Running Head: Value-Directed Remembering in Alzheimer's Disease

Aging, Memory Efficiency and the Strategic Control of Attention at Encoding: Selective Impairments of Value-Directed Remembering in Alzheimer's Disease

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Abstract

Selecting what is important to remember, attending to this information, and then later recalling it can be thought of in terms of the strategic control of attention and encoding, and can lead to the efficient use of memory. The present study used a selectivity task, where items were paired with varying point values, to examine how the ability to selectively and strategically remember information of differing value is influenced by aging and Alzheimer's disease. Younger adults and healthy older adults were able to strategically and efficiently encode and remember high value items, but AD led to a specific impairment in selectivity. Although individuals with AD recalled high value items, they also recalled lower value items, and did not efficiently maximize memory performance (as measured by a selectivity index), relative to healthy older adults. Complex working memory span measures were especially predictive of the recall of the high value items. This pattern suggests that AD leads to deficits in attentional control, which can lead to impairments in value-directed remembering.

The ability to attend to important information is critical in order to later recall this information. Selecting what is important to remember, attending to this information, and then recalling it can be thought of in terms of the strategic control of attention, and can lead to the efficient use of memory (Castel, 2007). Although Alzheimer's disease (AD) is most often characterized in terms of loss of memory function, there is accumulating evidence that suggests that part of the initial impairment lies in attentional control (see Balota & Faust, 2001, and Perry & Hodges, 1999, for reviews). Impairments in attentional control can lead to impairments in encoding and maintaining relevant information in working memory (Hasher & Zacks, 1988), inhibitory control (Amieva, Phillips, Della Sella, & Henry, 2004), as well as retrieval and response control (Castel, Balota, Hutchison, Yap, & Logan, 2007). The present study examines how the ability to selectively attend to information that differs in value is influenced by aging and Alzheimer's disease. This approach not only allows one to examine attentional control and memory capacity, but also the efficient use memory in the context of paying attention to, and encoding, high value information.

There is considerable evidence that healthy older adults show various degrees of impairment on a wide range of cognitive tasks (Balota, Dolan, & Duchek, 2000). Specifically, tasks that involve executive processes, working memory, and frontal lobe function are thought to be especially impaired, leading to other attentional and memory deficits (West, 1996). This has lead to various theories that attempt to describe and account for the changes in cognitive function in old age, centering on reductions in available processing resources (Craik, 1982, 2002), general slowing of processing (Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1996), declines in working memory capacity (McCabe, Smith, & Parks, 2007; Park et al., 1996) and reductions in inhibitory control (Hasher & Zacks, 1988; Rabbitt, 1965). The notion that there are breakdowns in the ability to control partially activated, but incorrect, information has also been quite useful in terms of accounting for some of the cognitive deficits that are associated with AD (e.g. Balota & Ferraro, 1993, 1996; Spieler, Balota, & Faust, 1996; Perry & Hodges, 1999). Although Alzheimer's disease is often characterized by impairments in memory performance, tests that examine the impairments in the control of attention, and the development of behavioral measures that can detect early changes and declines in these areas, may also serve as useful measures for the early diagnosis and treatment of AD.

The role of attention in memory performance has been a central theme in many lines of research, with the main finding being that distraction or divided attention lead to reductions in overall memory (e.g., Craik, Govoni, Naveh-Benjamin & Anderson, 1996). However, one method of reducing memory deficits that result from a lack of available attentional resources is to use some form of strategic control to focus attention on the necessary "to be remembered" information, and thereby encourage selectivity about which information is processed (Logan, Sanders, Snyder, Morris, & Buckner, 2002; Perfect & Dasgupta, 1997). This process of strategic control likely relies on a form of attentional control that has been examined using many techniques, and has often shown robust individual differences (e.g., Engle & Kane, 2004). Furthermore, control of attention and working memory has also revealed somewhat striking differences between individuals and various groups and populations in terms of age differences and AD (e.g. Balota & Faust, 2001; Faust & Balota, 2007). However, in many of these studies, the critical measure is overall memory *quantity*, whereas very few studies have examined memory *efficiency*, which may be related to frontal lobe function and executive control. The present study seeks to examine how attentional control can lead to efficient encoding of high value information, by comparing measures of both memory quantity (number of items recalled) and memory efficiency (the average value of recalled items). Of primary interest is whether memory quantity and efficiency were both selectivity impaired in AD relative to healthy younger and older adults.

The link between attentional control and memory performance in AD, and how attentional control can influence memory performance, is the central theme in the current investigation. In order to examine how one can selectively encode information using strategic control, different values (e.g., points) can be assigned to to-be-remembered information, thereby allowing one to examine the extent to which people use this value based information to guide the efficient use of memory (by recalling the high point value items). The selectivity paradigm has been used to this end, and involves presenting items paired with point values, with the point value indicating how important it is to remember each item (see Castel, Benjamin, Craik & Watkins, 2002; Castel, Farb, & Craik, 2007; Hanten, Li, Chapman, Swank, Gamino, Roberson, & Levin, 2007; Watkins & Bloom, 1999).

In the selectivity paradigm, participants are presented with lists of words, with each word in the list having a distinct value ranging from 1 point to 12 points. Participants are told to remember as many words as they can, and that their goal is to maximize their score, which is the sum of the point values of each recalled word. After recall, participants are told their score, and then are given a new list, with instructions to try to achieve as high a score as possible. In addition to simply measuring the overall total point score achieved, a selectivity index (SI) can be calculated, which is the participant's score relative to an ideal score based on the number of words recalled. For example, if you were a participant and you recalled three words (the 8, 10, and 12 point words), your score would be 8+10+12 = 30 points. An ideal score (if you recalled 3 words) would be 10+11+12 = 33 points (i.e., recalling the top three value words). Your efficiency index would be your actual score divided by the ideal score, actual/ideal = 30/33 = .91 (see Castel et al., 2002, for more details about the selectivity index). Thus, the SI provides a selectivity, or efficiency, index based on one's actual score, relative to an idea score, taking into account the number of words recalled. In previous work, although healthy older adults recalled few words than younger adults, their selectivity index was similar to the younger adults. The similarity in SI index occurred because the older adults focused on the high value words to maximize their score, whereas the younger adults recalled high value words and some additional low value words. Thus, the selectivity index provides a useful measure of memory efficiency, one that goes beyond simply measuring the overall quantity of recalled items.

The selectivity task can also afford a measure of learning which items to attend to across lists. Specifically, participants are presented with several lists or trials, and after each list they are given feedback about their score, which is the sum of the point values of the words that they recalled. The number of items presented in each list (12) is greater than the typical memory span of an individual, so participants soon realize they cannot remember all of the items. Participants typically learn to modulate which items to attend to, as reflected by the finding that the selectivity index begins to increase across successive lists. Thus, in order to achieve an optimal score (i.e., efficient use of memory), participants need to focus or attend to the high value items, and recall them on the immediate memory test. This ability (a form of strategic control over memory) has been examined with children and begins to emerge as early as the age of six (Hanten et al., 2007), and is impaired in children with traumatic brain injury. In addition, Castel (2007) has shown that healthy older adults being to develop a strategy (after several lists) of focusing on the higher value items, in order to maximize their score, despite recalling fewer items relative to younger adults. Thus, although healthy older adults recall fewer words than younger adults, they are efficient in terms of focusing on high value words in order to maximize their overall score.

Given that previous research has established that healthy older adults were able to strategically allocate attention to higher value items (see Castel, 2007, for a review), we attempted to extend this work to address whether older adults with very mild and mild AD would display impairments in this type of task. Thus, we were interested in measuring memory capacity (or quantity) as well as the ability to selectivity encode and retrieve information according to value, a form of memory efficiency. Specific impairments in selectivity in AD would suggest that memory impairments in AD are not simply a global memory deficit. The ability to selectively encode information that is of high importance, and distinguish between low and high value information in order to maximize memory efficiency, is crucial to effective use of memory. To examine this issue of memory selectivity, healthy younger and older adults, and individuals with very mild to mild AD, participated in a modified form of the selectivity/selective learning task (e.g., Castel et al., 2002; Hanten et al., 2007).

In addition to examining how selective encoding is affected by AD, we were also interested in examining how age-related and AD-related changes in executive control measures, as reflected by reading and operation span, might influence selective encoding. According to many models of working memory, attention is allocated to task demands in working memory by a limited capacity central executive (Baddeley, 2000; Engle, Tuholski, Laughlin, & Conway, 1999). Individual differences in the efficiency of the central executive, or working memory capacity, have been shown to predict many higher-level cognition tasks (see Engle & Kane, 2004 for a review) and have typically been measured using complex span tasks. Because selective encoding in the selectivity task involves strategically allocating limited attention resources to ongoing processing, we were interested in examining whether individual differences in working memory capacity would be related to efficient selection (as measured by the selectivity index). Because age and AD have both been found to reduce the efficiency of the working memory system (Logie, Cocchini, Della Sala, & Baddeley, 2004; McCabe, Robertson & Smith, 2005), we hypothesized that age and AD related changes in working memory capacity would mediate, to some degree, any changes seen in selective encoding. Thus, selectively encoding high value information in the selectivity task requires allocation of attention to high value items while concurrently ignoring or inhibiting low value items, and it was hypothesized that working memory capacity should be related to selective encoding of high value items.

Methods

Participants

Participants were recruited from the Washington University Alzheimer's Disease Research Center (ADRC), and consisted of 109 healthy older adults and 54 individuals with early stage AD. The healthy older adults (range of ages 57–96) had a mean age of 74.85 years (*n* =109, *SD* = 8.6), the individuals with very mild AD (ages 56-88) had a mean age of 75.90 years (*n* = 41, *SD* = 7.3), and the individuals with mild AD (ages 61–86) had a mean age of 76.77 years (*n* = 13, *SD* = 7.1) There were no significant differences among the groups of older adults in terms of mean age (all *p*s > .46). In addition, 35 younger adults (age 25 or younger) were recruited from the Washington University student community and participated for course credit or were paid $10. The younger adults had a mean age of 19.49 years (*n* = 35, *SD* = 1.5).

The healthy older adults and the individuals with AD were seen by a physician and completed a battery of psychometric tests approximately once a year, and were screened by a physician for neurological, psychiatric, or medical disorders with the potential to cause dementia. The inclusion and exclusion criteria for a diagnosis of AD have been described in detail elsewhere (e.g., J. C. Morris, McKeel, Fulling, Torack, & Berg, 1988; Morris, 1993) and conform to those outlined in the criteria of the National Institute of Neurological and Communications Disorders and Stroke—Alzheimer's Disease and Related Disorders Association (McKhann et al., 1984). Dementia severity for each individual with AD recruited from the Washington University Medical School Alzheimer's Disease Research Center (ADRC) was staged in accordance with the Washington University Clinical Dementia Rating Scale (Hughes, Berg, Danziger, Coben, & Martin, 1982; J. C. Morris, 1993). According to this scale, a score of 0 indicates no cognitive impairment, a score of 0.5 indicates very mild dementia, a score of 1.0 indicates mild dementia, and a score of 2.0 indicates moderate dementia. At the Washington University Medical School ADRC, a Clinical Dementia Rating Scale score of 0.5 has been found to accurately indicate the earliest stages of AD (J. C. Morris et al., 1991). Both the reliability of the CDR and the validation of the diagnosis (based upon autopsy) by the research team have been excellent (93% diagnostic accuracy) and well documented (e.g., Berg et al., 1998). Thus, individuals given a AD diagnosis of CDR 0.5 are very likely in the earliest detectable form of AD.

Psychometric Test Information

In addition to participating in the experimental task, all of the healthy older adults and those with AD who were recruited from the ADRC participated in a two hour battery of psychometric tests as part of a larger longitudinal study of cognitive performance in healthy aging and AD. The results from the Psychometric tests are displayed in Table 1. Memory performance was assessed with the Wechsler Memory Scale and scored accordingly: Logical Memory, immediate, with no delayed recall (recall of scoring units 0-23), Forward and Backward Digit Span (# correct digits, 0-8 or 0-7, respectively) (Wechsler & Stone, 1973). General intelligence was assessed with the Information (scoring range 0-29), Block Design (scoring range 0-48), and Digit Symbol (scoring range 0-90) subtests of the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1955). Visual perceptual-motor performance was assessed with the Benton Visual Retention Test and the Benton Copy Test (# correct, # errors) (Benton, 1963), and Part A of the Trail Making Test (# of seconds to complete) (Armitage, 1946). Finally, the Boston Naming Test (Goodglass & Kaplan, 1983) was administered as a test of semantic/lexical retrieval (# correct of 60). Psychometric tests are scored such that greater scores indicate better performance with the exception of Trailmaking A and Benton copy errors, for which higher scores indicate poorer performance. Psychometric testing always occurred within a two-month window of the selectivity task testing session.

In addition to the standardized tests, participants also completed the reading span and computation span tasks, tests of working memory capacity (WMC; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2007). The reading span task required participants to read sentences (e.g., *The four-legged animal that barks is the mouse*) on a computer screen, decide whether the sentences were statements that were true or false, and commit the final word in each sentence to memory. One to four sentences were presented, three at each length, and participants attempted to recall the final word of each sentence auditorily, in order, immediately after the last sentence was presented. Sentence sets began with set size one and increased to the next longer set size, provided recall was correct for two of the three trials at a given length. The reading span score was the number of trials correctly recalled through the largest set size at which they recalled most of the trials correctly. Computation span was identical to reading span except that rather than reading sentences and recalling words, subjects were asked to complete simple addition and subtraction problems (e.g., 6 + 4 = 9?), decide whether they were correct or not, and remember the middle number from the problem (e.g., 4). As shown in Table 1, the AD groups performed more poorly than the healthy older group on most tests. Since the younger adults were not recruited by the ADRC, they did not receive the psychometric battery, but they did complete the WMC tasks. Because younger adult data were not included in the table, we note here that they outperformed healthy older adults (and therefore all groups) on reading span (M = 8.61, SD = 1.94), $F(1, 138) = 15.55$, MSE

= 43.78, $p < .0001$, and computation span ($M = 12.58$, $SD = 4.06$), $F(1, 131) = 27.76$, $MSE = 411.25$, $p < .0001$.

Procedure

Participants were told that they would be studying lists of words, and each word would be paired with a number (a point value) ranging from 1 to 12. The words were visually presented one at a time on the center of a computer screen at a rate of one word every two seconds, and each list contained 12 words with each word paired with a unique number between 1 and 12. Participants were told that each word and number will appear on the screen for two seconds, followed by another word and number. They were told that the number that was paired with each word was a point value and that the point value indicates how important it is to remember the word (e.g., much like a game in which the words are worth different amounts of money). They were told that their task was to try to get as many points as possible, and that this could be accomplished by remembering as many of the high point value words as they could, although recalling any word would increase their score. Participants were told they just needed to verbally recall the word, and not the value of the word, and that the experimenter would record their response. Examples of the scoring procedure were given, such that participants were made aware that their score would be composed of the point values of the words they recalled (e.g., if you recall three words, table, donkey, apple, and these words were paired with the 8, 10, and 12 point values, then your score would be 8 + 10 + 12, which is 30). Participants were told that after they had seen the list words, they will see the word "RECALL" on the screen, and that they should immediately recall as many words as they could remember, and would then be told their point value total for that list. Participants were given up to

30 seconds to recall the words, and were then given feedback regarding their score. They were then given another list of new words, and would repeat this for seven more lists. They were told that their task for each list was to maximize their total point score. They were also told that they should pay as much attention to the words and the numbers, and that although it would be difficult to remember all of the words, they should try to keep their score as high as possible. After being invited to ask any questions they had about the procedure, participants were presented with the first list and recall session, after which they were once again prompted to ask any questions about the procedure.

Materials and Design

The words were presented on the center of a computer screen in white Times New Roman 48-point font, on a black background. The words in each list were concrete nouns that contained between four and five letters. The mean hyperspace analog to language (HAL, Burgess & Lund, 1997) frequency of the words was 33,374, (Log HAL = 9.03) as obtained from the elexicon.wustl.edu Web site (see, Balota et al., 2007). The words were randomly sorted into eight lists of 12 words. For each list, each word was assigned a unique number between 1 and 12, such that a different value was present in each serial position for each list (to ensure that the higher and lower value words were well distributed across serial positions). To ensure that this was the case, the mean value of each word for each serial position ranged from 6.2 to 6.8. Finally, three different versions of the order of the eight lists were created, and participants were assigned to one of the three versions.

Results

The selectivity task affords several measures of memory performance, including memory capacity (mean number of words recalled), sensitivity to value (how well one successfully recalls words based on the point value of the words), as well as memory efficiency (the selectivity index, or SI). The results will be presented in terms of (a) overall recall performance and measures from the selectivity index, (b) the degree to which various groups were sensitive to point value, (c) selectivity and recall performance as a function of list, and finally (d) the relationship between selectivity, recall and measures of working memory.

Recall and Selectivity Index

The results for overall recall performance and the mean selectivity index for each group are displayed in Table 2. The younger adults recalled more words than the other groups, and a one-way ANOVA showed a main effect of group on recall performance, $F(3, 194) = 73.99$, $MSE = .952$, $p < .0001$. Post-hoc (Tukey) tests showed that all groups differed significantly from one another in terms of overall recall ($p < .001$).

In terms of the selectivity index (SI), a one-way ANOVA showed a significant effect of group on SI, $F(3, 194) = 7.01$, $MSE = .080$, $p < .0001$. Post-hoc (Tukey) tests showed that younger and older adults did not differ from one another ($p = .81$) in terms of the mean SI, replicating Castel et al. (2007, 2002), but these two groups did differ from the two AD groups (all ps<.001). Interestingly, the very mild AD group did not significantly differed from the mild AD group, $p = .21$.

Although younger adults recalled more words, healthy older adults were just as selective even though they didn't recall as many words, as shown in other studies using the selectivity index (Castel et al., 2002, 2007). However, the individuals with early stage AD resulted in poorer recall, as well as significantly lower SI, even at the earliest stage of the disease, suggesting an impairment in being able to selectivity encoding high value items.

The Overall Effect of Value on Recall

Figure 1 displays the probability of recalling a word based on the point value of each word. As shown, participants' recall was sensitive to value, with higher value words being recalled more often than lower value words. A 4(group: young, healthy old, very mild AD and mild AD) x 12 (point value) mixed model ANOVA was conducted, and yielded a main effect of group $F(3, 194) = 73.65$, $MSE = .079$, $p < .0001$, indicating that the groups differed in overall memory performance (see Table 2 for overall recall collapsed across value for each group). There was a main effect of point value, $F(11, 2134) = 92.38$, $MSE = .035$, $p < .0001$, indicating that overall, memory performance was influence by point value. There was also a significant interaction of group and point value, $F(33, 194) = 5.85$, $MSE = .079$, $p < .0001$, suggesting that the groups differed in terms of the degree to which point value influenced recall. As shown, there were large differences in recall for the high value words, but virtually no difference for the low value words.

Selectivity Index and Recall as a Function of List Position

Participants were presented with eight different lists in the present task, and it is likely that over the course of the experiment, performance changed as participants learned effective strategies to enhance recall, remember high value words and maximize their total point score. Hence, one might ask if there are different levels of improvement across groups across the trials. In order to address this, we examined whether recall and

SI changed over the course of the task, and whether these measures changed at different rates for different groups of participants.

In order to examine whether participants learned to be more selective over the course of task, the average selectivity index was calculated separately for List 1-4 and List 5-8, and these were examined as a function of group. A 4 (group: young, healthy old, very mild AD and mild AD) x 2 (list position: Lists 1-4, Lists 5-8) mixed model ANOVA was conducted, which yielded a main effect of group $F(3, 194) = 7.78$, $MSE = 1.07$, $p < .001$, indicating that the groups differed in overall selectivity index (SI) performance. There was also a main effect of list position, $F(1, 194) = 9.92$, $MSE = .50$, $p < .01$, indicating that SI increased for the last four lists of the task, as compared to the first four. Most importantly, however, there was no significant group x list position interaction, $F < 1$, indicating that the increase in selectivity during the task was independent of group membership. There is a nominally greater increase in SI for older adults as compared to the other groups, but there were no significant interactions of list position and group when comparing healthy older adults with any of the other individual groups (p's > .09).

In order to examine whether recall changed over the course of the task we also calculated average recall for Lists 1-4 and Lists 5-8 separately. A 4 (group: young, healthy old, very mild AD, mild AD) x 2 (list position: Lists 1-4, Lists 5-8) mixed model ANOVA was conducted, which yielded a main effect of group $F(3, 194) = 88.13$, $MSE = 144.31$, $p < .0001$, indicating that the groups differed in overall recall performance. There was also main effect of list position, $F(1, 194) = 23.21$, $MSE = 6.72$, $p < .0001$, indicating that SI increased for the last four lists of the task, as compared to the first four. Finally, there was a significant group x list position interaction, $F(1, 227) = 3.18$, $MSE =$

.92, $p < .05$. We examined this interaction further by comparing recall as a function of list position for each group separately, i.e., we conducted a one-way within-subjects ANOVA for each group. This analysis revealed an increase in recall from the first-four to the last-four lists for young, $F(1, 65) = 6.89$, $MSE = 2.90$, $p < .05$, old, $F(1, 108) = 19.19$, $MSE = 5.15$, $p < .0001$, and AD 0.5, $F(1, 40) = 31.22$, $MSE = 8.73$, $p < .0001$, but not for the AD 1.0 group, $F < 1$. Thus, the AD 1.0 group did not improve their recall performance across the first and second halves of the task, despite an increase in SI on par with the other groups. This indicates that in terms of learning during the task, SI and recall were dissociated, providing evidence that these two measures provide distinct indices of performance.

Factor Analysis of Recall as a Function of Serial Position

According to the value-directed remembering framework, participants prioritize encoding according to an item's value, and selectively attend to items of higher value. If this is indeed the case, it may be possible that low- and high-value items would comprise distinct factors. Models of working memory capacity and attention (e.g., Cowan, 2001; Cowan, Chen, & Rouder, 2004), suggest that people can maintain a fixed number of items (e.g., four, plus or minus one unit) in a short term activated working memory store. To examine this possibility in the present context, the average recall level of items of each value, 1-12, were submitted to an exploratory factor analysis. Exploratory factor analysis (or EFA) provides a method for reducing a large number of variables, or items, to a smaller number of factors based on similarities among those items. In the present context, factor analysis can be used to examine whether the 12 items of differing values in each list could be reduced to a smaller number of factors, and furthermore, whether low- and high-value items created separate factors that could be distinguished from one another.

The EFA was conducted using a principal component analysis, keeping factors with eigen values greater than one, and then submitting the factors to a varimax rotation. As shown in Table 3, the EFA distinguished two factors that accounted for a total of 54% of the variance in recall performance. The stronger of the two factor loadings for each item is highlighted in the Table. The factor loadings can be interpreted as the strength of the relationship between that item and the factor, in much the same way that a correlation coefficient would be interpreted. As shown in Table 3, the first factor clearly included items of Values 1-7, and the second factor included items of Values 8-12. Thus, based on the pattern of recall across individuals, there was a clear division between the five highest value items and the seven lowest value items, which is somewhat consistent with fixed capacity models of working memory. This factor structure is revealed to some extent by a visual inspection of Figure 1, which shows a relatively flat recall function for low value items for all groups, with a sharp increase in recall somewhere between items of values 6-8.

Based on the visual inspection of Figure 1, and the factor structure revealed by the EFA, it appears that age and AD have differential effects on recall of high-value and low-value information. In order to better understand the pattern of data, separate one-way ANOVAs examining recall of the high-value factor and low-value factor as a function of group (younger, older, AD) were conducted. The ANOVA examining the high-value factor revealed a main effect of group, $F(2, 195) = 62.72$, $MSE = 1.60$, $p < .0001$, which resulted from greater recall for younger adults compared to older adults, $F(1, 142) =$

51.60, *MSE* = 1.15, $p < .0001$, as well as greater recall by older adults compared to individuals with AD, $F(1, 161) = 41.18$, *MSE* = 1.14, $p < .0001$. The ANOVA examining the low-value factor revealed a main effect of group, $F(2, 195) = 31.97$, *MSE* = 0.37, $p < .0001$, which resulted from greater recall for younger adults compared to older adults, $F(1, 142) = 51.89$, *MSE* = 0.66, $p < .0001$, but there was not difference in recall for older adults compared to individuals with AD, $F < 1$. In summary, aging affected recall regardless of value, but AD specifically affected recall of high-value items, rather than low-value items.

It is also worthwhile to address whether the factor structure that was apparent in the entire sample was similar within the young, old, and AD participant groups separately. If it was, it would suggest that each group is using similar strategies in terms of selectively encoding the few highest value items and ignoring the majority of lower value items. We addressed this issue by examining whether by calculated a two-factor solution for each of groups separately. The AD 0.5 and AD 1.0 participants were combined in to one group (AD) in order to increase power (as there were only were only 13 participants in the original AD 1.0 group). As shown in Table 3, the factor structure replicated for all groups. Indeed, the data unequivocally support to contention that the five highest value items comprise one factor (possible item maintained in working memory), and the seven lowest value items comprise another factor, for all of the groups in the study. This exploratory factor analysis is both novel and powerful in terms of providing converging validity for the notion that all participants are selectively attending to only the few highest value items, but the AD group is simply less efficient at doing so.

The Role of Working Memory Capacity in Selectivity

We now turn to the relationship between recall and selectivity performance in the selectivity task and working memory capacity. Interestingly, Hanten et al. (2007) found in a child sample ages 6-18 years old that although SI increased with age, selective learning was not related to total number of words recalled. Working Memory Capacity (WMC) has been conceptualized as the ability to control attention during complex cognitive activities, especially under conditions in which it is difficult to maintain task goals, or when interference is present (Engle & Kane, 2004). Hence, WMC is conceptualized as executive attention, or the central executive component of the working memory system. WMC is traditionally measured using complex span tasks, like the reading span task, in order to assess individual differences in the functioning of the central executive component of the working memory system (Daneman & Carpenter, 1980; Engle, Tuholski, Laughlin, & Conway, 1999).

The selectivity task would appear to require efficient WMC because participants are asked to maintain the goal of discriminating high from low value items, while quickly allocating attentional resources to the encoding of the higher value items, at the expense of the low value items. Hence, we examined the relationship between the WMC measures and both the recall of low-value and high-value items, and the selectivity index. Past research has shown that performance on complex span tasks, i.e., WMC, is related to recall, which is consistent with the idea that recall depends on executive attention for effective encoding and retrieval of items from long-term memory (McCabe, Smith, & Parks, 2007; Park et al., 1996). Of greater interest in the current context is the extent to which WMC, or the efficiency of the central executive, is differentially related to encoding and recall of low-value and high-value items. If WMC is related to recall of high-value items (but not low value items), it would provide converging evidence for the role of attentional resources in value-directed remembering. Moreover, to the extent that WMC is related to value-directed remembering in AD patients, it would provide converging evidence that differences in attentional control are an important factor in the overall level of memory impairment seen in these individuals.

The role of WMC in the recall of low-value and high-value items, as well as overall selectivity, as measured by the selectivity index (SI), was examined by first calculating z-scores for both the reading span and computation span tasks, and then combining the z-scores for both tasks to create a single, WMC factor score. Note that scores for the computation span task were missing for 4 of the 35 young adults, 7 of the 108 healthy older adult controls, and 6 of the 54 individuals with AD. Because some of these missing scores were due to difficulty with the arithmetic portion of the task, and therefore they were not missing at random, these participants' data for all WMC tasks were removed from the regression analyses.

There were no significant correlations between WMC and recall in young adults, likely owing to a small sample size and a restriction of range. However, for healthy older adult controls and individuals with AD, WMC was positively correlated with recall of high-value items, but not with recall of low-value items, as shown in Table 4. This supports the hypothesis that selectively attending to higher value items depends on the ability to control attention, and furthermore, that within a sample of individuals diagnosed with AD, having a greater ability to control attention is related to more efficient control of memory. Moreover, there was a significant negative correlation between recall of low-value and high-value items in healthy older adult controls and individuals with AD, indicating that when participants recalled more of the higher value items they also recalled fewer lower value items. One interpretation of these data is that when limited attentional resources were allocated to encoding of higher value items, there were less resources available for selection of lower value items, leading to a seemingly adaptive pattern of selection and recall.

General Discussion

The present study investigated selective learning in healthy younger and older adults, and those with very mild and mild AD. Although previous research has widely documented impairment in memory in old age and AD, the present study shows that although AD is related to poorer memory, it is also associated with a specific deficit in being selective and strategic about encoding operations, which likely contributes to their poorer memory efficiency. Previous work has shown that AD leads to impairments in inhibitory control (see Amieva, Phillips, Della Sella, & Henry, 2004, for a review), such as inappropriate selection of task-irrelevant dimensions in the Stroop and Simon task. For example, in the Stroop (color-word interference) task, AD lead to a disproportionate increase in intrusion errors (naming the word, instead of the color, on incongruent color naming trials, e.g., Spieler, Balota & Faust, 1996). A similar pattern of results was obtained in the Simon (location response interference) task, in which individuals with AD showed greater interference and error rates in the presence of incongruent mappings between target location and the location of the appropriate response key (e.g, Castel, Balota, Hutchison, Yap, & Logan, 2007). In general, declines in working memory may be related to deficits in the control of attention in AD (e.g., Belleville, Chertkow, & Gauthier, 2007), and the present study investigated the link between the control of attention and the ability to encode and remember information based on the value of the items for participants with very mild and mild AD.

The present study builds on research that examines how attentional control and working memory are affected by AD, and extends this work to control over encoding operations in light of prioritizing items in memory. In the selectivity task, there is no "inappropriate" response in that encoding or retrieving *any* word will enhance one's score (participants were not given feedback regarding SI, but rather simply their raw score). However, in order to optimize one's score in light of constraints on quantity recalled one needs to focus on high value information, which is under the subjective control of the participant. Participants should initiate a strategy to enhance their score, partially based on encoding operations, and integrate feedback experience and performance from previous lists. Older adults, who recalled fewer words than younger adults, were still able to selectively encode and recall high value words (replicating previous work by Castel et al., 2002, 2007). However, individuals with early stage AD not only recalled fewer words, but the ability to efficiently direct attention to high value words and later recall them was impaired. This ability to selectively encode information is likely dependent on several possibly interrelated abilities, including inhibitory control, working memory capacity, monitoring, and metacognitive control related to using performance on previous trials to update resource allocation strategies.

In the present study we investigated how executive control abilities, as reflected by working memory capacity, was related to selective encoding. In the older adult and AD groups the results clearly showed that working memory capacity was related to recall of high value items, but not with recall of low value items, indicating that those with more efficient central executive functioning were more efficient at directing their attention to encoding of higher value items. The correlation between working memory capacity and recall of high value items was not simply due to general memory ability, as the correlations between working memory capacity and recall of low value items was not significant. Moreover, the correlation between working memory capacity and the selectivity index was significant in the older adult group, and was marginally so in the AD group ($p = .054$), suggesting that the overall efficiency of memory encoding is related to the overall efficiency of the central executive component of the working memory system. However, the finding that the correlation between working memory capacity and the selectivity index was fairly weak is also noteworthy. This suggests that there are strategic processes involved in selective encoding that are not shared with complex span tasks. These strategic processes may be more metacognitive in nature, and possibly involve monitoring and control functions that are not necessarily attention dependent (e.g., using feedback to decide how many items one should attempt to encode well).

Another noteworthy finding in the present study is that an exploratory factor analysis revealed two distinct factors related to recall of high and low value items. The five highest value items loaded on one factor, and the seven lowest value items loaded on another. This factor structure was the same when all groups were combined in to one analysis, and also when separate analyses were conducted on each group. This suggests that all participants were selectively attending to the few highest value items, and these items were psychologically distinct from the lower value items. Thus, despite age and AD related declines in recall, there were no declines in the number of high value items that individuals were attempting to selectively rehearse. Nonetheless, there were important differences between groups in recall of low and high value items. First, older adults were better able to encode and recall the high value items than were individuals with AD (see Figure 1), which was confirmed by comparing the factor scores for high-value and low-value items. Note also that this difference in specific to AD, because aging affected factor scores for high-value and low-value items. Another important difference revealed by the factor analysis was that older adults and individuals with AD appeared to show a tradeoff in recall of high and low value items. This was revealed by the negative correlation between the high- and low-value factors within these groups. This result was not found in the younger adult group, which suggests that older adults and AD groups were using their limited resource selectively. In other words, those who were able to effectively encode the higher value items did so at a cost to being able to recall lower value items.

The ability to effectively 'use memory' (see Benjamin, 2007), in light of memory impairment and to judge how important it is to remember certain information, is a critical function for older adults (e.g., Castel, 2007). Thus, the examination of memory efficiency provides additional measures of cognitive function that are important to consider as older adults attempt to adaptively optimize memory (e.g., Dixon, Rust, Feltmate, & Kwong See, 2007), in order to obtain a complete picture of memory function in older adults. It is critical to consider not simply the amount of information that is remembered, but rather how value, or value-directed remembering, can be incorporated in order to maximize memory performance, especially in older adults (Castel, 2007). The current study allowed an examination of memory efficiency and the ability to attend to high value information in light of memory limitations. Although the selectivity task could be compared to the directed forgetting paradigm (in which participants are told explicitly to remember or forget certain items), the selectivity task involves the use of strategic control and choice regarding which items to rehearse and try to recall, and unlike the directed forgetting paradigm, all items are useful to remember, but the reward is graded based on point value. Andrés, Van der Linden and Parmentier (2007) found that frontal lobe patients do show directed forgetting effects (i.e., the capacity to actively forget certain information), although we know of no previous published investigation of directed forgetting and AD. Thus, the present findings provide some insight regarding the strategic control of remembering and forgetting, and how this relates to value, in older adults and those with AD.

The selectivity task can also be considered a task with prominent goal maintenance demands (e.g., Braver et al., 2001; Kane & Engle, 2003), as one must maintain the task goal of selectively attending to high-value items during the task. Because participants are trying to maintain items in working memory while strategically allocating attention to the encoding of more items, maintenance of the goal of attending to high-value items may be very difficult. Thus, the selectivity task shares some processing overlap with complex working memory span tasks (e.g., reading span), but unlike memory span tasks the selectivity task does not simply involve the use of a covert rehearsal strategies to maintain and recall short lists of items in serial order (e.g., McCabe, in press). Indeed, although recall of high-value items was related to performance on complex span tasks in the current study, particularly for the AD group, selectivity was still largely independent of working memory capacity. Measures like the selectivity index that go beyond simply assessing how much information can be retained are important because they provide insight regarding how attention and memory are inter-related, and how higher level-strategy use influences memory efficiency, which appears to be compromised in AD.

The present results could very well be interpreted in terms of impairments in working memory in AD (e.g., Belleville, Chertkow, & Gauthier, 2007) and reductions in inhibitory control of encoding and retrieval operations (e.g., Amieva, Phillips, Della Sella, & Henry, 2004), and goal maintenance regarding the task instructions (Braver et al., 2001). However, the construct of inhibition is a somewhat elusive measure, as inhibitory control can be described in many different terms, levels and types (see Faust & Balota, 2007; Kramer, Humphrey, Larish, Logan, & Strayer, 1994; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003). It may be that only certain types of inhibitory function become impaired in old age and AD (Amieva et al., 2004). For example, recent research suggests that inhibitory processing for healthy older adults may not be impaired in certain domains, such as retrieval induced forgetting (Aslan, Bäuml, & Pastötter, 2007). Although the present task may not tap a specific inhibitory mechanism, it does promote the necessity to focus attention towards high value items, while directing less attention toward (or perhaps inhibiting attention from) lower value items. Thus, the selectivity task may capture a form of strategic control of attention that later leads to value directed remembering.

It should be noted that in the present study, the AD individuals (who were diagnosed with very mild to mild AD) did show some degree of selectivity, and were well above chance in terms of selecting high value items relative to lower value items, and were not simply recalling a random selection of items. Thus, each group demonstrated some proficiency with the task, and was able to direct attention to the recall of high value information, but individuals with AD still recalled proportionally more lower value information than the other groups. This could also be interpreted in terms of poor metacognitive skills in AD, or less awareness (and execution) of the need to focus on high value information in order to optimize one's score. Although the distinction between WM capacity and the selectivity index was partially established in the present analyses, it may be the case that unlike the healthy older adults who learned to selectively focus on high value information, those with AD were not able to efficiently and adaptively focus on fewer items with higher values in order to achieve an optimal score.

The selective learning task is useful to test how executive control, learning and monitoring can lead to effective memory strategies for both children (e.g., Hanten et al., 2007), and healthy older adults (e.g, Castel et al., 2002; 2007). In terms of AD, an impairment in selectivity learning and recall might reflect a lack of awareness of memory ability (and not using feedback). A recent neuroimaging study with younger adults has shown that value (in the form of monetary incentive presented prior to learning) can lead to differential encoding of high and low value information, via dopamine release in the hippocampus (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006). Adcock et al. (2006) used a procedure much like the selectivity paradigm, in which cues signaled a high ($5.00) or low (10 cents) value monetary reward for memorizing an upcoming scene. Subjects (all younger adults) were tested a day later and were significantly more likely to remember scenes that followed cues for high-value rather than low-value reward. Although this specific work has not been extended to older adults (but see Bäckman et al.,2006, for a review of aging, dopamine, and memory), it may be that older adults greatly benefit from this dopamine release when value is added to items, resulting in good memory for high value information. AD may lead to impairments or reductions in dopamine release during the encoding of high value information (e.g, Bäckman, Nyberg, Lindenberger, Li, & Farde, 2006). At another level, this may also be consistent with impairments in monitoring encoding operations in AD, a hypothesis that has received some support in the domain of metacognition and aging (e.g., Dunlosky et al., 2007). Although this ability may be related to frontal lobe function (e.g., West, 1996), or frontal lobes communicating with, and directing, hippocampus activity (Moscovitch & Winocur, 1992), future research is needed to be able to detect individual differences in the ability to selectively encode high value information. Furthermore, more work is need to understand how the learning and implementing of suitable strategies for maximizing memory performance occurs, both on later lists (such as in the present selectivity task), or when applying this strategy in other situations (e.g., transferring to a new environment/task that requires the prioritizing of encoding certain information, when presented with large amounts of information). Finally, awareness of memory impairments and the use of value-directed remembering to try to focus on high value information may provide potential new directions for interventions and training programs to improve memory in healthy older adults and those with AD.

References

Adcock, R. A., Thangavel, A., Whitfield-Gabrieli, S., Knutson, B., & Gabrieli, J. D. E (2006). Reward-motivated learning: Mesolimbic activation precedes memory formation. *Neuron, 50*, 507–517.

Amieva, H., Phillips, L. H., Della Sella, S. & Henry, J. D. (2004). Inhibitory functioning in Alzheimer's disease. *Brain, 127*, 949-967.

Andrés, P., Van der Linden, M., & Parmentier, F. B. R. (2007). Directed forgetting in frontal patients' episodic recall. *Neuropsychologia, 45*, 1355-1362.

Armitage, S.G. (1946). An analysis of certain psychological tests used in evaluation of brain injury. *Psychological Monographs, 60* (1, Whole No. 277), 1-48.

Aslan, A., Bäuml, K.-H., & Pastötter, B. (2007). No inhibitory deficit in older adults' episodic memory. *Psychological Science, 18*, 72–78.

Bäckman, L., Nyberg, L., Lindenberger, U., Li, S.-C., & Farde, L. (2006). The correlative triad among aging, dopamine, and cognition: Current status and future prospects. *Neuroscience and Biobehavioral Reviews*, 30, 791-807.

Baddeley, A.D. (2000) The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 417-423.

Balota, D. A., Dolan, P. O., & Duchek, J. M. (2000). Memory changes in healthy young and older adults. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 395-410). Oxford University Press.

Balota, D. A., & Faust, M. E. (2001). Attention in dementia of the Alzheimer's type. In F. Bolla & S. Cappa (Eds.), *Handbook of neuropsychology: Vol. 6. Aging and dementia* (2nd ed., pp. 51–80). New York: Elsevier Science.

Balota, D. A., & Ferraro, F. R. (1993). A dissociation of frequency and regularity effects in pronunciation performance across young adults, older adults, and individuals with senile dementia of the Alzheimer type. *Journal of Memory and Language, 32,* 573–592.

Balota, D. A., & Ferraro, F. R. (1996). Lexical, sublexical, and implicit memory processes in healthy young and healthy older adults and in individuals with dementia of the Alzheimer type. *Neuropsychology, 10,* 82–95.

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. I., Kessler, B., Loftis, B., et al. (in press). The English lexicon project. *Behavior Research and Methods.*

Benton, A.L. (1963). *The revised Visual Retention Test: Clinical and experimental applications.* San Antonio, TX: Psychological Corp.

Belleville, S., Chertkow, H., & Gauthier, S. (2007). Working memory and control of attention in persons with Alzheimer's disease and mild cognitive impairment. *Neuropsychology, 21*, 458-459.

Benjamin, A. S. (2007). Memory is more than just remembering: Strategic control of encoding, accessing memory, and making decisions. In A. S. Benjamin & B. H. Ross (Eds.), *The psychology of learning and motivation*, Vol. 48. London: Academic Press.

Braver, T. S., Barch, D. M., Keys, B. A., Carter, C. S., Cohen, J. D., Kaye, J. A., Janowsky, J. S., Taylor, S. F., Yesavage, J. A., Mumenthaler, M. S., Jagust, W. J., & Reed, B. R. (2001). Context processing in older adults: Evidence for a theory relating cognitive control to neurobiology in healthy aging. *Journal of Experimental Psychology: General, 130*, 746-763.

Burgess, C., & Lund, K. (1997). Modelling parsing constraints with high dimensional context space. *Language and Cognitive Processes, 12*, 177–210.

Castel, A. D. (2007). Aging and memory for numerical information: The role of specificity and expertise in associative memory. *Journal of Gerontology: Psychological Sciences, 62*, 194-196.

Castel, A. D. (2007). The adaptive and strategic use of memory by older adults: Evaluative processing and value-directed remembering. In A. S. Benjamin & B. H. Ross (Eds.), *The psychology of learning and motivation*, Vol. 48 (pp. 225-270). London: Academic Press.

Castel, A. D., Benjamin, A. S., Craik, F. I. M., & Watkins, M. J. (2002). The effects of aging on selectivity and control in short-term recall. *Memory & Cognition, 30*, 1078-1085.

Castel, A. D., Farb, N., & Craik, F. I. M. (2007). Memory for general and specific value information in younger and older adults: Measuring the limits of strategic control. *Memory & Cognition, 35*, 689-700.

Castel, A. D., Balota, D. A., Hutchison, K. A., Logan, J. M., & Yap, M. J. (2007). Spatial attention and response control in healthy younger and older adults and individuals with Alzheimer's disease: Evidence for disproportionate selection breakdowns in the Simon task. *Neuropsychology, 21,* 170-182.

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General, 125*, 159-180.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24*, 87-185.

Cowan, N., Chen, Z., & Rouder, J. N. (2004). Constant capacity in an immediate serial-recall task: A logical sequel to Miller (1956). *Psychological Science*, *15*, 634-640.

Daneman, M., & Carpenter, P.A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*,450-466.

Dixon, R. A., Rust, T. B., Feltmate, S. E., Kwong See, S. (2007). Memory and aging: Selected research directions and application issues. *Canadian Psychology, 48*, 67-76.

Dunlosky, J., Cavallini, E., Roth, H., McGuire, C. L., Vecchi, T., & Hertzog, C. (2007). Do self-monitoring interventions improve older adult learning? *Journal of Gerontology: Psychological Sciences, 62*, 70-76.

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. Ross (Ed.), *The Psychology of Learning and Motivation* (Vol. 44, pp. 145-199). NY: Elsevier.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory and general fluid intelligence: A latent variable approach. *Journal of Experimental Psychology: General, 128*, 309-331.

Faust, M.E., & Balota, D.A. Inhibition, facilitation, and attention control in dementia of the Alzheimer type: The role of unifying principles in cognitive theory development. In D. S. Gorfein & C. McLeod (Eds.), *The place of inhibition in cognition*, Psychology Press.

Goodglass, H., & Kaplan, E. (1983). *Boston Naming Test.* Philadelphia, PA: Lea & Febiger.

Hanten, G., Chapman, S. B., Gamino, J. F., Zhang, L., Benton, S. B., Stallings-Roberson, G., Hunter, J. V., & Levin, H. S. (2004). Verbal selective learning after traumatic brain injury in children. *Annals of Neurology, 56,* 847-853.

Hanten, G., Li, X.,Chapman, S. B., Swank, P., Gamino, J. F., Roberson, G., & Levin, H. S. (2007). Development of verbal selective learning. *Developmental Neuropsychology, 32*, 585-596.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology learning and motivation* (Vol. 2, pp. 193-225). San Diego, CA: Academic Press.

Hughes, C. P., Berg, L., Danziger, W. L., Coben, L. A., & Martin, R. L. (1982). A new clinical scale for the staging of dementia. *British Journal of Psychiatry, 140,* 566–572.

Kane, M.J., & Engle, R.W. (2003). Working-memory capacity and the control of attention: The contributions of goal maintenance, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132*, 47-70.

Kramer, A.F., Humphrey, D. G., Larish, J. F., Logan, G. D., & Strayer, D. L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention. *Psychology and Aging, 9*, 491-512.

Logan, J. M., Sanders, A. L., Snyder, A. Z., Morris, J. C., & Buckner, R. L. (2002). Under-recruitment and non-selective recruitment: Dissociable neural mechanisms associated with aging. *Neuron, 33*, 827-840.

Logie, R., Cocchini, G., Della Sala, S., & Baddeley, A. (2004). Is there a specific executive capacity for task co-ordination? Evidence from Alzheimer's disease. *Neuropsychology, 18*, 504-513.

MacLeod, C. M., Dodd, M. D., Sheard, E. D., Wilson, D. E., & Bibi, U. (2003). In opposition to inhibition. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 43) (pp. 163-214). San Diego, CA: Academic Press

McCabe, D. P. (in press). The role of covert retrieval in working memory span tasks: Evidence from delayed recall tests. Journal of Memory and Language.

McCabe, D. P., Roediger, H. L., McDaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2007). *The relationship between working memory capacity, executive functioning, and general fluid intelligence: Converging evidence for an executive attention construct.* Manuscript in preparation.

McCabe, D. P., Smith, A. D., & Parks, C. P. (2007). Inadvertent plagiarism in young and older adults. *Memory & Cognition, 35*, 231-241.

McCabe, D. P., Robertson, C. L., & Smith, A. D. (2005). Age differences in Stroop interference in working memory. *Journal of Clinical and Experimental Neuropsychology, 27*, 633-644.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price, D., & Stadlan, E.M. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA work group under the auspices of the Department of Health and Human Services Task Force on Alzheimer's Disease. *Neurology, 34,* 939-944.

Myerson, J., Hale, S., Wagstaff, D., Poon, L. W., Smith, G. A. (1990). The information-loss model: A mathematical theory of age-related cognitive slowing. *Psychological Review*, *97*,475-487.

Morris, J. C. (1993). Clinical dementia rating. *Neurology, 43,* 2412–2414.

Morris, J. C., McKeel, D. W., Jr., Storandt, M., Rubin, E. H., Price, J. L., Grant, E. A., Ball, M. J., & Berg, L. (1991). Very mild Alzheimer's disease: Informant-based clinical, psychometric, and pathologic distinction from normal aging. *Neurology, 41*, 469-478.

Morris, J. C., McKeel, D. W., Jr., Fulling, K., Torack, R. M., & Berg, L. (1988). Validation of clinical diagnostic criteria for Alzheimer's disease. *Annals of Neurology, 24,* 17–22.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 315-372). Hillsdale, NJ; Erlbaum.

Park, D. C., Smith, A. D., & Lautenschlager, G., Earles, J., Frieske, D., Zwahr, M., & Gaines, C. (1996). Mediators of long-term memory performance across the life span. *Psychology and Aging, 11(4),* 621-637.

Perfect, T. J., & Dasgupta, Z. R. R. (1997). What underlies the deficit in reported recollective experience in old age? *Memory & Cognition, 25*, 849-858.

Perry, R. J. & Hodges, J. R. (1999). Attention and executive deficits in Alzheimer's disease: A critical review. *Brain, 122*, 383-404.

Rabbitt, P. R. (1965). An age-decrement in the ability to ignore irrelevant information. *Journal of Gerontology, 20*, 233-23.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*,403-428.

Spieler, D. H., Balota, D. A., & Faust, M. E. (1996). Stroop performance in healthy younger and older adults and in individuals with dementia of the Alzheimer type. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 461-479.

Thorndike, E. L., & Lorge, I. (1944). *The teacher's word book of 30,000 words.* New York: Columbia University, Teachers College Press.

Watkins, M. J., & Bloom, L. C. (1999). *Selectivity in memory: An exploration of willful control over the remembering process*. Unpublished manuscript.

Wechsler, D. (1955). *Wechsler Adult Intelligence Scale* (Manual). San Antonio, TX: Psychological Corp.

Wechsler, D., & Stone, C.P. (1973). *Wechsler Memory Scale* (Manual). San Antonio, TX: Psychological Corp.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120*, 272-292.

West, R. L. (1995). Compensatory strategies for age-associated memory impairment. In A. D. Baddeley, B. A. Wilson, & F. N. Watts (Eds.), *Handbook of memory disorders* (pp. 481-500). London: Wiley.

Zacks, R. T., & Hasher, L. (2006). Aging and long-term memory: Deficits are not inevitable. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 162-177). New York: Oxford University Press.

Zacks R. T., & Hasher L. (1994). Directed ignoring: Inhibitory regulation of working memory. In Dagenbach D, Carr TH, editors. Inhibitory processes in attention, memory, and language. San Diego (CA): Academic Press; 1994.
p. 53-112.

Table 1: Means (and standard deviations) of scores on Psychometric tests for healthy older adults and individuals with AD. F and p values reflect one-way ANOVAs.

Psychometric Test	Healthy Older Adults	Very mild AD	Mild AD*	F value (p value)
WMS Logical Memory	10.78 (3.41)	7.39 (4.07)	3.90 (2.10)	24.81 (p<.0001)
WMS Digits Forward	6.55 (1.47)	6.41 (1.23)	6.57 (1.22)	0.586 (p=.559)
WMS Digits Backward	5.02 (1.27)	4.36 (1.33)	4.00 (1.22)	4.31 (p<.05)
Trail Making Form A (total seconds)	39.86 (21.64)	50.58 (26.07)	78.00 (40.50)	15.41 (p<.0001)
Trail Making Form B (total seconds)	90.52 (37.78)	128.63 (41.91)	150.60 (40.33)	18.63 (p<.0001)
Boston Naming Test	55.35 (5.61)	48.97 (8.65)	41.00 (10.65)	19.10 (p<.0001)
Benton Copy	9.77	9.69	8.66	10.40

Form D	(.63)	(.75)	(1.07)	(p<.0001)
WAIS Block Design	31.93 (8.23)	23.36 (11.62)	20.02 (11.66)	16.79 (p<.0001)
WAIS Information	21.52 (4.04)	18.36 (5.72)	13.20 (4.96)	17.62 (p<.0001)
WAIS Information	21.52 (4.04)	18.36 (5.72)	13.20 (4.96)	17.62 (p<.0001)
WAIS Digit Symbol	46.51 (11.65)	36.11 (12.69)	24.20 (12.77)	17.40 (p<.0001)
Reading Span	7.27 (1.60)	5.59 (1.90)	4.00 (1.41)	35.51 (p<.0001)
Computation Span	8.42 (3.78)	6.28 (3.47)	4.33 (2.67)	21.81 (p<.0001)

Note: AD = Alzheimer's Disease; WAIS-R Wechlsler Adult Intelligence Test-Revised;

WMS = Wechsler Memory Scale

* Complete psychometric data only available from 10 of the 13 mild AD participants

Table 2: The mean number of words recalled, and mean selectivity index, for healthy younger adults, healthy older adults and individuals with very mild and mild Alzheimer's disease (AD). Standard error is presented below each mean. Coefficient alpha for recall was .88 and for SI was.72.

	Words Recalled	Selectivity Index
Young adults (N=35)	5.68 (0.24)	.59 (.04)
Older adults (N=109)	3.54 (0.08)	.57 (.02)
Very mild AD (N=41)	2.83 (0.14)	.40 (.05)
Mild AD (N=13)	1.95 (0.23)	.29 (.12)

Table 3. Factor Analysis Showing the Two Primary Factors Underlying Recall Performance for Low-Value Items and High-Value Items. In All Groups Items of Values 1-7 and Items of Values 8-12 Loaded on Separate Factors

	All Groups		Young		Old		AD	
	V1-7	V8-12	V1-7	V8-12	V1-7	V8-12	V1-7	V8-12
Value 1	**.73**	-.14	**.79**	.20	**.43**	-.44	**.83**	-.15
Value 2	**.72**	-.14	**.87**	-.13	**.50**	-.38	**.41**	-.33
Value 3	**.78**	-.04	**.84**	-.14	**.73**	-.12	**.72**	-.09
Value 4	**.71**	.10	**.79**	-.11	**.69**	-.03	**.67**	.21
Value 5	**.66**	.04	**.65**	.10	**.62**	-.09	**.35**	-.54
Value 6	**.63**	.23	**.53**	.52	**.55**	.04	**.66**	-.23
Value 7	**.50**	.44	**.50**	.17	**.45**	.15	**.33**	.21
Value 8	.25	**.72**	.19	**.61**	.23	**.61**	.30	**.64**
Value 9	.16	**.76**	.01	**.77**	.12	**.69**	.24	**.67**
Value 10	-.05	**.80**	-.14	**.46**	-.10	**.71**	-.14	**.81**
Value 11	-.10	**.78**	.11	**.74**	-.19	**.69**	-.54	**.63**
Value 12	-.20	**.71**	-.01	**.31**	-.44	**.48**	-.26	**.78**
% Variance	28%	26%	31%	18%	22%	20%	25%	26%

Table 4. Correlations between Working Memory Capacity and Recall of Low-Value Items (Recall 1-7), High-Values Items (Recall 8-12), and Selectivity Index.

	WMC	R1-7	R8-12	SI
Young Adults (N = 35)				
WMC	-			
Recall 1-7	.05	-		
Recall 8-12	.16	.14	-	
Selectivity	.00	**-.61**	**.44**	-
Healthy Older Adults (N = 102)				
WMC	-			
Recall 1-7	-.08	-		
Recall 8-12	**.30**	**-.28**	-	
Selectivity	**.22**	**-.70**	**.64**	-
Alzheimer's Disease (N = 48)				
WMC	-			
Recall 1-7	.17	-		
Recall 8-12	**.57**	**-.30**	-	
Selectivity	.28	**-.69**	**.78**	-

Correlation coefficients in bold type are significant at $p < .05$

Figure 1: The mean probability of recall as a function of point value averaged across alls lists for healthy younger adults, healthy older adults and individuals with very mild Alzheimer's disease (AD 0.5) and mild Alzheimer's disease (AD 1.0).

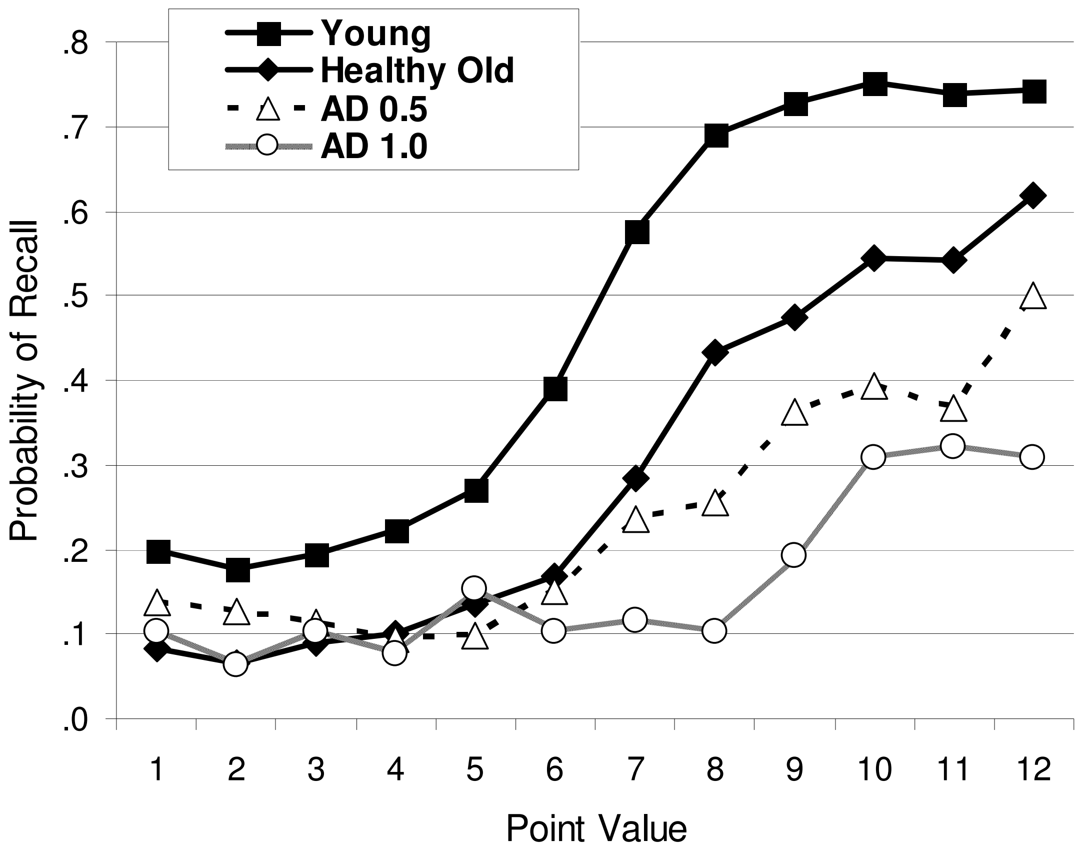


Figure 2: Selectivity Index or SI (top panel, Figure 2A) and recall (Figure 2B, bottom panel) as a function of list order (first four lists = average of Lists 1-4) or (2nd four lists =average of Lists 5-8), for Young Adults, Healthy Older Adults, and individuals with very mild Alzheimer's disease (AD 0.5) and mild Alzheimer's disease (AD 1.0).

Figure 2A

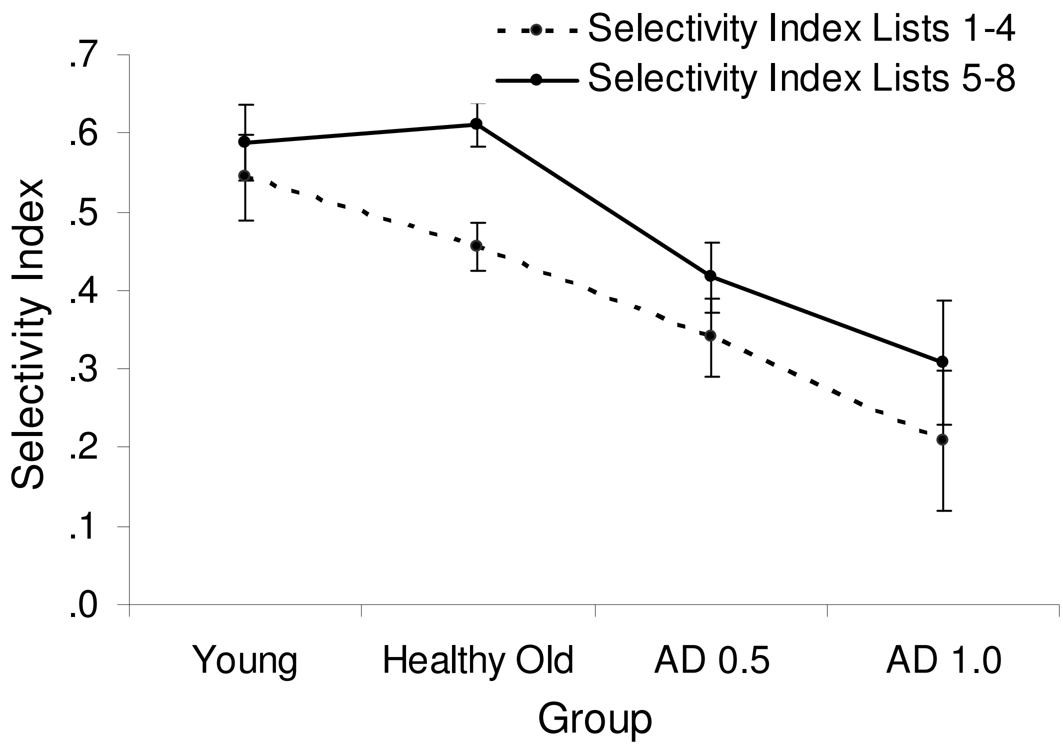
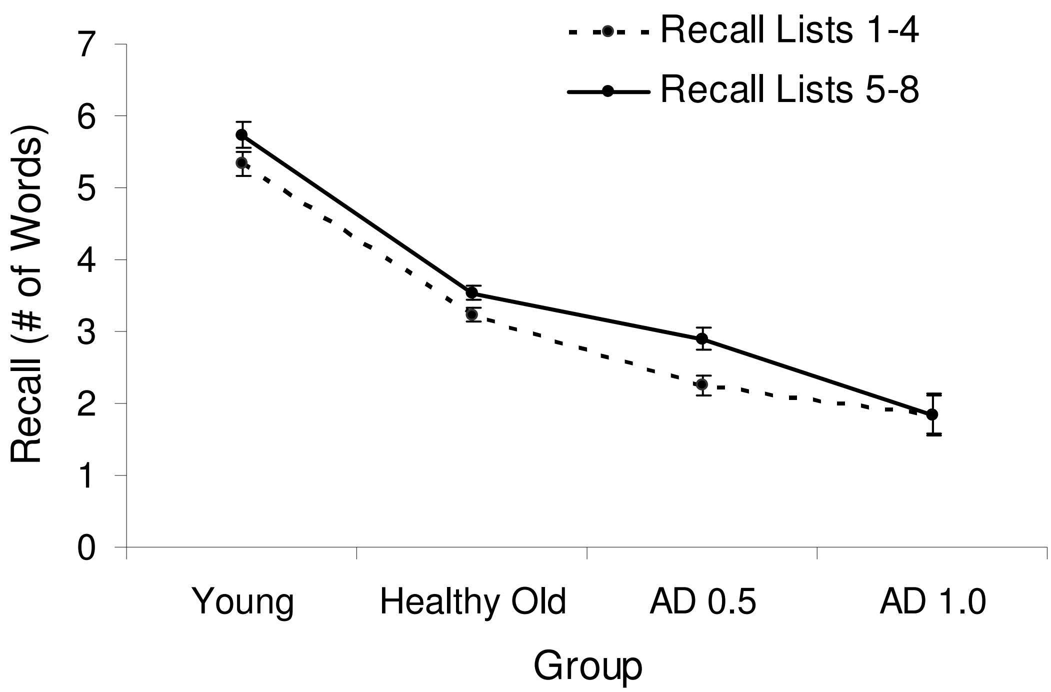


Figure 2B


Recall Lists 1-4
Recall Lists 5-8
7
6
5
4
3
2
1
0
Recall (# of Words)
Young
Healthy Old
AD 0.5
AD 1.0
Group

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