It was thought that the accountants and bookkeepers who were recruited for the present study (all of whom had at least 20 years of experience working with numerical information) would be able to process numerical information in a meaningful way, leading to better memory performance for this type of association, relative to the other older adults. This would suggest that the ability to remember associative information (and any age-related differences in associative memory performance) is dependent on the specificity of the materials used, and the manner in which the information is processed in light of prior knowledge and experience.

## **Method**

### Participants

In total, 48 undergraduate students from the University of Toronto (33 women and 15 men, mean age = 21.5, mean number of years of education = 15.3) volunteered to participate and received course credit for participation. Forty-eight older adults (34 women and 14 men, mean age = 71.3, mean number of years of education = 14.1) also participated in the study, and were paid \$10 for their participation. The older adults tested in this experiment were high functioning and in good health; they lived in the community and made their own way to the laboratory to participate. Both younger and

older participants were randomly assigned to participate in either the related or unrelated object condition, such that 24 of each age group participated in each condition.

In addition to the older adults group just described, a further group of older adults who had some degree of professional experience working with numerical information (specifically, retired book-keepers and accountants) was recruited for this study by advertising in a local senior's newspaper. This group was comprised of 12 older adults (7 women and 5 men, mean age = 73.9, mean number of years of education = 15.3) who had more than 20 years of professional experience as a book-keeper or accountant/financial assistant. These older adults were paid \$10 for their participation

### Materials

The stimuli used in the present study were short phrases that consisted of a two-digit number, an object and a location. The objects and locations were either related (doctors in a hospital), or unrelated (nails in a bowl), and the numbers were random two-digit numbers (see Appendix 3.1 for the actual phrases used in the experiment). The materials were developed by asking a group of subjects (who did not participate in the actual experiment) to provide nouns that were either related to the location, or completely unrelated (but still plausible). For each location, the participants was asked to provide three nouns that were somewhat related to the location (in order, starting with the "first noun that came to mind"), and three nouns that were completely unrelated to the location. The responses provided by these participants (3 older adults and 3 younger adults) were then used to develop the phrases, such that none of the related phrases consisted of nouns rated by any of the participants as the "first noun that came to mind", and such that none

of the unrelated nouns and location pairs were entirely implausible (as determined by an independent judge).

### Procedure

Participants were told that they would be presented with short phrases that consisted of a two-digit number (quantity information), an object and a location. The participants were told that they should remember this information for a later cued recall memory test, in which they would be presented with the locations (one at a time) and would need to recall the object and number that was paired with the location. Participants were presented each phrase on a computer screen for 10 seconds. Younger and older participants were randomly assigned to either the related or unrelated condition (with the exception of the older accountants/book-keepers who all participated in the unrelated condition). At test, participants were presented with the locations one at a time, and were told to call out what was there (the object that was originally paired with the location) as well as how many (the two-digit number that was originally paired with the object and location). If they could not remember the exact number or object, the participants were told that they should guess and provide any information that might be correct. Participants had up to 10 seconds to respond. The experimenter (who sat behind the participant and out of sight) recorded the responses. Participants were debriefed following the testing session.

### **Results and Discussion**

The results for correct cued recall of number and object information are shown in Figure 3.2. Recall of number information was not scored correct unless participants provided the exact number that was originally paired with the object and location. Since



the experiment consisted of two separate (between-subject) conditions, separate ANOVAs were carried out on the related and unrelated conditions. In the related condition, a 2 (group, younger and older adults) by 2 (information type, number and object) ANOVA resulted in a significant main effect of information type,  $F(1, 46) = 344.18$ ,  $MSE = 4.12$ ,  $p < .0001$  (object information was better recalled relative to numbers), and age,  $F(1, 46) = 10.82$ ,  $MSE = 15.04$ ,  $p = .002$  (young adults recalled more than older adults), as well as an age by information type interaction,  $F(1, 46) = 14.22$ ,  $MSE = 4.12$ ,  $p < .0001$ . Figure 3.2 shows that the interaction can be interpreted as older adults having more difficulty than younger adults when the information type is quite specific (numerical information), compared to more general, related information, in which there are small or negligible age-related differences. The finding of minimal age-related differences for semantically related word pairings is consistent with previous research (Naveh-Benjamin, 2000; Light, 1992) suggesting that when semantically rich information is present in an associative memory task, older adults can take advantage of it to match the performance of younger adults.

[Insert Figure 3.2 about here]

The differential effect of information type on memory performance for younger and older adults should disappear when the object information is unrelated (i.e. a more arbitrary association). To examine this possibility, a similar 2 (group, younger and older adults) by 2 (information type) ANOVA was carried out on the data from the unrelated condition. This led to a significant main effect of information type,  $F(1, 46) = 126.30$ ,  $MSE = 4.99$ ,  $p < .0001$  (object information was better recalled relative to numbers), and group,  $F(1, 46) = 25.06$ ,  $MSE = 15.97$ ,  $p < .0001$  (young adults recalled more than older

adults), but the interaction was not significant,  $F(1, 46) = 1.01$ ,  $MSE = 4.99$ ,  $p = .32$ . This result suggests that both younger and older adults show a deficit in binding unrelated information when tested with a cued recall task, although older adults' overall performance was worse than the younger adults.

If expertise in a specific domain can influence the manner in which information is processed and later retained, it might be expected that the older accountant group would be especially good at recalling the numerical information, relative to the other groups and other types of information. The results displayed in Figure 3.2 suggest that this was indeed the case, and to confirm this observation a 3 (group, younger adults, older adults, and older accountants) by 2 (information type) ANOVA was carried out. There was a main effect of information type,  $F(1, 57) = 90.43$ ,  $MSE = 4.58$ ,  $p < .0001$  (object information was better recalled relative to numbers), and group,  $F(2, 57) = 14.54$ ,  $MSE = 15.01$ ,  $p < .0001$  (young adults recalled more than older adults) as well as a significant interaction,  $F(2, 57) = 7.44$ ,  $MSE = 4.58$ ,  $p = .001$ . From Figure 3.2, it appears that the older retired accountants displayed exceptionally good memory for the numerical information. In order to examine memory performance for just the recall of numerical information, a one-way ANOVA with follow up  $t$ -tests (Tukey's) was conducted with the three groups as a between-subject variable, and the performance on numerical information as the dependent variable. This performance resulted in a significant effect of group,  $F(2, 59) = 15.78$ ,  $MSE = 8.08$ ,  $p < .0001$ , and the post-hoc tests showed that the older accountant group and younger group did not differ from one another ( $p = .32$ ), but that both groups displayed better numerical memory performance than the older group ( $p < .001$  in both cases). A similar one-way ANOVA was also conducted using object recall

as the dependent measure. This yielded a significant effect of group,  $F(2, 59) = 10.84$ ,  $MSE = 11.50$ ,  $p < .0001$ . The post-hoc tests showed that the two older groups did not differ from each other ( $p = .29$ ), and that the younger group differed from both the older accountants ( $p < .05$ ) and regular older adults ( $p < .001$ ). This finding suggests that expertise can influence associative memory in terms of domain specific information (numerical information in this case) a finding that is well established, [see Hambrick and Engle (2002), Kramer & Willis (2003) and Kramer et al. (2004) for recent reviews], but does not necessarily lead to better overall associative memory performance for other materials.

The ability to remember specific arbitrary numerical information bound to other items is impaired in older adults, but expertise modulates and greatly reduces this deficit in associative memory. If the associative deficit is fundamentally related to the arbitrary and low semantic value of the information, it may be possible to reduce or reverse this effect by using information or situations in which numerical information can have high semantic value and is related to prior knowledge. To examine this possibility in more detail, the following experiments examine how numerical information that contains some semantic value (grocery prices) can be meaningfully linked to objects (grocery items), and how the ability to remember these associations is modulated by the nature of the price (realistic versus unrealistic prices). Also, given that both younger and older adults have experience with grocery items and prices, the role of prior knowledge and expertise in this domain can be examined, with the expectation that both age groups should perform well when binding meaningful units of information (market value prices) with grocery items.

## Experiment 5

If older adults have difficulty remembering and binding arbitrary numerical information to item information, and if this is mediated by the fact that numerical information typically has low semantic value (such as in Experiment 4), it may be possible to reduce or eliminate this effect when numerical information has greater semantic value. Craik and Bosman (1992) have suggested that when tasks are high in “schematic support”, age-related differences in memory performance are reduced because older adults can rely on knowledge to integrate incoming information into a schematic ensemble. Schematic support can be defined as the mental equivalent of environmental support, and implies that the process of learning consists to some extent of building up “mental schemes” or organized bodies of knowledge about the outside world, and that these schemes can then serve as the basis for the interpretation of further events (Bartlett, 1932). Thus, in situations in which older adults can use previously developed mental schemas to organize and retain incoming information, age-related differences in memory performance may be reduced or even eliminated. Following on the findings from the older retired accountant and book-keepers, it was of interest to find a task and materials for which both younger and older adults had some experience (i.e. prior knowledge and a certain common level of expertise) that involved binding numbers with items.

To examine this possibility in the context of associative memory, in Experiment 5 a paradigm was designed in which participants studied item information (pictures of common grocery items) paired with the item’s price. In one condition, the prices were congruent with current market value of each grocery item (e.g. butter \$2.99), whereas in a second condition the prices were all much higher than market value (e.g. soup \$14.39),

and were randomly assigned to the items. It was expected that when the prices were congruent with approximate market value, participants could make use of these schematic associations by relying on increased “schematic support”, as suggested by Craik and Bosman (1992), to help remember the prices and this would reduce age differences in the ability to remember the price-item pair. However, when the higher than market value prices were arbitrarily assigned to items, then younger adults would outperform older adults because there would be very little schematic support.

## **Method**

### Participants

Twenty-four undergraduate students from the University of Toronto (4 women and 20 men, mean age = 20.3, mean number of years of education = 15.2) volunteered to participate and received course credit for participation. Twenty-four older adults (17 women and 7 men, mean age = 70.3, mean number of years of education = 15.4) also participated in the study, and were paid \$10 for their participation. The older adults were high functioning, in good health, lived in the community and made their own way to the laboratory to participate.

### Materials

The stimuli were comprised of 40 pictures of common grocery items taken from a local Internet grocery shopping web site. The size of the pictures was kept relatively constant, (approximately 5 cm by 5 cm) and appeared in the centre of the computer screen (see Appendix 3.2 for some sample stimuli). Of these 40 pictures, 20 were randomly assigned to the usual price condition and the remaining 20 were assigned to the

unusual price condition. Four different versions of the presentation list were created, such that items that were in the usual price condition for one participant would appear in the unusual price condition for the next participant. In the usual price condition, prices of each item were derived based on the actual market price of the item from the same local Internet grocery shopping web site, and these prices ranged from \$1.19 to \$7.99. In the unusual price condition, the market value prices of each item were inflated by a random dollar value between 6 and 8, so as to reduce predictability of the inflated price, and these prices ranged from \$7.19 to \$15.99. In both conditions, all prices ended in the digit “9”, and participants were made aware of this prior to the study session. The order of the conditions was counterbalanced across participants, such that participants began with either the usual or the unusual price condition.

### Procedure

Participants were tested individually, and were told that they would be studying grocery items and the prices of the items for a later memory test. In usual price condition, they were informed that the prices reflected the approximate market value of each item (i.e. a realistic price), and in the unusual price condition they were informed that the prices would be much higher than what they might expect to pay for the items. They were told that after studying 20 items they would be given a memory test in which they would be presented with each item one at a time (in a random order), and they should try to recall the price of the item. The experimenter then answered any questions and the participant initiated the study session by pressing the space bar. After the study session, participants were presented with the items one at a time, and were asked to recall the price (or approximate price) of each item. Participants were told to guess and provide

an answer for each item, even if they could not remember the exact price of the item.

After a short break, the participants were given instructions and began the next condition.

During the study phase, each picture, the name of the item and the corresponding price appeared on the centre of the screen for 10 seconds, with the name appearing above the picture in Times New Roman typeface (see Appendix 3.2). The next item appeared immediately afterwards, and after the 20<sup>th</sup> item, an instruction screen appeared describing the memory test. During the memory test, the items were presented without their price, and the participant was instructed to call out the price of each item, which was presented for 10 seconds or until the participants gave a response. The experimenter, who sat behind the participants (out of sight), recorded the response of the participant. At the end of the test session, participants were asked to estimate how much money they would have spent if they purchased all of the items at the specified prices, and to rate on a 10-point scale how often they went grocery shopping.

## **Results and Discussion**

The results from Experiment 5 are shown in Figure 3.3 in terms of the proportion of correctly recalled prices for each of the two conditions. Correctly recalled prices were defined as cases in which participants provided the exact price of the item, and errors were cases in which participants recalled incorrect prices. In order to determine if there was an effect of price type (regular or unusual) on memory performance, and if this differed as a function of age group, a 2 by 2 repeated-measure ANOVA was conducted. There was a significant main effect of price type,  $F(1, 46) = 92.87$ ,  $MSE = 3.51$ ,  $p < .001$  (regular prices were better recalled than unusual prices), and age group,  $F(1, 46) = 4.98$ ,

$MSE = 11.76, p < .05$  (young adults recalled more than older adults), and a significant interaction between age group and price type,  $F(1, 46) = 31.45, MSE = 3.51, p < .01$ . The interaction was driven by younger adults outperforming older adults in the unusual price condition,  $t(46) = 5.81, p < .0001$ , whereas no difference between the two groups was present in the regular price condition,  $t(46) = -0.63, p = .53$ .

[Insert Figure 3.3 about here]

In some situations, it is possible that participants provided incorrect answers that were still somewhat close to the correct price of the item, suggesting some “gist-based memory” for the price information. One way to examine incorrect responses provided by participants is in terms of the degree of the deviation between the actual price and the response, resulting in an absolute deviation score reflecting how close the incorrect response was to the actual price. These data are presented in Figure 3.4 in terms of the average deviation of incorrect price responses, and were analyzed using a 2 (age group) by 2 (price type) ANOVA. There was a significant main effect of price type,  $F(1, 46) = 97.96, MSE = 1.01, p < .001$  (responses for regular priced items deviated less than unusual items) but a non-significant effect of age group,  $F(1, 46) = 2.49, MSE = 1.18, p = .12$ , and a non-significant interaction between age group and price type,  $F(1, 46) = 2.75, MSE = 1.01, p = .11$ . This suggests that both groups provided an answer that was close to the actual value in the market value condition, perhaps by relying on prior knowledge of the prices in the absence of actually remembering the specific price. In the unusual price condition, the incorrect responses provided by both younger and older adults deviated by a larger amount than in the market value condition, but the observation that both groups were somewhat equivalent suggests that the older adults rarely provided a market value



price for the unusually high priced items, and that both younger and older adults can remember the general nature of the price (i.e. “much too high”) when retrieving price information about these items.

[Insert Figure 3.4 about here]

Following each test, participants were asked to estimate how much money they would have spent if they had purchased all of the items in each condition. In the usual price condition, the actual value of all 20 items was \$63.30, and younger adults gave a mean estimate of \$57.06 ( $SEM = \$3.40$ ) while older adults gave a mean estimate of \$51.09 ( $SEM = \$3.14$ ), and these values did not differ significantly,  $t(46) = 1.29, p = .20$ . In the unusual price condition, the actual value of all 20 items was \$221.10, and younger adults gave a mean estimate of \$178.08 ( $SEM = \$13.94$ ) while older adults gave a mean estimate of \$156.51 ( $SEM = \$14.91$ ), and again these values did not differ significantly,  $t(46) = 1.06, p = .30$ .

It is conceivable that one reason older adults performed well in the market value conditions is that they have more experience grocery shopping relative to the younger university students. To address this, following the memory test both groups were asked to rate how often they went grocery shopping on a scale of 1 to 10, with 1 being “never” and 10 being “very often”. Older adults provided a higher rating ( $M = 8.1, SD = 1.5$ ) than younger adults ( $M = 5.1, SD = 2.7$ ), and this difference was found to be significant,  $t(46) = 4.74, p < .0001$ . For the younger adults, there was no significant Pearson correlation between rating and number of correct responses in the usual price condition ( $r = .24, p = .25$ ) or in the unusual price condition ( $r = .08, p = .71$ ), although there was a significant correlation between performance in the unusual price and the usual price

condition,  $r = .61, p < .01$ . For the older adults, there was no significant Pearson correlation between rating and number of correct responses in the usual price condition ( $r = -.03, p = .88$ ) or in the unusual price condition ( $r = -.04, p = .85$ ), although again there was a significant correlation between performance in the usual price and the unusual price condition,  $r = .57, p < .01$ .

Although older adults appear to engage in more frequent grocery shopping behaviour according to these subjective ratings, it is not likely that this contributed differentially to memory performance for the two groups. Given that prices of grocery items often fluctuate within a certain range and rarely remain constant, it is conceivable that having more experience might influence background knowledge regarding prices but would not lead one to correctly “guess” the correct market value price of an item in the memory test. In fact, one could argue that greater amounts of knowledge regarding prices could lead to greater interference during the memory test, especially for older adults. Thus, an older adult might be very familiar with paying \$3.29 for milk, and after studying “milk-\$3.79” during the experiment, might have to inhibit the “prepotent” response of “\$3.29” and provide the studied price. Hasher, Zacks and May (1999) suggest that the ability to restrain reliance on a prepotent response (a response that is activated but not appropriate) is related to an inhibitory mechanism in working memory, and in the present experiment it appears that both younger and older adults can inhibit the prepotent response and rely on some form of episodic memory for the prices. In any case, based on the subjective ratings it appears that both groups are somewhat familiar with grocery prices, and this is likely what provides both groups with greater levels of schematic support in the market value condition. It may be that older adults engage in a

greater degree of “evaluative processing” (by deciding if the price is truly consistent with what they might expect to pay) when presented with items paired with market value prices relative to younger adults, leading to a greater benefit in this condition.

The results show that when items are paired with market value prices, there are no age-related differences in later memory for the price information when re-presented with the item. However, when more arbitrary item-price pairings are studied, both groups show a reduction in performance, but younger adults outperform older adults in this condition. This might occur because younger adults can recall the precise numerical value of the overpriced items (an arbitrary association), whereas older adults might simply encode and retrieve the price information in a more general manner. Thus, a younger adult might recall that butter was exactly \$17.89, whereas an older adult simply recalls that the price was “well above market value” or “around 17 dollars”. This suggests that in the absence of schematic support, older adults rely on more general representations of price whereas younger adults can recall these somewhat arbitrary values. This issue is examined in more detail in Experiment 6.

### **Experiment 6**

In many cases, although older adults may not be able to recall precise associative information, they may remember important aspects about the items such as the general nature of the link between two items. This notion is consistent with that of Craik (2002), who suggested that older adults have difficulty remembering specific information, but can recall more general or gist-based information. Consistent with this idea, there is good evidence from the false memory literature to suggest that older adults rely on gist-based

representations of the past. In the standard Deese/Roediger/McDermott paradigm (Deese, 1959; Roediger & McDermott, 1995), older subjects are more likely to false alarm to the “critical semantic associate” (a highly-related semantic associate word that was not presented during encoding) relative to younger adults in both recognition (Norman & Schacter, 1997; Koustaal & Schacter, 1997) and recall tasks (Kensington & Schacter, 1999; Norman & Schacter, 1997; Tun et al., 1998). Explanations of this result emphasize either age-related improvements in gist memory or age-related declines in verbatim memory.

Fuzzy-trace theory (Brainerd & Reyna, 1990) explains the distinction between reasoning and memory, according to which the accuracy of reasoning is independent of the accuracy of the memory inputs used for reasoning (for a review, see Brainerd & Reyna, 1992, 2001). By accuracy of memory, Brainerd and Reyna refer to *verbatim* memory, which is the memory for the exact sensory inputs in a given situation in the past. This type of memory can be contrasted with *gist* memory, a highly abstracted and semantic-rich level of representation. The use of one type of memory over the other can be manipulated by changing the level of task specificity. In general, Reyna (1992) found that many memory tasks demanded verbatim specificity, while reasoning tasks could be accomplished with gist representations, and that older adults tend to rely on gist-based memory in many memory-demanding situations.

It may very well be the case that older adults encode (and later retrieve) information in a gist-based manner, resulting in efficient memory performance under certain conditions. For example, instead of remembering that one’s flight departs at 2:08 pm, an older adult (as well as many younger adults) might remember this information as

“around 2 p.m.”, or “shortly after 2 p.m.”. The difference may be that a younger adult can (if necessary) recall the precise time, but more often than not relies on a more general level of representation, whereas an older adult relies on a general level of representation but cannot access more precise or specific information (possibly because it wasn’t initially encoded or is not necessary for the task).

To examine this in more detail, in Experiment 6 participants studied item-price pairs that were either under-priced (e.g. \$0.39 for a jar of pickles), over-priced (\$17.89 for a jug of milk) or market-value (\$1.89 for a head of broccoli). After the study period, participants were given a cued recall test in which they were presented with the items and had to recall the prices, as well as whether the items were over priced, under priced or market value. This allows for an examination of more general associative memory representations (e.g. I can’t remember how much the milk was exactly, but I remember it was much too expensive, maybe \$18.99?) that may be intact in the elderly. In the present experiment, it was hypothesized that older adults would be able to remember the specific prices of market value items as well as the younger adults (as seen in Experiment 5), but that for both under and over priced items, younger adults would be more accurate at recalling the specific price. In terms of remembering the general category of the prices of each item, if older adults rely on an efficient form of gist-based memory then older adults might be just as good as younger adults at identifying under priced, over priced, and market value items, suggesting that at this level of analysis there are small or negligible age-related differences in terms of memory for associative information. This finding would imply that gist-based representations are well maintained by older adults, whereas younger adults can retrieve more specific information regarding the price that was

originally associated with each item. The finding that older adults are just as good as younger adults at remembering prices that are consistent with schemas (and whether the items were congruent or incongruent with market value) would suggest that when associative information is rich in semantic content, older adults can capitalize on prior knowledge to remember both general and specific forms of associative information.

## **Method**

### Participants

In total, 24 undergraduate students from the University of Toronto (20 women and 4 men, mean age = 18.5, mean number of years of education = 13.3) volunteered to participate and received course credit for participation. Twenty-four older adults (15 women, 9 men, mean age = 69.9, mean number of years of education = 15.8) also participated in the study, and were paid \$10 for their participation. The older adults tested in this experiment were high functioning and in good health; they lived in the community and made their own way to the laboratory to participate.

### Materials

The materials were similar to those used in Experiment 5, with the exception of the addition of under-priced items. In total, 21 items were presented to participants, with 7 items paired with market value prices, 7 items paired with unrealistically high prices and 7 items paired with unrealistically low prices. As in Experiment 5, the picture of the item was presented with the price above the item, with each price ending in a “9”. In the market price condition, prices of each item were based on the actual market price of the item from the same local Internet grocery shopping web site, and these prices ranged

from \$1.19 to \$7.99. For the overpriced items, the market value prices of each item were inflated by a random dollar value between 6 and 8, so as to reduce predictability of the inflated price, and these prices ranged from \$7.19 to \$15.99. For the under priced items, unique values ranging from \$0.19 to \$0.89 were randomly assigned to items such that they reflected under value as determined by an independent judge. All prices ended in the digit “9”, and participants were made aware of this prior to the study session. Three different versions of the presentation order and test order were used, and each consisted of different item-price pairing such that each item appeared equally often as an overpriced, under priced and market value pairing.

### Procedure

Participants were tested individually, and were told that they would be studying grocery items and the prices of the items for a later memory test. The study and test procedure was very similar to that of Experiment 5 with some important exceptions. Participants were told that some of the items would be paired with prices that reflect the normal market value, whereas other items would be paired with prices that “were much too high” or “much too low” relative to market value. Participants were told that they should try and remember the price of each item, as well as whether the items were overpriced, under priced or market value, for a later memory test. They were told that after studying 21 items they would be given a memory test in which they would be presented with each item one at a time in a random order, and they should try and recall the price of the item, as well as whether the item was over priced, under priced, or market value. The experimenter then answered any questions and the participant initiated the study session by pressing the space bar. After the study session, participants were

presented with the items one at a time, and were asked to recall the price of each item as well as the value category of the item (over priced, under priced, or market value). If the participants could not remember the price, they were told to guess and provide an answer for each item, even if they could not remember the exact price of the item.

During the study phase, each picture, the name of the item and the corresponding price appeared on the centre of the screen for 10 seconds, with the name appearing above the picture in Time New Roman typeface (see Appendix 3.2). The next item appeared immediately afterwards, and after the last item, an instruction screen appeared describing the memory test. During the memory test, the items were presented without their price, and the participant was instructed to call out the price of each item as well as the value category of the item, which was presented for 10 seconds or until the participants gave a response. The experimenter, who sat behind the participants (out of sight), recorded the response of the participant. At the end of the test session, participants were asked to estimate how much money they would have spent if they purchased all of the items at the specified prices, and to rate on a 10-point scale how often they went grocery shopping.

### **Results and Discussion**

The results for price recall are shown in Figure 3.5. In terms of overall price recall performance (collapsed across all three types of item-price pairings), younger adults recalled more exact prices than older adults, and this approached conventional levels of significance,  $t(46) = 1.93, p = .06$ . In order to examine recall performance as a function of the three price types (under priced, over priced and market value), a repeated measure ANOVA was conducted with age as the between subject variable. There was a



main effect of price type,  $F(2, 92) = 30.85$ ,  $MSE = 1.45$ ,  $p < .0001$ , with the prices or market value items being better recalled than over and under priced items. The effect of age approached significance  $F(1, 46) = 3.14$ ,  $MSE = 3.36$ ,  $p = .08$ , with younger adults recalling more prices than older adults, and there was a significant interaction of age and price type,  $F(2, 92) = 7.85$ ,  $MSE = 1.45$ ,  $p < .01$ . Follow-up  $t$ -tests revealed that this interaction was driven by younger adults outperforming older adults for the under and over priced items ( $p < .01$ ), but no age related difference was present for the market value items ( $p = .25$ ), replicating the main findings from Experiment 5.

[Insert Figure 3.5 about here]

In order to obtain a measure for remembering the value category of each item, participants were asked to recall the general category of the price (under priced, over priced or market value) of each item, and the results are shown in Figure 3.6. In terms of overall value category recall performance (collapsed across all three types of item-price pairings), there were no age-related differences in performance,  $t(46) = 0.69$ ,  $p = .50$ . In order to examine value category recall performance as a function of the three price types (under priced, over priced and market value), a repeated measure ANOVA was conducted with age as the between subject variable. There was a main effect of price type,  $F(2, 92) = 7.23$ ,  $MSE = 1.07$ ,  $p < .01$ , with market and over priced items being better recalled in terms of price range relative to under priced items. However, there was no significant main effect of age,  $F(1, 46) = 0.48$ ,  $MSE = 3.74$ ,  $p = .49$ , showing that overall both groups were equally good at remembering the price range of the items. Finally, there was a significant interaction of age and price type,  $F(2, 92) = 3.55$ ,  $MSE = 1.07$ ,  $p < .05$ . Follow-up  $t$ -test revealed that this interaction was driven by older adults

outperforming younger adults for the market value items ( $p < .05$ ), but there were no age-related differences for the under priced ( $p = .55$ ) or over priced ( $p = .62$ ) items.

[Insert Figure 3.6 about here]

As in the previous experiment, following the memory test participants were asked to rate to rate how often they went grocery shopping on a scale of 1 to 10, with 1 being “never” and 10 being “very often”. Older adults provided a higher rating ( $M = 7.2$ ,  $SD = 1.7$ ) than younger adults ( $M = 4.7$ ,  $SD = 2.8$ ), and this difference was again found to be significant,  $t(46) = 3.87$ ,  $p < .0001$ . For the younger adults, there was no significant Pearson correlation between rating and number of overall correct price responses ( $r = .08$ ,  $p = .73$ ) or between rating and number of correct responses in the value category condition ( $r = -.07$ ,  $p = .75$ ), although there was a significant correlation between performance for price recall and value category recall,  $r = .48$ ,  $p = .05$ . For the older adults, there was no significant Pearson correlation between rating and number of overall correct price responses ( $r = .01$ ,  $p = .95$ ) or between rating and number of correct responses in the value category condition ( $r = -.04$ ,  $p = .86$ ), although again there was a significant correlation between performance for price recall and value category recall,  $r = .56$ ,  $p = .01$ .

Following the memory test, participants were also asked to estimate how much money they would have spent if they had purchased all of the presented items. The actual value of all 21 items was \$131.19, and younger adults gave a mean estimate of \$111.13 ( $SEM = \$13.63$ ) while older adults gave a mean estimate of \$98.67 ( $SEM = \$10.62$ ), and this was not found to be significantly different for the two group,  $t(46) = 0.72$ ,  $p = .47$ .

As discussed previously, although these ratings might suggest that older adults have more experience in grocery shopping, this experience does not necessarily lead to better price memory since grocery prices fluctuate within a certain range. It may be the case that having some degree of experience with grocery prices leads to a certain level of expertise that allows people to engage in evaluative processing of the prices, and this leads to an enriched encoding process in terms of remembering price information.

In terms of remembering the general category of the prices of each item, older adults were just as good as younger adults at identifying under priced, over priced, and market value items, suggesting that at this level of analysis there are small or negligible age-related differences in terms of memory for associative information. This finding implies that gist-based representations are well maintained by older adults, whereas younger adults can retrieve more specific information regarding the price that was originally associated with each item. The finding that older adults are just as good as younger adults at remembering prices that are consistent with schemas (and whether the item-price pairings were congruent or incongruent with market value) suggests that when associative information is rich in semantic content and allows for evaluative processing, older adults can capitalize on prior knowledge to remember associations.

### **General Discussion and Summary – Experiments 4-6**

In the previous three experiments, the ability to remember numerical information was examined in order to further understand how younger and older adults process and bind information that has a high degree of specificity and a varying level of semantic value. Numerical information can greatly vary in terms of its semantic value (e.g. depending on the context in which it is processed) and this property was utilized to

examine how expertise and schematic support can mediate associative memory performance in both younger and older adults. When numerical information is highly specific, arbitrary, and lacks meaningful context, older adults have difficulty remembering the associations between numbers and items, much like unrelated word pairs in the previous experiments. However, when expertise and prior knowledge can be used to organize and evaluate incoming information, older adults are quite good at remembering associations between item and numerical information, suggesting that associative information is well retained under certain encoding and retrieval situations.

In line with the findings from the present studies, Hinrichs and Novick (1982) found evidence for two types of number encoding operations. They make the distinction between nominal encoding, in which each digit in a number is equally important to remember (e.g. a phone number), and magnitude encoding, in which approximations can be made about the entire number (e.g. the price of car) in order to facilitate memory performance. This distinction maps on to the verbatim/gist dichotomy proposed by Brainerd and Reyna (1990, 1992, 2001), and suggests that numerical information can be processed in several different ways, depending on the context. Although Hinrichs and Novick examined this by testing only younger adults, it is clear from the present investigation that younger and older adults process and retain numerical information in different ways, such that the need to remember more arbitrary and specific numerical representations lead to larger age differences in memory performance in some situations. However, when older adults can rely on prior knowledge, the ability to remember the associations between numbers and items (such as market value prices and grocery items) is greatly facilitated. This might be due to older adults engaging in evaluative processing,

in which they compare the association of the item and price to previous item-price associations with which they are familiar, leading to a stable representation of the episode of encountering the specific item-price pairing during the experiment.

The finding that older adults have difficulty remembering arbitrary associations between numbers and items, but that they can still remember some information about the “general” association suggests that associative information is not simply forgotten. In Experiment 6, although older adults had difficulty remembering the precise price of overpriced and under priced items, they were just as good as the younger adults at identifying the price range of each item. This suggests that at this “level” of associative memory, age-related differences in memory performance are minimized, reflecting the possibility that older adults engage in encoding or retrieval operations that only allow for a more general representation of these kinds of associations. This observation has implications for theoretical models of associative memory, and also suggests that older adults likely engage in different (sometimes less efficient, but sometimes highly efficient) encoding and retrieval operations depending on the task and situation, relative to younger adults. Implications for these observations and findings, as well as a theoretical framework to organize and interpret the results are presented in the following section.

## **CHAPTER FOUR: GENERAL DISCUSSION, THEORETICAL CONTRIBUTIONS, AND IMPLICATIONS**

### General Summary

The present series of experiments examined how younger and older adults remember item and associative memory, and how this ability is mediated by attentional resources, the specificity of the association, and the degree of schematic support that accompanies encoding and retrieval. The first set of experiments demonstrated that older adults had a disproportionate impairment for associative information in a word pair recognition task that was greater than both younger adults under full and divided attention. The observation of an associative memory impairment in older adults is consistent with previous findings (Chalfonte & Johnson, 1996; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Naveh-Benjamin, 2000; Kahana, Howard, Zaromb, & Wingfield, 2002) and is likely due to a reduction in available processing resources, leading to an increased reliance on familiarity in associative recognition situations (Jacoby et al., 1996; Jones, Jacoby, & Gellis, 2001; Jones & Jacoby, 2001). The second set of studies showed how the degree of specificity, or arbitrariness, of an association contributes to associative memory impairments for both younger and older adults, and how older adults can make use of expertise and schematic support to reduce and eliminate associative memory impairments. The findings from these experiments shed light on what factors give rise to associative memory impairments and how the encoding and retrieval of associative information can be conceptualized for both younger and older adults. In the following section, the main results from the series of experiments are discussed and interpreted in order to provide a general explanation for age-related

differences in associative memory. The present experimental findings are also incorporated into current theories regarding cognitive psychology and cognitive aging, and a new conceptual framework is developed that attempts to explain how associative memory performance changes in old age.

### Mechanisms of Associative Memory in Older Adults

The findings from the present studies address how associative memory can be measured, and how certain types of associations seem to be impaired in older adults whereas other kinds of associations are well maintained by older adults. Older adults made more false alarms to recombined items relative to younger adults, likely as a result of relying on familiarity, as opposed to more precise representations of associative information (Jacoby et al., 1996; Jones, Jacoby, & Gellis, 2001; Jones & Jacoby, 2001). It may be that reductions in processing resources leads the reliance on familiarity when processing recombined items on a recognition memory test. One operation that might prevent associative memory errors is a “recall-to-reject” process (e.g. Humphreys, 1978; Rotello & Heit, 2000) in which participants can recall the original pairing of items in order to reject rearranged pairings in an associative recognition task. This operation of recall-to-reject allows for a reduction in false alarms to conjunction lures, and Donaldson and Rugg (1998) found that neural correlates of recollection were frequently associated with correctly identify old words pairs as well as when younger participants correctly rejected conjunction pairs. It is likely that older adults do not employ this operation to the same degree as younger adults, and often rely more on a global sense of familiarity in the absence of recollection. Recent research has shown that healthy older adults as well as

those with early stages of Alzheimer's disease show impaired recall-to-reject processing, resulting in a greater liability to false alarm in an associative recognition task (Gallo, Sullivan, Daffner, Schacter, & Budson, 2004). Thus, it may be that increasing age and reductions in frontal lobe function lead to a reliance on familiarity and an impairment in terms of remembering specific details and arbitrary associations that allow one to reject recombined pairs in a recognition memory paradigm.

An alternative suggestion that might explain the age-related differences in memory for associative information in the word pair paradigm centres on the notion that older adults have an impaired ability to bind appropriate units of information. This notion suggests that type of encoding processes differ for young and older adults, with older adults forming less precise (or perhaps loose associations) during the study phase. Thus, instead of encoding and binding two words within a word pair, older adults associate the words with other information, either other words that were presented on the list or simply other unrelated information that came to mind during encoding. Another possibility is that older adults encode the presentation of item according to the general time frame in which the items were presented, such that instead of forming a link between two simultaneously presented words, a more general link is formed that associates the words with a particular list or a general episode of study. This would suggest that "defective" binding occurs, or possibly "over-binding" units of information that are not intended to be bound in the first place. Speculatively, older adults may bind many items to a general time period (i.e. over-binding) as opposed to binding specific items to one another as dictated in the associative memory task. This form of binding might then lead to more conjunction errors. Kroll et al. (1996) suggest that this might



underlie the associative memory deficits found in amnesic patients, and this would be in line with views that older adults have difficulty inhibiting irrelevant information in working memory (Hasher & Zacks, 1988; Zacks, Hasher, & Li, 2000). Thus, it may be the case that older adults have difficulty refraining from binding elements that are not intended to be bound, or that older adults bind information in a more global manner. The products of this excessive or global binding (although acceptable in terms of the construction of semantic memory, and may be one reason older adults show high false memory effects in the false memory/DRM paradigm) result in impairments in terms of the episodic memory for unrelated word pairs and other kinds associative information. Although this is somewhat speculative in the present study, further research that examines how breakdowns in the different mechanisms involved in binding contribute to impaired association memory is needed, especially in terms of how aging influences associative memory performance.

One reason that older adults have difficulty recruiting appropriate resources when binding arbitrary items of information may be related to issues of executive control. As suggested by Jacoby and Hay (1996), older adults are not impaired in terms of the automatic mechanisms that contribute to memory performance, while more controlled processing, such as recollection, are impaired. In this case, automatic processing is described as a fast, unaware process that is under the control of the stimuli rather than the intention of the participant (e.g. Hasher & Zacks, 1979). For example, in the directed forgetting paradigm in which participants are presented with words followed by a cue to either remember or forget the word, older adults produced more “to-be-forgotten” word intrusions on an immediate recall test relative to younger adults (Zacks, Radvansky, &

Hasher, 1996). This finding may suggest inappropriate binding between the word and cue, as well as an overall reduction in the ability to suppress the processing and retrieval of items designated as to-be-forgotten, consistent with Hasher and Zacks' (1988) hypothesis of impaired inhibitory mechanisms in older adults.

Although there appear to be a number of different ways in which aging can contribute to impairments in associative information in the laboratory, recent research has examined how associative learning can be improved by using self-monitoring and self-testing (e.g. Dunlosky & Hertzog, 1998b). Dunlosky, Kubat-Silman, & Hertzog (2003) designed a procedure in which older adults were involved in a memory training program that emphasized self-paced associative learning by incorporating self-testing procedures for associations that were deemed to be more difficult to remember. Age-related deficits in associative memory were greatly reduced using this method, and this suggests that the successful use of monitoring skills can improve associative learning in old age. Consistent with this finding, Dodson and Schacter (2002) found that if older adults make use of a “distinctiveness heuristic” at retrieval, then this would reduce false alarms in an associative recognition test. The distinctiveness heuristic involves presenting stimuli (at encoding) in two different modalities (e.g., a spoken word as well as its visual analogue) and reinforcing the use of this information during a recognition test by reminding participants to make use of perceptual details and recollection when responding to recombined or similar stimuli at test. This reduced the false memory effect for both younger and older adults, suggesting that older adults can rely on distinctiveness and recollection processes under certain conditions.

The instruction to rely on the distinctiveness heuristic at retrieval could possibly reduce associative memory impairments that have been observed for older adults on recognition memory tests. Jennings and Jacoby (2003) have implemented an approach for training memory in older adults that distinguishes between recollection and automatic influences. Participants were given multiple trials of a continuous recognition task in which they had to use recollection to identify repeated items. After each correct trial, the number of intervening items between repetitions was gradually increased (incremented-difficulty approach). The findings suggest that an incremented-difficulty approach can enhance the ability to recollect information across increasing delay intervals, possibly reducing age-related deficits in associative memory performance, and the reliance on familiarity in recognition memory tests. Although a variety of heuristics, strategies, and training situations have shown some promise for reducing age-related associative memory impairments in the laboratory, it appears that the implementation of these procedures in everyday function is often the biggest challenge for older adults.

Although it remains unclear what mechanisms contribute to associative memory performance in younger and older adults, it is apparent that large age-related differences exist in some situations whereas under other conditions these differences are reduced or eliminated. This suggests that one must use a variety of tasks to assess associative memory, given that younger and older adults likely rely on different processes depending on the situation. It may be the case that unless otherwise necessary, older adults use a more general gist-based encoding operation and familiarity-guided retrieval process, whereas younger adults utilize all available cognitive processes to obtain detailed information and encoding and make use of this information at retrieval. The possible

distinction between these and other different “styles” or methods of memory processing is examined in the following section.

### Memory for Gist and Specific Information in Older Adults

There is a growing literature that suggests that older adults encode and retain “gist-based” information, and the findings from the present study are largely consistent with this observation. Fuzzy-trace theory (Brainerd & Reyna, 1990) explains the distinction between reasoning and memory, according to which the accuracy of reasoning is independent of the accuracy of the memory inputs used for reasoning (for a review, see Brainerd & Reyna, 1992). By degree of accuracy of memory, Brainerd and Reyna refer to two distinct types of memory representation. The first is *verbatim* memory, which is the memory for the exact sensory inputs in a given situation in the past. This type of memory can be contrasted with *gist* memory, a highly abstracted and semantics-rich level of representation. The use of one type of memory over the other can be manipulated by changing the level of task specificity. In general, Reyna (1992) found that many memory tasks demanded verbatim specificity while reasoning tasks could be accomplished with gist representations. Reyna also suggests a “fuzzy processing preference”, according to which gist representations are used by default to answer questions unless the task requires verbatim specificity. This observation is especially interesting given the findings from the present study in which older adults had the greatest difficulty binding arbitrary units of information (unrelated word pairs) but age-related differences were reduced when the task involved semantically-rich material. Under conditions when binding involved relevant and semantically rich information (such as grocery items and prices), older

adults benefit by relying on evaluative processing to remember specific information about item-prices pairings, as well as more general information about the price categories of previously studied items.

In one sense, verbatim representations seem more basic than their gist counterparts. They are simply copies of the exact percept of an event, stored in a fairly “non-semantic” way. Gist representations, on the other hand, are complex and integrative constructions. The nature of the relationship between these forms of representation is elusive, although one possibility is that verbatim representations must be initially involved in abstracting the meaning or gist of presented information. The relationship between gist and verbatim representations, once they have become more stable, remains a matter for debate. Early work denied the possibility of distinct gist representations, arguing that the retrieval of gist representations is accomplished by sophisticated processing of verbatim representations as needed (Glucksberg & Danks, 1975). Other work has suggested that once a gist representation has become stable, verbatim representations may no longer be necessary (Carpenter, Miyake, & Just, 1994; Daneman & Merikle, 1996) and this may be especially the case with older adults (Turk-Browne, Castel, & Craik, 2004). At the other end of the scale, some work on longer-term retention of verbatim and gist representations suggests that verbatim memory results from a reconstructive process based on gist memory (e.g. Potter, 1993). Many studies have provided converging evidence that the two types of representation are stored separately and processed in parallel (Brainerd & Gordon, 1994; Reyna & Brainerd, 1992; Reyna & Kiernan, 1994), more consistent with the latter two approaches.

Fuzzy-trace theory has been previously examined from an aging perspective, typically with respect to rates of forgetting of gist and verbatim information (for a review, see Brainerd, 1996). The standard paradigm begins by training participants such that their verbatim and gist memory is at ceiling in an acquisition session. After varying length of time, participants are given delayed recall tests and memory for gist and verbatim information is compared. These studies have found that the ability to retain verbatim information deteriorates more quickly than the ability to retain gist information, and the results are suggestive that this becomes even more apparent in older adults (e.g. Schacter, Koustaal, Johnson, Gross & Angell, 1997; Titcomb & Reyna, 1995; Tun, Wingfield, Rosen & Blanchard, 1998; Turk-Browne, Castel, & Craik, 2004). Research from the false memory literature has also highlighted selective age-related deficits in processing and remembering verbatim versus gist information. In the standard Deese/Roediger/McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), older subjects are more likely to false alarm to the critical semantic associate, an obvious member of the semantic class which makes up the study list but is missing, than younger adults in both recognition (Norman & Schacter, 1997; Koustaal & Schacter, 1997, Balota et al., 1999) and recall (Kensington & Schacter, 1999; Norman & Schacter, 1997; Tun et al., 1998) tasks. This type of finding suggests that age-related improvements are present for gist memory (or perhaps a greater reliance on veridical gist memory in old age), accompanied by age-related declines in verbatim memory.

Brainerd and Reyna (2001) have argued that since all of the words that are presented in the DRM paradigm are very familiar during the test phase, it is unlikely that age-related improvements in gist memory could be responsible for the obtained pattern of

results. They suggest that the increased false alarm rate can be attributed to declines in the accessibility of the verbatim trace of the word list. They further argue that if younger adults can rely on verbatim representations, and older adults are unable to, then in situations in which gist access is encouraged over verbatim access the difference between the two groups should be reduced. In support of this, a study by Tun et al. (1998) shows that age-related differences decreased when participants were encouraged, through task demands, to rely on a gist representation of the study list, and work by McCabe and Smith (2002) has shown that older adults can reduce false alarms to the critical lure if warned prior to the encoding session about the nature of the task and materials. This suggests that although older adults may typically rely on gist-based representation, under certain conditions they are able to access and use more specific information. These results are consistent with the present findings in which older adults can remember gist-based information about prices, as well as more specific information about market value prices, by relying on the use of schemas and evaluative processing.

Another way to describe the findings from the present study is in the context of episodic and semantic memory systems (Tulving, 1972, 1983; Schacter & Tulving, 1994). In Experiments 5 and 6, that dealt with the influence of prior knowledge (a form of information or structure that is related to the semantic memory system), older adults benefited from situations that allowed for reliance on schematic support. In this setting, improved memory performance in older adults is observed because participants can rely on *both* episodic and semantic memory when processing the grocery items and prices. For example, episodic memory is involved when remembering the item-price pair during the study phase, and recalling prior episodes of seeing similar items in a grocery store,

while semantic memory is also relied on in terms of knowing the prices of certain studied items and being able to compare the studied prices with general knowledge about typical grocery prices. The recruitment of these two memory systems leads to better memory performance in these types of situations, especially for older adults who access prior knowledge regarding grocery prices. Thus, in this case, schematic support may be defined as the ability to rely on semantic memory to interpret incoming information that is to be processed and stored in episodic memory, and this is an especially effective way for older adults to form and retain episodic memories.

#### The Role of Prior Knowledge and Expertise in Memory for Associations

The ability to integrate incoming information with pre-existing knowledge allows for some organization of this information into a structured format. Schematic support implies that the process of learning consists of building up mental schemes or organized bodies of knowledge about the outside world, and that these schemes can then serve as the basis for the interpretation of further events. It has been repeatedly shown that knowledge in a particular domain can facilitate memory for domain-relevant information, such as chess position (Chase & Simon, 1973), bridge hands (Engle & Bukstel, 1978), dance steps (Allard & Starkes, 1991), maps (Gilhooly, Wood, Kinnear, & Green, 1988), music (Meinz & Salthouse, 1988), and baseball-related information (Hambrick & Engle, 2002; see Kramer et al., 2004, for a recent review).

The investigation of how expertise can reduce age-related differences in cognitive skills and memory performance has been mixed, with some studies showing that expertise can help to reduced age-related differences (i.e., serving as a form of



compensation), while other studies showing that many conditions exist where younger adults outperform older adults even at high levels of expertise. For example, age-related expertise-based effects (often thought of as a form of compensation) have been observed for complex game playing, such as chess and Go (Charness, 1981a&b; Masunaga & Horn, 2001), as well as in professions such as piloting and memory for air traffic commands (Morrow, Leirer & Altiere, 1992; Morrow, Leirer, Altiere & Fitzsimmons, 1994; Morrow et al., 2001; Tsang & Shanner, 1998; Tsang & Voss, 1996), medical laboratory technical work (Clancy & Hoyer, 1994; Dollinger & Hoyer, 1996) and for musical professions (Krampe & Ericsson, 1996). On the other hand, Morrow et al. (2001) found no evidence to suggest that aviation-related experience (which corresponded positively with aviation knowledge) reduced the negative effect of age on memory for air-traffic control messages, while in the domain of music expertise Mainz and Salthouse (1998) and Mainz (2000) found no evidence for an age by experience interaction on recall of visually presented melodies. In a slightly different approach, Lindenberger, Kliegl and Baltes (1992) found that older graphic designers attained higher levels of mnemonic performance (using the method of loci to remember information) than older adults who were not graphic designers, but were not able to reach younger adults' levels of performance on an imagery-based memory task. Thus, it appears that in many situations, prior knowledge and levels of expertise have similar effects on younger and older adults' memory performance, but that these effects do not reliably attenuate age differences in memory performance on domain-relevant tasks.

The present study used two different forms of expertise and prior knowledge to examine how these factors might reduce age-related differences in association memory

tasks. In the first case, older adults with professional experience working with numerical information (retired accountants and book-keepers) showed high levels of performance in terms of binding arbitrary numerical information with other types of information. This suggests that expertise in a particular domain can influence the manner in which certain information is remembered and associated with other units of information. It remains unclear whether this reflects a difference in strategy use by experts, or whether it is the salience of numerical information for this group of individuals that leads to superior memory. Since a group of younger accountants was not tested in the present study, the degree to which this form of expertise can attenuate age-related differences within this domain is not known, but it does show that older adults can rely on prior experience to retain and bind incoming information. This observation extends to other situations in which prior knowledge can influence the ability to remember item and association information, such as in the context of grocery items and prices, a domain in which many individuals have a certain degree of experience or perhaps a basic level of expertise. In this case, older and younger adults can make use of prior knowledge and schematic information to organize and process information in an evaluative manner, and this leads to successful binding of the prices to particular items. Although some might argue that experience with grocery items and prices is not a pure form of expertise, the fact that prior knowledge can initiate or enhance evaluative processing of information may be the critical factor that contributes to a reduction in age-related differences in associative memory. In order to extend previous examinations of expertise and age differences in associative memory performance, it is important to use other materials or tasks that have everyday significance (see Neisser, 1978, for a similar argument). The use of items and

tasks that are encountered in the everyday world provides some structure for the individual to organize and encode incoming information, and this appears to be especially important for older adults. In light of the present findings, it is interesting to explore the mechanisms or processes that give rise to the “expertise advantage” and whether expertise can specifically influence the manner in which one encodes and retrieves verbatim and gist-based information. It may be the case that expertise, or experience with a certain type of task or material, influences the manner in which one encodes the degree of precision or the specificity of the information in questions.

### Memory, Grain Size and Aging

The findings from the false memory/DRM literature suggest that older adults may utilize gist-based encoding and retrieval operations under certain situations, but it remains unclear why older adults use gist processing as opposed to relying on verbatim information. Although a general reduction in available processing resources may partially explain the reliance on gist, older adults may be able to maximize memory performance using appropriate “grain-size” analysis (Koriat & Goldsmith, 1994, 1996; Goldsmith, Koriat, & Weinber-Eliezer, 2002) in conjunction with environmental and schematic support. Control over grain size can be defined as the operation in which one chooses the level of detail (“precision”) or generality (“coarseness”) at which to encode and later report remembered information (Goldsmith, Koriat, & Weinber-Eliezer, 2002). For example, if one witnesses a crime and attempts to remember certain characteristics of the assailant, one could encode (and/or later retrieve) precise information such as “the man was 5 feet, 10 inches tall”, or more general information, such as the man was “about six

feet tall”, or “about my height”. Goldsmith et al. highlight an important distinction between memory accuracy and memory quantity, such that people can withhold information that they might feel unsure about or provide relatively coarse information that is unlikely to be wrong, or fits appropriately with the situation. According to this notion, the rememberer has the ability to strategically control and regulate the grain size of their answers to accommodate the competing goals of accuracy and informativeness, suggesting that grain size is mediated by both cognitive and metacognitive processes. It may also be the case that expertise in a particular domain gives the remembering more control over grain size, leading to better memory accuracy.

Although Koriat et al. (2000) have not directly applied the grain-size notion to cognitive aging, the findings from the present studies (as well as those from the false memory/DRM literature) suggest that it may be the case that older adults choose to employ a broader “grain-size” analysis during both encoding and retrieval operations, leading to what appear to be impairments in terms of memory for specific items and associative information. On the other hand, the same finding may result from an age-related inability to analyze and encode information at the specific level of analysis that is required for recognizing subtle changes in associative information. This would be in line with several findings from the present experiments, in which older adults have difficulty distinguishing between word pairs that are very similar to those that were recently studied, but that when the task involves related information or information that can be analyzed using a broad grain size, age differences are reduced. For example, older adults could recall which grocery items were paired with prices that were incongruent with expectations (a broad grain size) but had greater difficulty remembering the precise price

of these over priced or under priced item (a more fine-grained analysis). It is interesting to note that prior knowledge and expertise can fine-tune the level of grain size, such that when prices were market value, older adults could rely on a more specific level of grain size to retrieve the exact price. Why older adults select (or can only use) certain levels of grain-size is an important issue to examine in the future, as is looking at age-related differences in the ability to adaptively and volitionally alter the level of grain-size analysis that is appropriate for the task at hand. It may be that older adults typically use (or can only use) a coarse/broad grain size in certain tasks (such as binding and later recognizing previously studied unrelated word pairs), whereas younger adults can adaptively modify grain size, leading to age-related differences in the ability to remember associative information. The mechanisms that control grain size analysis appear to be intact in older adults under certain situations, and it may be the case that control over grain size is mediated by motivation, expertise and schematic support, as well as memory capacity, especially for older adults.

#### Situated Levels of Associative Memory (SLAM) Framework

The findings from the present set of studies fits with other work in the domain of cognitive aging as explained in the previous sections, but often it is helpful to organize the findings in a framework which emphasizes the main theme of the results. One way to conceptualize the findings from the present studies is in terms of a hierarchical organization of associative memory, in which access to various levels of “associative specificity” depends on the person’s ability (e.g. memory capacity, encoding and retrieval processes, and control over memory) and various situational factors (e.g. the type of

material and the need to remember specific/verbatim information relative to more general gist-based information). To illustrate how associative specificity and situational factors contribute to memory performance in younger and older adults, a theoretical framework can be devised to organize the data and findings from the present set of studies, as well as those from previous related work. This framework, referred to as the “Situating Levels of Associative Memory” (or “SLAM”) framework, suggests that different levels of associative information are initially encoded, and that access to these hierarchical levels of precision depend on the situation or task at hand, as well as the individual’s ability to access the desired level of information representation.

The development of hierarchical models of cognition has been very useful as conceptual frameworks to describe scripts and schemas, organization of factual knowledge, autobiographical memory, and memory for text and stories (see Cohen, 2000, for a review). As illustrated in Figure 3.1, and based on the notion put forth by Craik (2002), the ability to remember general and specific associative information is likely dependant on a variety of factors, including attention and cognitive resources. Craik (2002) suggested that as to-be-remembered information becomes more specific, age-related differences in memory performance become more apparent. In the present context, the ability to remember general and more specific levels of associative information likely depend on the person’s ability and can be influenced by factors such as motivation, materials and context, expertise and prior knowledge, control over attention, and memory capacity. In line with the grain size framework (Koriat et al., 2000), in many situations the types of encoding and retrieval operations that are relied upon depend on the degree of precision that is required. Thus, different levels of associative

information may be similar to varying levels of grain size. For example, in some situations one may need to encode specific information (e.g., your hotel room number is 1203), whereas in other cases relying on a more coarse or general level of representation is sufficient (e.g., remembering that your flight leaves at noon, rather than precisely 12:03 pm).

The incorporation of several units of information to form a memory representation involves the use of associative information, and the SLAM framework emphasizes how units of information are bound to form both simple pairing of items as well as more complex associative representations. It may be the case that older adults rely on a more general level of information representation whenever possible, such as remembering ones flight leaves at noon, or that one's hotel room is on the 12<sup>th</sup> floor, but have greater difficulty recalling more precise information, such as the exact time of the flight or exact room number. Some research that is consistent with this notion is a source memory experiment (Dodson, Holland, & Shimamura, 1998) that was conducted with younger adults under either full or divided attention at retrieval, and showed that divided attention impaired participants' memory for specific-source information (i.e., specific voice and source information about the speaker) but did not affect memory for partial source information (i.e. remembering the gender of the speaker). Other work by Ferguson et al. (1992) and Johnson et al. (1995) found that older adults were worse than younger adults at identifying the speaker of a previously heard word when the words were spoken by two different women, but older adults were just as good as younger adults at remembering whether the words were spoken by either a woman or a man. These findings suggest that divided attention, as well as aging, can influence the level and

type of access one has to representations of source and other associative information. Building on the grain size framework, SLAM extends these ideas to cognitive aging and memory for associative information. Thus, the SLAM framework is constructed to allow for several types of representations (varying from general to more precise and specific), and access to various types of specificity is dependent on task demands and the person's ability and need to tap different levels of association information.

It is the interaction of the person's ability and certain situational factors which gives rise to critical types of cognitive processing, and in the present context older adults likely benefited from the use of "evaluative processing" to access specific types of associations. Evaluative processing refers to situations in which one makes judgments or appraisals regarding to-be-remembered information, leading to a deeper level of processing and a stable memory representation. When evaluative processing is minimal (such as remembering and recognizing arbitrary associations in the first three experiments), age-related differences were apparent, but when older adults engaged in evaluative processing based on prior knowledge, the age-differences for associative information were minimal. The SLAM framework suggests that when the person can capitalize on the use of prior knowledge in order to engage in evaluative processing, memory performance (especially for older adults) is maximized. This suggests that one of the best situational variables that can lead to efficient access to the various levels of associative information is the need for evaluative processing of both encoding and retrieval cues.

The actual brain mechanisms that are critically involved in access to SLAM are not known, but drawing on the findings of frontal lobe function and aging (e.g., West,



1996) and the use of grain size in memory accuracy (Koriat et al., 2000), some possible systems can be hypothesized. It may be, much like the models developed by Moscovitch and Winocur (1992; Moscovitch, 2000), that the frontal lobes and hippocampus are critically involved in governing the use of grain size and the encoding and retrieval of appropriate levels of associative memory. More specifically, the frontal lobes, which are known to show some volumetric depletion in old age (Raz, 2000) may dictate the strategic regulation of grain size, and this is why older adults often lack the proper “resolving power” (to borrow a term from Craik, 2002) in order to focus resources on a precise level of associative memory. However, when the task or the stimulus gives some degree of support, then this gives the appropriate cue to regulate grain size. Drawing on the present findings, it may be the case that as frontal lobe functioning declines in efficiency in old age, prior knowledge, evaluative processing, expertise or simply interesting and engaging materials and tasks are needed to “jump start” this system to engage an efficient grain size of memory analysis. The frontal lobes may be the starting point or area in terms of regulating grain size at both encoding and retrieval, whereas the hippocampus is more involved in an automated binding process that results in a “bound product” and access to the various levels of associative information or this bound product is again dictated by frontal lobe efficiency.

The situational factors that contribute to the ability to recognize and recall associative information can include the need to encode and recall specific links, the payoff for retrieving this information, and the context that contributes to the need to remember precise or more specific associative information. For example, in some cases it may only be necessary to encode and retrieve general information (such as knowing a

flight leaves at “just after 2 pm” rather than precisely “2:03 pm”). In some situations, it may be the case that older adults are *more* discriminating than younger adults in terms of deciding what information will be processed and retained for later use, and this might be an efficient strategy in light of reduced memory capacity. Older adults might intentionally not direct sufficient processing resources toward tasks they feel are unimportant or irrelevant (such as remembering an unrelated word pair, or the precise price of an overpriced grocery item) and save these resources for remembering information that is deemed important or salient (such as remembering numerical information if one has experience working with numbers, or remembering the precise price of a market value grocery item). Consistent with this notion, Fung and Carstensen (2003) found that older adults had better memory for advertisements that promised to help realize emotionally meaningful goals relative to other types of advertisements, suggesting that older adults selectively guide and control encoding processes to information they feel is relevant and important. The source memory study by Rahhal, May, and Hasher (2002) also fits this point of view, in the sense that when source information is made conceptually important (the source, a male or female voice that spoke a fact, indicates whether the fact was true or false), older adults perform just as well as younger adults in terms of remembering the truthfulness of the information. Although it is difficult to attribute all age-related differences in memory performance to a lack of motivation, difficulty in remembering perceptual information, or the reduced ability to direct resources to appropriate stimuli, it is important to consider these factors when assessing a general process such as binding information. The SLAM framework takes into account situational variables and the fact that motivational factors and the

saliency of the information to the individual can influence the level or type of associative information that is encoded and retrieved, and that this can vary according to the age of the individual.

In the present study, it appears that older adults often encoded (and later retrieved) more general information about the over and under priced items because, to them, that was the salient bit of information that was represented by the associative information. For example, in Experiments 5 and 6, when the prices were market value, older adults had a more specific representation of the association because they could utilize contextual and evaluative processing, and thus were better able to recall the precise prices because in this situation small deviations were critical in terms of the evaluation of the product's price. In other situations (such as with under and over priced items), older adults' reliance on evaluative processing might simply lead them to encode price information in a more general manner, because this is all that is necessary from the perspective of an experienced shopper. Working within the SLAM framework, the number and types of levels of associative memory are intentionally under defined, as this depends on the person's ability and the type of task. It is conceivable that older adults might still have access to more specific information within each category of "under priced" and "over priced", such that perhaps they could rank order the prices of each item within these categories even though they cannot access the specific prices. This would suggest that access to another more specific level of representation is available, and situations in which this might be useful (e.g., if you wanted to spend less money, would you buy the pickles or the broccoli?) it may be the case that older adults can utilize this information if dictated by the task at hand. Thus, the use of priming or implicit memory measures may

reveal that, to some degree, more specific associative information is in fact retained by older adults, although access to this information is impaired under explicit memory situations. Despite that many previous studies of memory functioning in the laboratory emphasize verbatim recall or recognition, as well as memory quantity, finding situations in which different levels or forms of associative memory are efficient representations may help complete the picture in terms of how memory changes and is relied upon in old age.

### Summary and Conclusions

The present series of experiments examined how a model of reduced attentional resources can simulate cognitive aging and how encoding and retrieval processes contribute to associative memory impairments in older adults. Previous research has shown that older adults display a specific impairment in the ability to remember associative information (e.g., Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000). The results from the present series of experiments suggest that although older adults may have particular difficulty remembering subtle changes in associative information, expertise, context, environmental and schematic support can mediate (and possibly even reverse) this pattern of results. Although a general reduction in processing resources may partially explain age-related memory performance, older adults may be able to optimize memory performance using appropriate “grain-size” analysis (Koriat & Goldsmith, 1994, 1996; Goldsmith, Koriat, & Weinber-Eliezer, 2002) in conjunction with environmental and schematic support. It may be the case that older adults choose to employ a broad or coarse “grain-size” analysis during both encoding and retrieval operations, leading to

what appear to be impairments in terms of memory for associative information. On the other hand, the same finding may result from an age-related inability to analyze and encode information at the specific level of analysis that is required for recognizing subtle changes in associative information. Given the numerous studies that show age-related impairments on memory tasks, it is suggestive that older adults display an inability to perform well under typical laboratory based memory conditions. However, studies that allow the use of gist-based processing or allow older adults to utilize prior knowledge show interesting exceptions to the typical finding of age-related impairments in memory. The present research shows both types of findings, with older adults displaying an associative impairment for word pairs, but a marked improvement when binding items that involve the use of prior knowledge. Why older adults select (or can only use) certain levels of grain-size is an important issue to examine in the future, as is looking at age-related differences in the ability to adaptively and volitionally alter the level of grain-size analysis that is appropriate for the task at hand. It may be that older adults typically use (or can only use) a coarse/broad grain size, whereas younger adults can adaptively modify grain size, leading to age-related differences in the ability to remember associative information.

In terms of encoding and retrieving different types of associative information, it is likely that there are many different “levels of associative information” that can be described and organized in a hierarchical fashion. In the present context, this can take the form of associating two arbitrary units of information, associating specific numbers or quantity information with items and sources, associating information that results in bound units that are consistent or inconsistent with prior knowledge, and at each of these levels

one can examine age-related difference in terms of the ability to encode and retrieve associations. This notion is developed in a framework that emphasized situated levels of association memory (SLAM), and the organization of the hierarchical levels of associative information may depend not only on the degree of specificity in which information is bound, but also on the need to recruit appropriate cognitive resources (as dictated by the task) and the ability to rely on prior knowledge and expertise. It is possible that when associative information involves the arbitrary binding of two or more unrelated items (which require a substantial amount of attentional resources and self-initiated processing), age-related differences are evident, more noticeable, and somewhat exaggerated. However, when the formation of associative information consists of using prior knowledge, evaluative processing (e.g. evaluating whether the binding of two items is consistent or inconsistent with expectation and prior knowledge), and has some degree of semantic value, then older adults can use appropriate cognitive resources to remember associations, resulting in negligible (or even reversed) age-related differences in memory performance.

In summary, it is apparent that the associative memory deficit that is often seen in old age can be partially explained by differences in encoding and retrieval operations, and differences in the ability to recruit appropriate attentional resources to specific tasks. Furthermore, the degree of specificity with which one examines the ability to bind information and remember associative information, the variety of materials that are employed to examine the retention of associative information and the different strategies and prior knowledge utilized by younger and older adults are important factors that can mediate associative memory performance.

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Table 2.1

Mean proportion of “old” responses to each of the four word pair types in the pair recognition test and in the item recognition (single word) test for Experiment 1A and B. In the word pair test, hits constitute “old” responses to old word pairs, and in the single word test, hits constitute “old” responses to both old and conjunction (conj) word pairs. Standard errors of the mean are presented in parentheses.

<u>Word Pair Type</u>	<u>Word Pair Test</u>				<u>Single Word Test</u>			
	<u>Old</u>	<u>Conj</u>	<u>Item</u>	<u>New</u>	<u>Old</u>	<u>Conj</u>	<u>Item</u>	<u>New</u>
<u>Experiment 1A</u>								
Full attention	.63 (.03)	.17 (.02)	.08 (.02)	.05 (.01)	.69 (.03)	.54 (.03)	.14 (.02)	.17 (.02)
Divided attention Encoding only	.39 (.03)	.28 (.03)	.21 (.03)	.15 (.02)	.42 (.03)	.37 (.03)	.23 (.03)	.21 (.03)
Older	.61 (.04)	.40 (.04)	.23 (.03)	.12 (.03)	.63 (.04)	.60 (.03)	.30 (.03)	.22 (.03)
<u>Experiment 1B</u>								
Divided attention Encoding & retrieval	.58 (.02)	.22 (.03)	.13 (.02)	.06 (.01)	.58 (.04)	.49 (.03)	.18 (.02)	.14 (.02)

Table 2.2

Mean proportion of “old” responses to each of the four word pair types in the pair recognition test in the three blocks of Experiment 2A, and for the two groups in Experiment 2B. Hits constitute “old” responses to old word pairs, and standard errors of the mean are presented in parentheses.

	Word Pair Type			
	Old	Conj	Item	New
<u>Experiment 2A</u>				
Full attention	.75 (.04)	.12 (.02)	.04 (.01)	.03 (.01)
Divided attention Encoding only	.42 (.04)	.20 (.03)	.11 (.02)	.05 (.01)
Divided attention Encoding & retrieval	.45 (.04)	.20 (.04)	.12 (.03)	.07 (.02)
<u>Experiment 2B</u>				
Full attention	.83 (.02)	.08 (.01)	.02 (.01)	.01 (.01)
Older	.70 (.03)	.42 (.04)	.18 (.02)	.10 (.02)

Table 2.3

Mean proportion of “old” responses to each of the four word pair types in the word pair recognition test Experiment 3. Hits constitute “old” responses to old word pairs, and standard errors of the mean are presented in parentheses

	Word Pair Type			
	Old	Conj	Item	New
<u>Experiment 3</u>				
Full attention	.78 (.05)	.19 (.06)	.08 (.04)	.03 (.03)
Divided attention Animacy task	.54 (.05)	.35 (.06)	.27 (.05)	.20 (.05)
Divided attention Bigger/smaller task	.49 (.06)	.42 (.06)	.29 (.06)	.26 (.06)
Older adults from Experiment 2	.70 (.03)	.42 (.04)	.18 (.02)	.10 (.02)

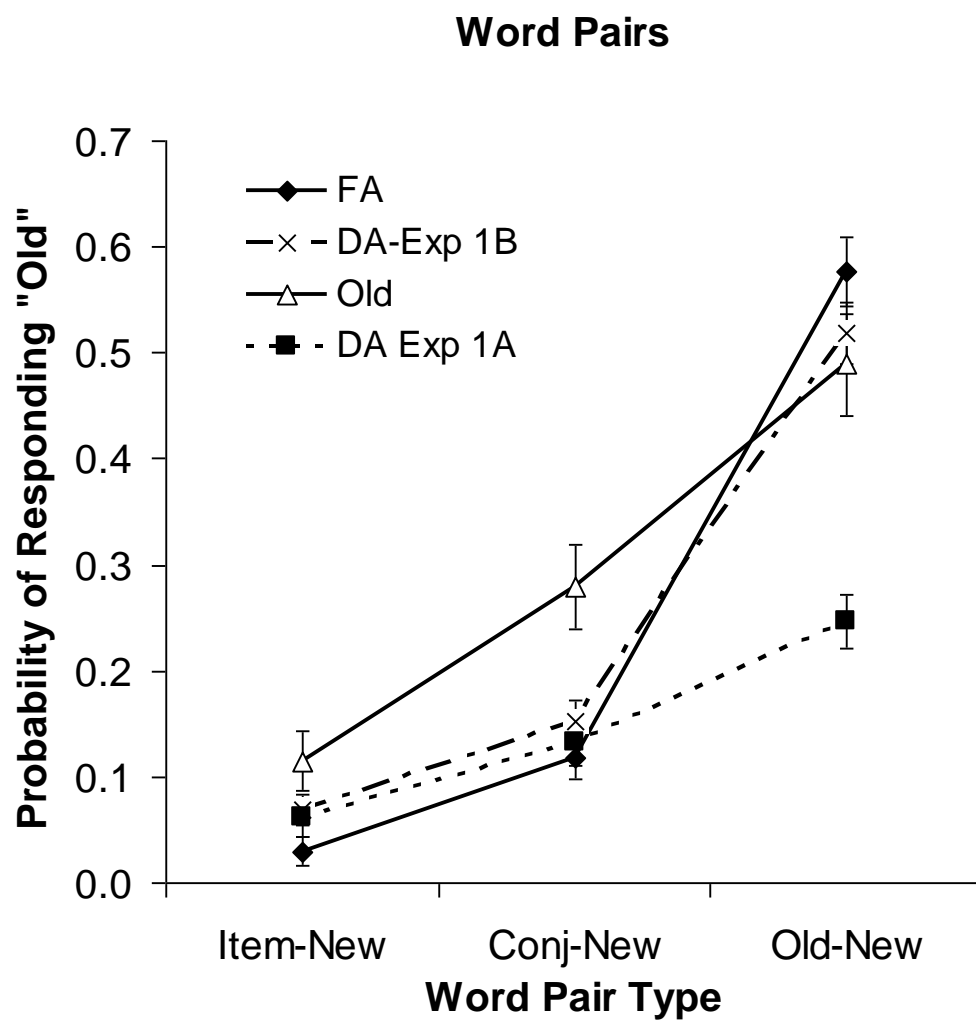


Figure 2.1

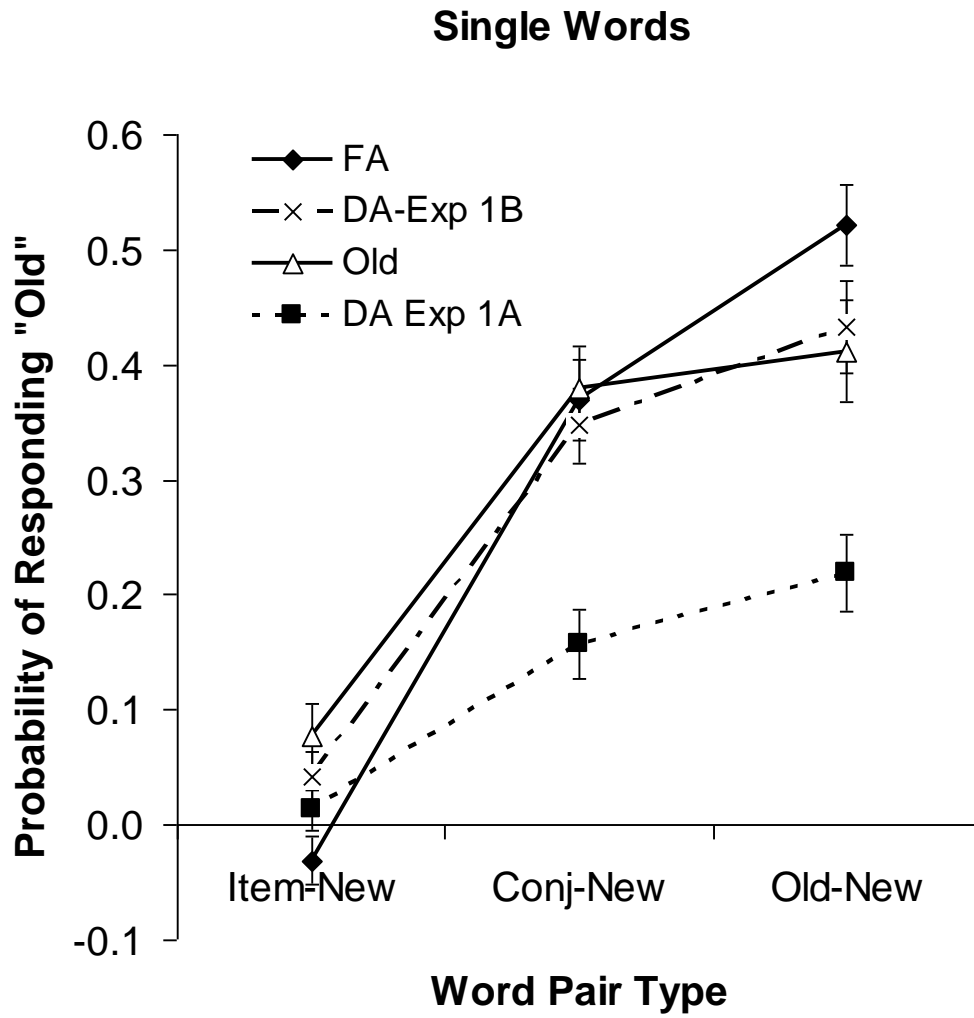


Figure 2.2

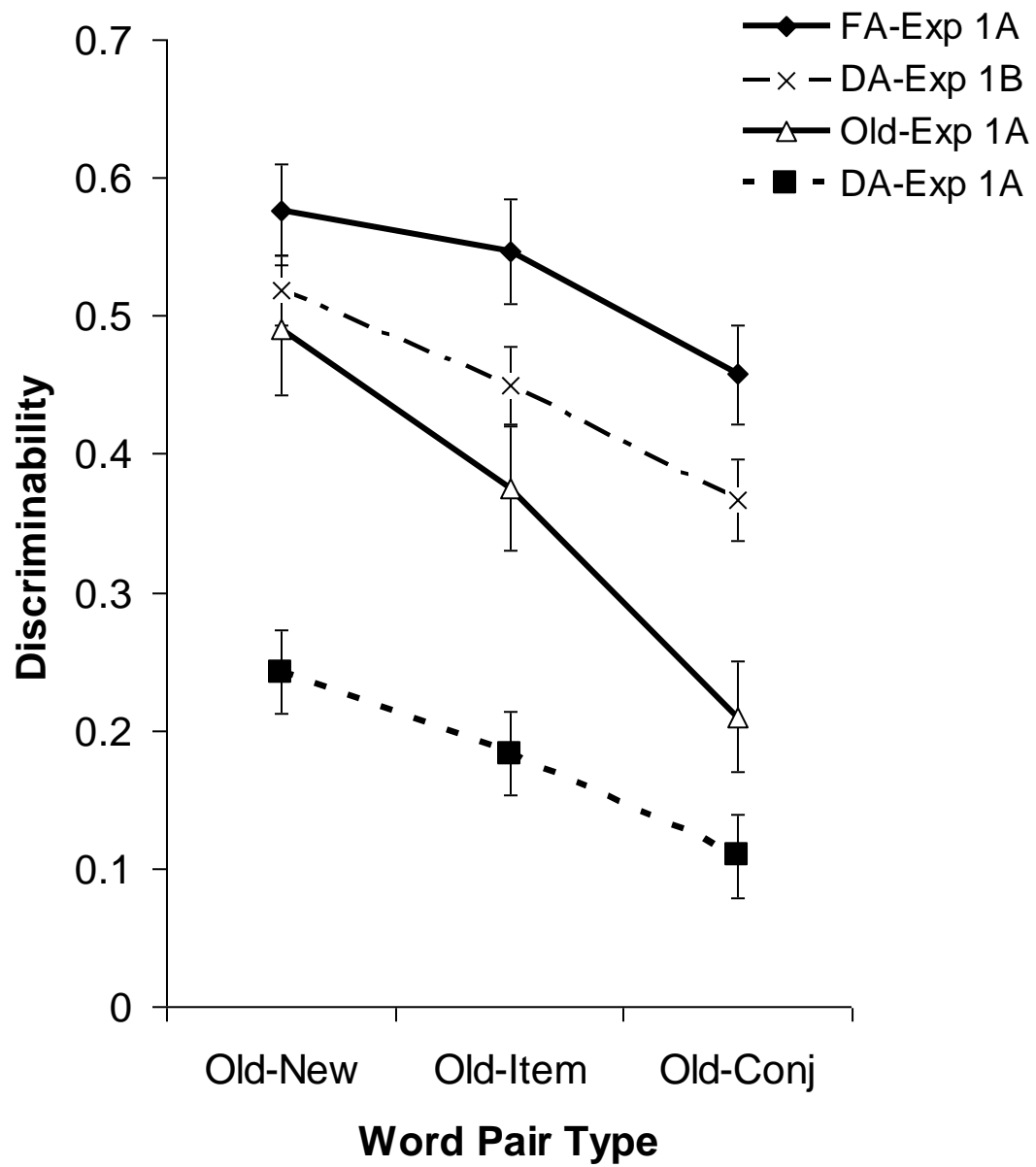


Figure 2.3

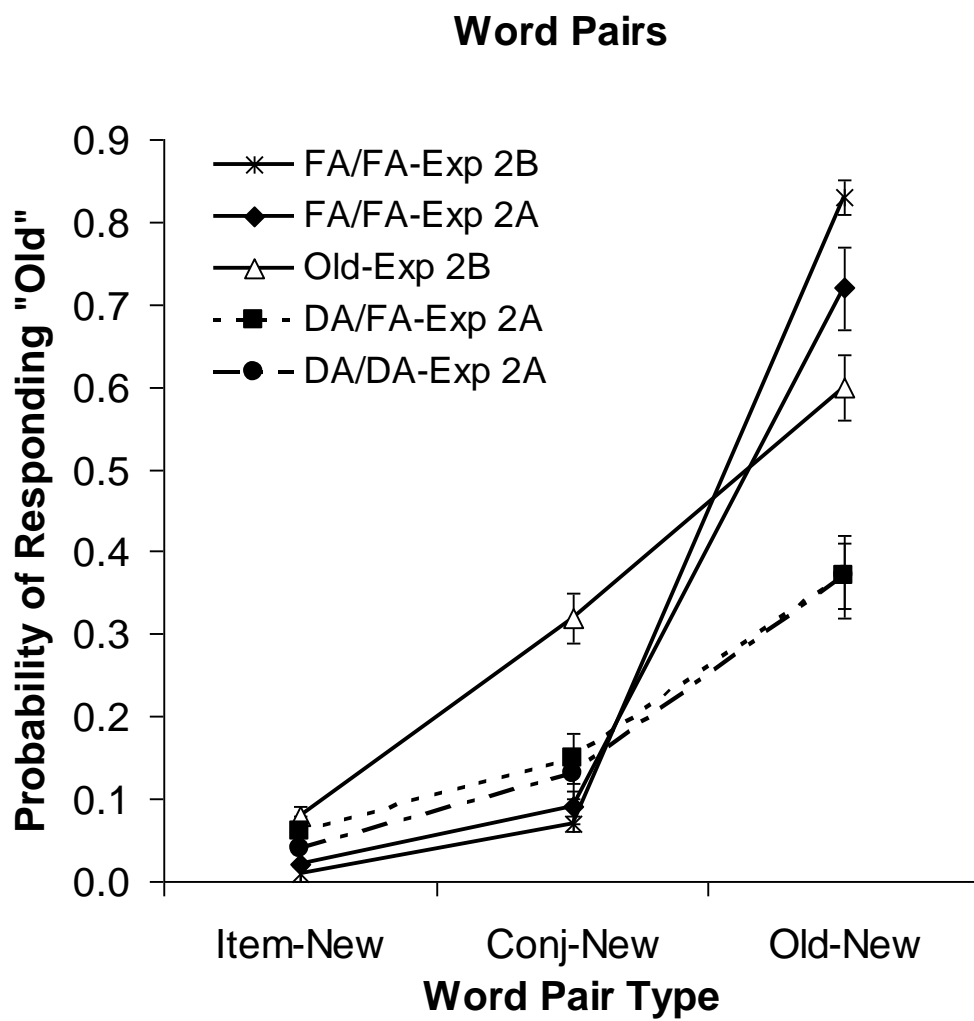


Figure 2.4



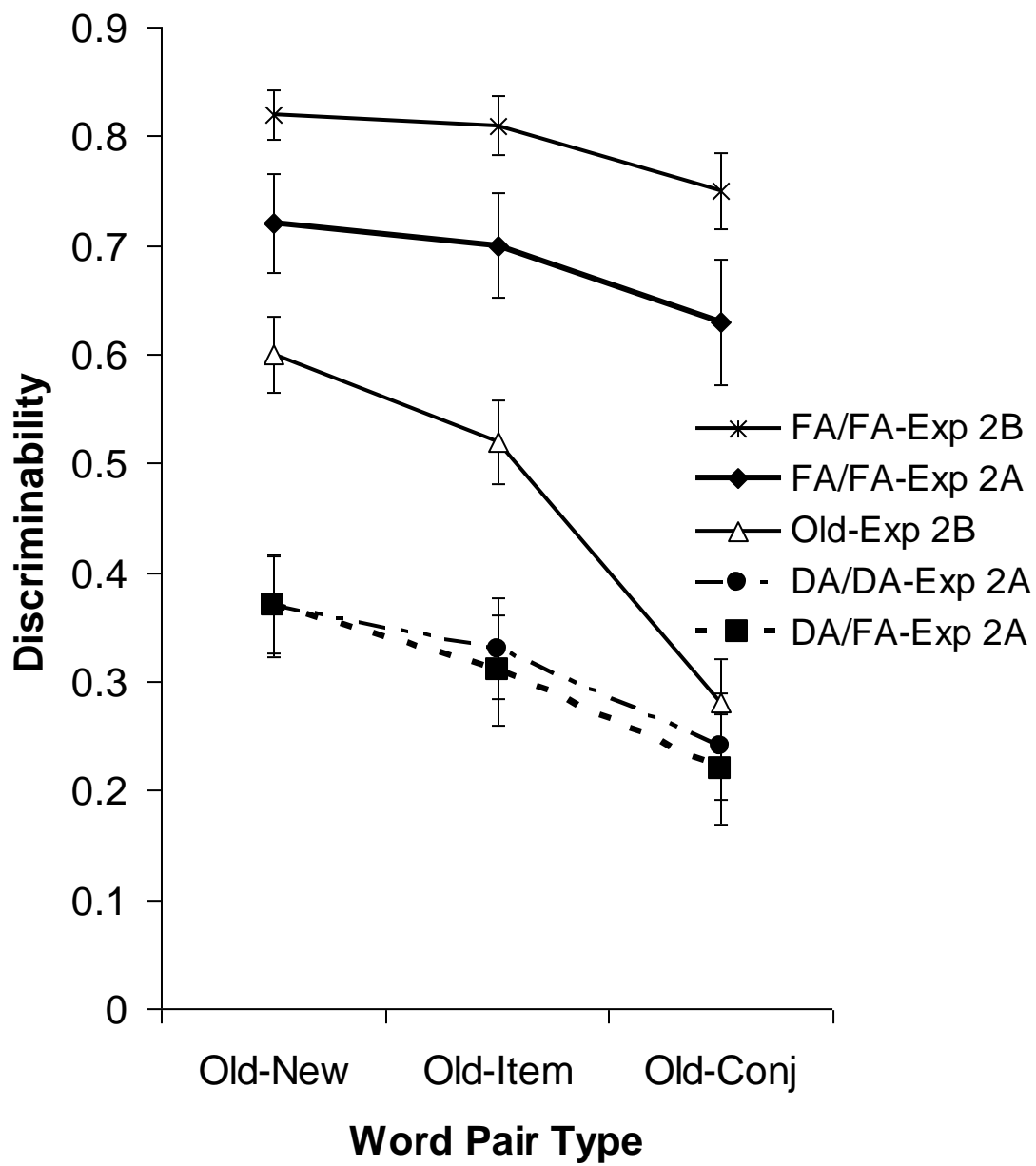


Figure 2.5

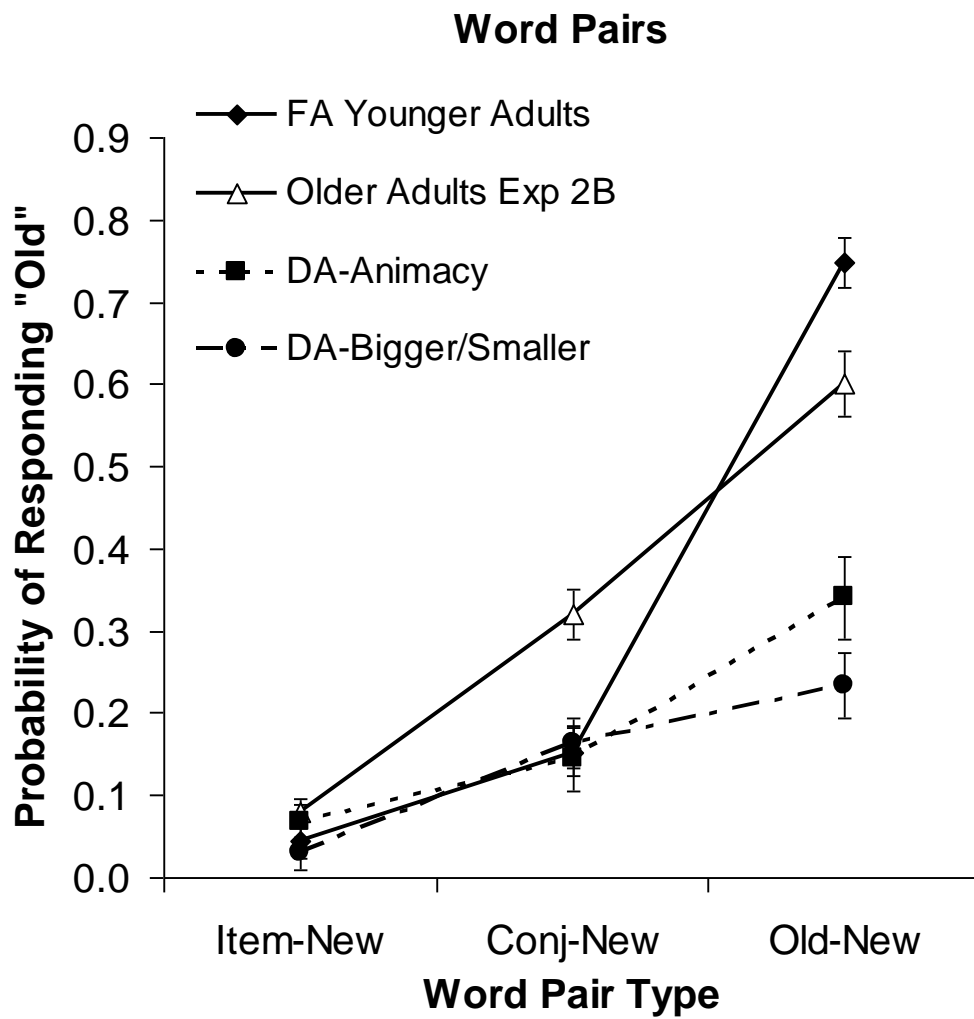


Figure 2.6

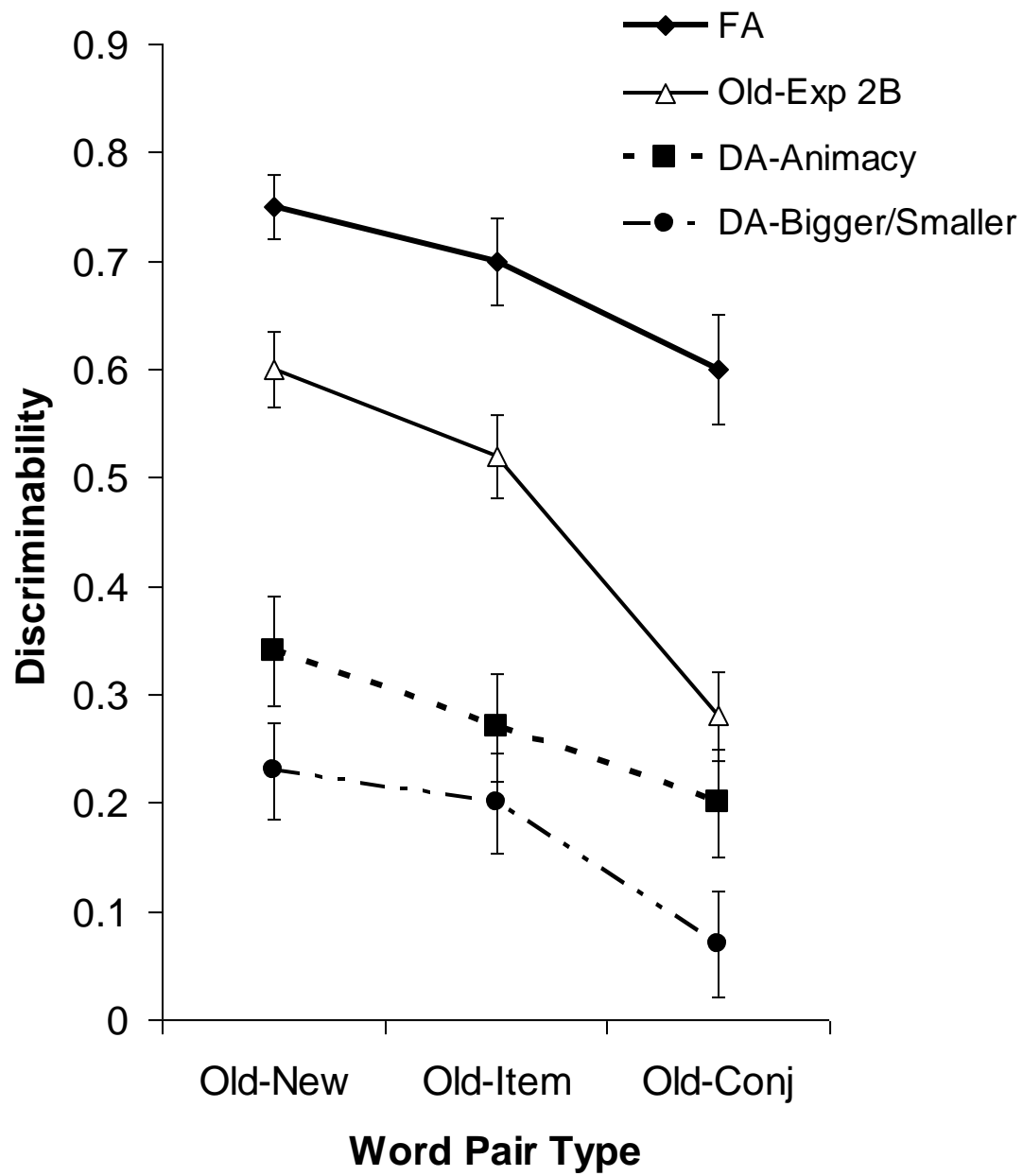


Figure 2.7

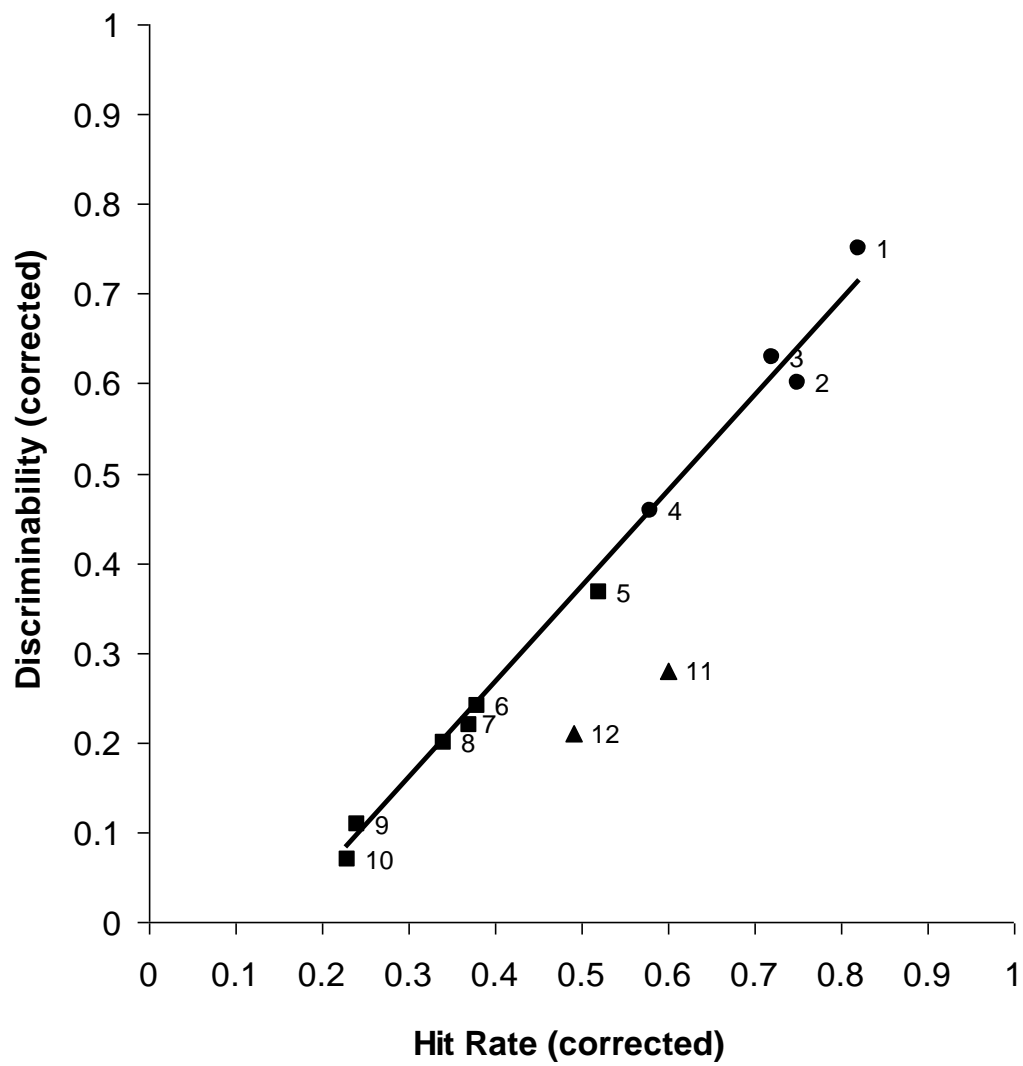
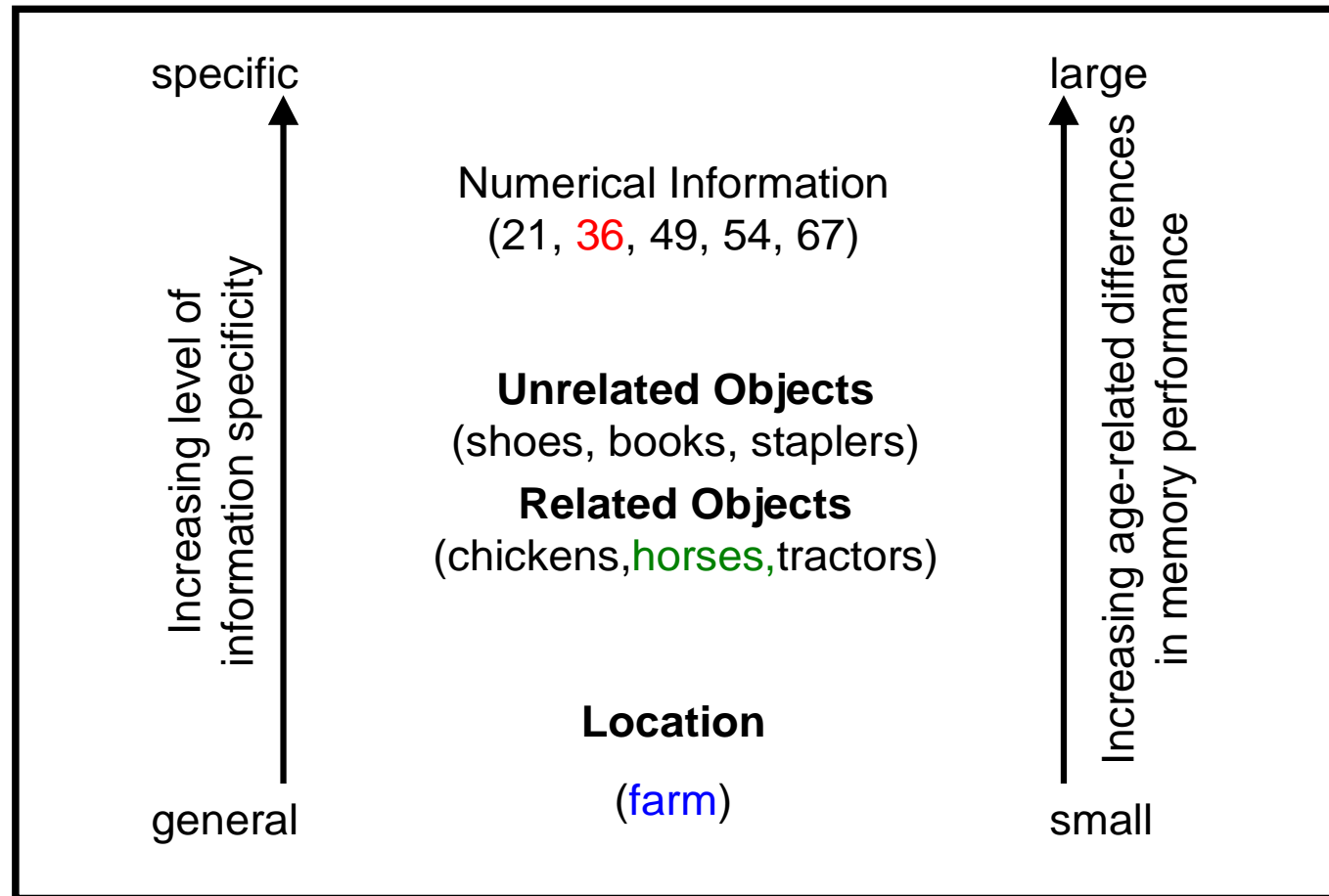


Figure 2.8

Study: There are 36 horses on the farm



Test: What was on the farm, and how many?

Framework based on Craik (2002)

Figure 3.1

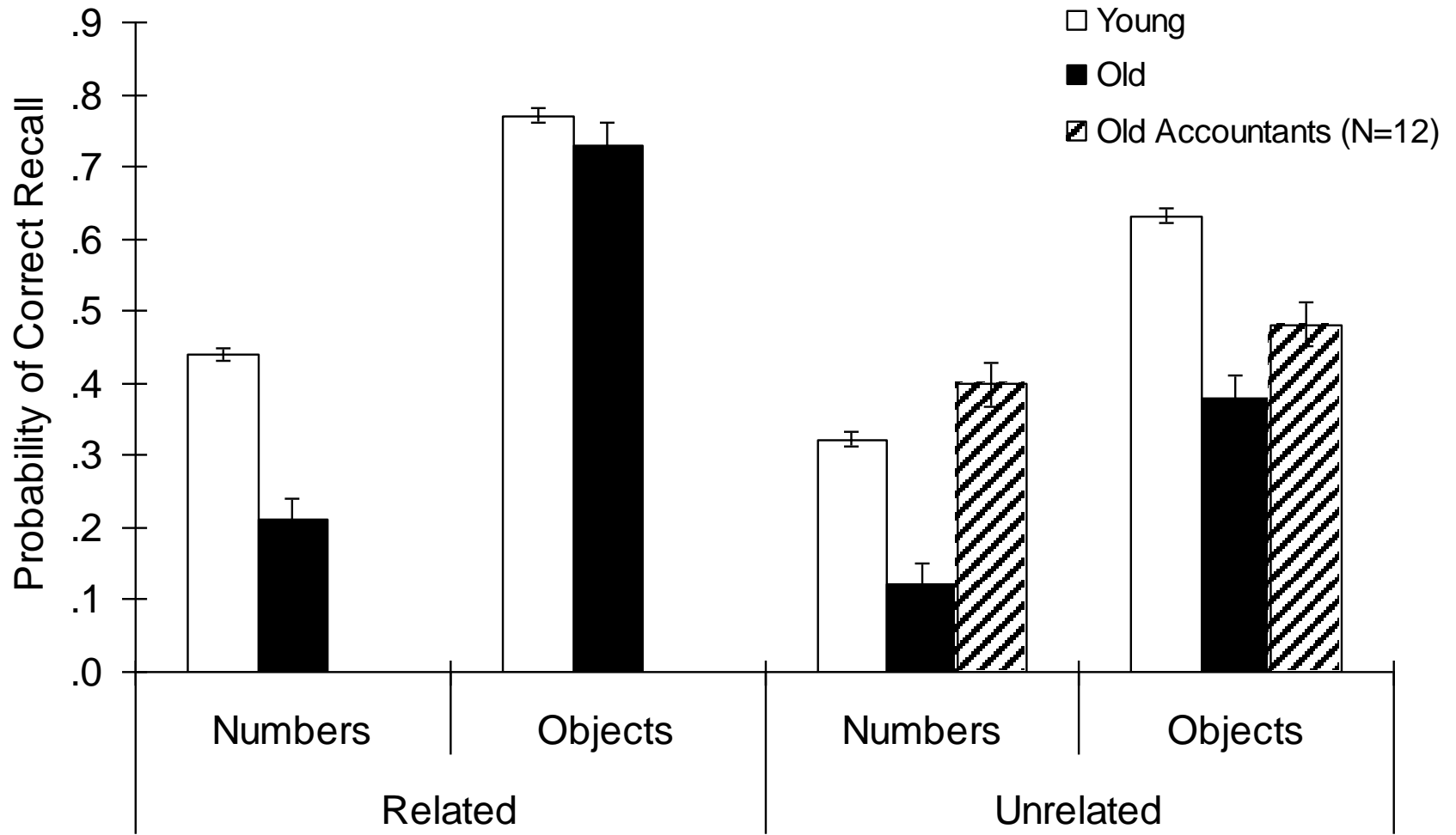


Figure 3.2

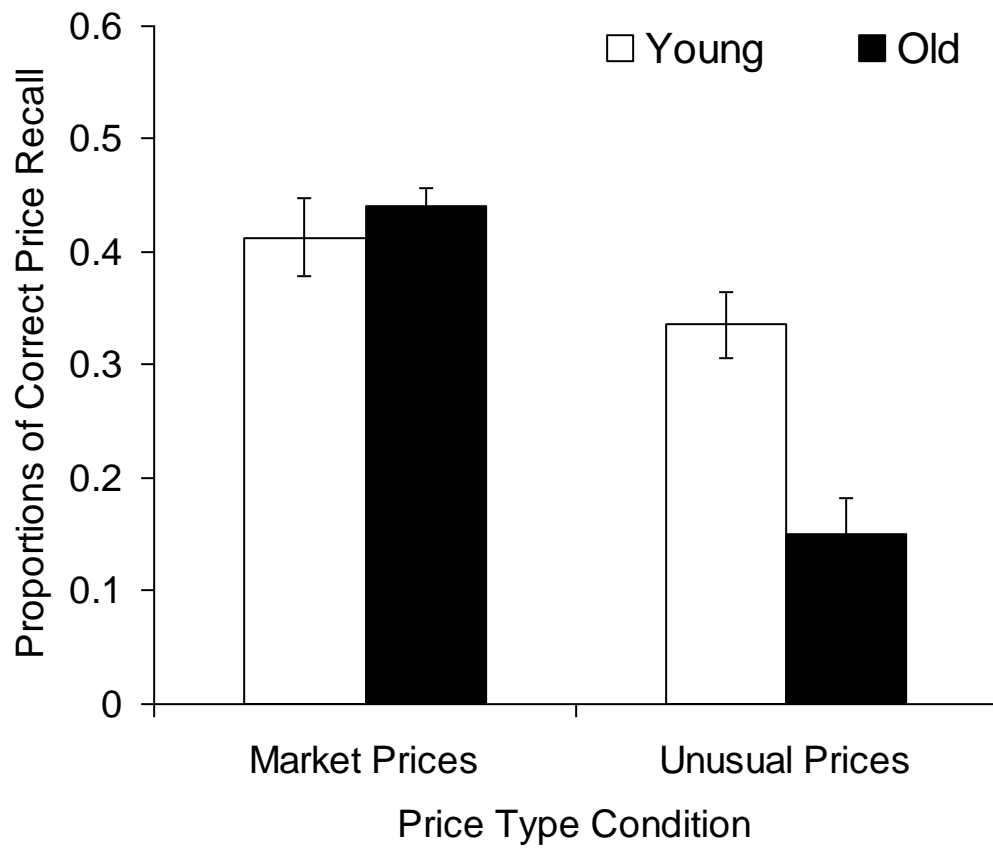


Figure 3.3

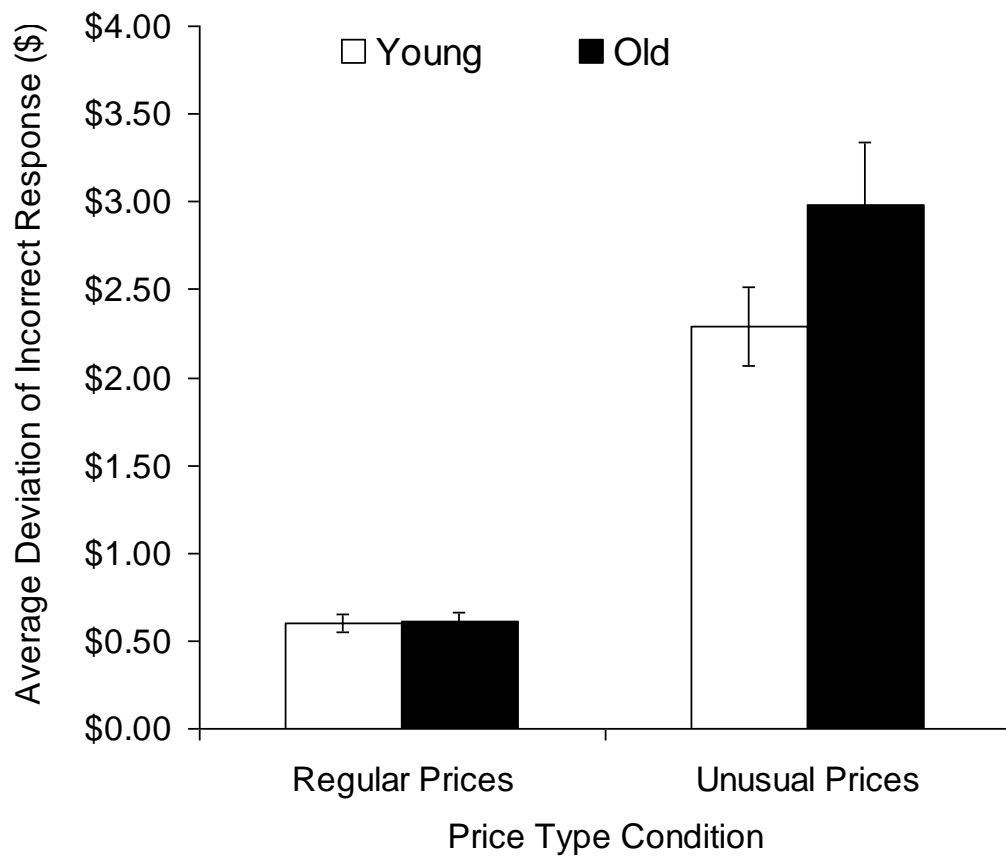


Figure 3.4



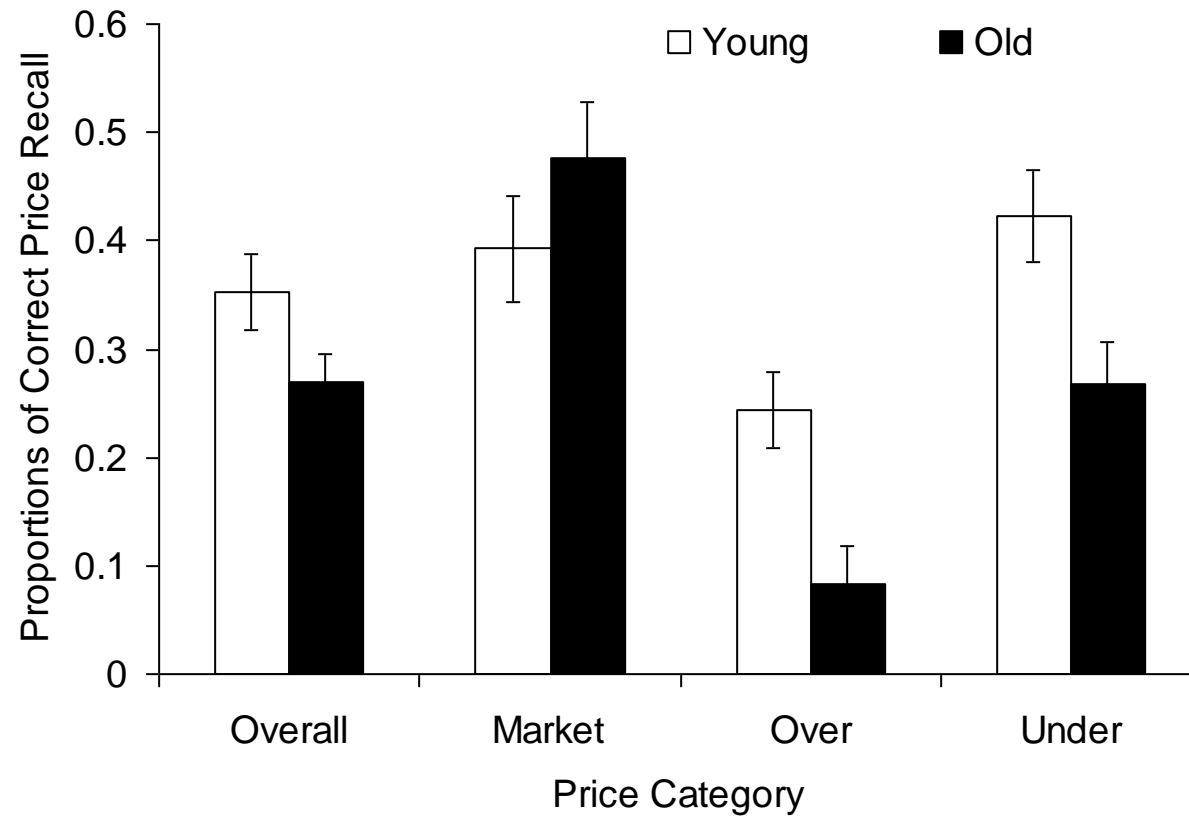


Figure 3.5

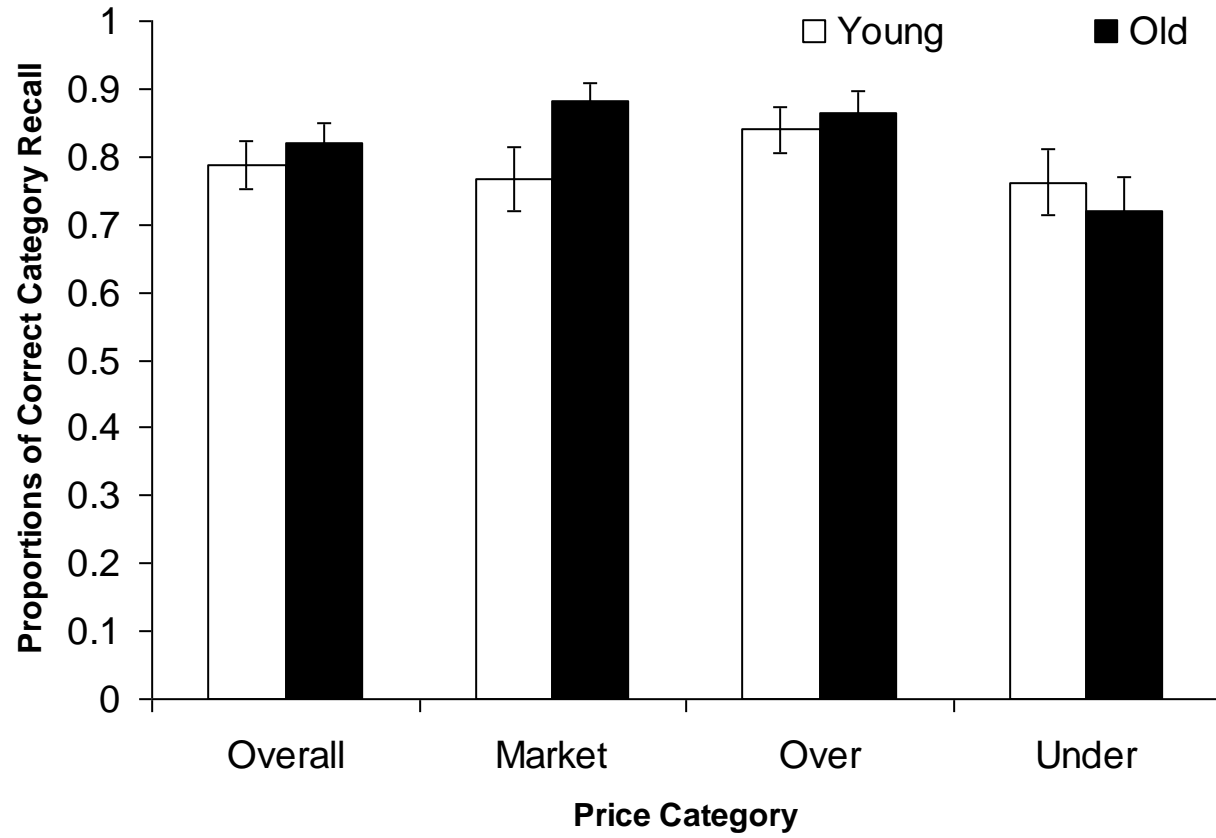


Figure 3.6

### Appendix 3.1

#### The related and unrelated phrases used in Experiment 4

##### Related object-location phrases:

49 grapes in the bowl  
51 cars in the garage  
85 books on the shelf  
14 eagles on the farm  
91 chairs at the table  
26 trees in the forest  
60 shirts in the closet  
21 beers in the fridge  
33 flowers in the garden  
75 trains at the station  
44 teachers at the school  
82 dollars in the wallet  
17 cooks in the kitchen  
96 hotels in the city  
54 doctors in the hospital  
38 pictures in the album  
67 taxis on the street  
72 fish in the lake

##### Unrelated object-location phrases:

49 nails in the bowl  
51 sacks in the garage  
85 skulls on the shelf  
14 trucks on the farm  
91 shoes on the table  
26 worms in the forest  
60 belts in the closet  
21 lemons in the fridge  
33 rakes in the garden  
75 pianos in the station  
44 phones in the school  
82 jewels in the wallet  
17 potatoes in the kitchen  
96 shops in the city  
54 pilots in the hospital  
38 files in the album  
67 snakes in the street  
72 rocks in the lake

**Appendix 3.2**Examples of materials used in Experiments 5 and 6.

Under priced Item

Chips \$0.29



Market Value Item

Cookies \$3.29



Over priced Item

Bananas \$11.89



Test Phase

Cookies

