January 2011

Age Differences in Proactive Facilitation and Interference: The Role of Remindings

Chris Wahlheim
Washington University in St. Louis

WASHINGTON UNIVERSITY IN ST. LOUIS

Department of Psychology

Dissertation Examination Committee:
Larry Jacoby, Chair
Dave Balota
Pascal Boyer
Randy Larsen
Henry Roediger, III
Lisa Tabor-Connor

AGE DIFFERENCES IN PROACTIVE INTERFERENCE AND FACILITATION:

THE ROLE OF REMINDINGS

by

Christopher Nathan Wahlheim

A dissertation presented to the
Graduate School of Arts and Sciences
of Washington University in
partial fulfillment of the
requirements for the degree
of Doctor of Philosophy

August 2011

Saint Louis, Missouri

ABSTRACT OF THE DISSERTATION

Age Differences in Proactive Interference and Facilitation:

The Role of Remindings

by

Christopher Nathan Wahlheim

Doctor of Philosophy in Psychology

Washington University in St. Louis, 2011

Professor Larry Jacoby, Chair

A common finding is that specific types of memory performance decline as a function of age. Among the situations that produce these differences are those in which proactive interference (PI) occurs. PI refers to impaired memory for new information as a result of previous learning of competing information. However, research has shown that PI situations can sometimes be facilitative to memory performance for both young and older adults when information is integrated effectively. One potential integration mechanism is the retrieval of earlier competing information during study of new information. Such instances have been referred to as "remindings", and they serve to preserve the temporal order of information. In the current experiments, I explored the role of remindings in age differences in memory performance in PI situations. A-B, A-D paired-associate learning paradigms were used to examine age differences in the effects of learning two responses (B and D) in association with one stimulus (A) on later memory for the response presented more recently (D). In addition, age differences in the occurrence of remindings were examined by comparing the tendency for responses that occurred first (B) to come to mind first at retrieval when participants were instructed to recall the response that occurred more recently (D). Results revealed that young adults were reminded more than older adults and that memory performance benefitted from remindings for each group. In addition, the deleterious effects of PI were observed when remindings did not occur. Finally, participants were sensitive to the effects of remindings, and there were individual differences in the extent to which remindings could be cognitively-controlled. Together, these findings illuminate the mechanisms underlying age differences in memory performance in PI situations, and potentially inform training regimens aimed at remediating age-related deficits produced by PI.

Acknowledgments

First and foremost, I would like to thank Larry Jacoby for his support, guidance, and suggestions on this and many other lines of research. In addition, I would like to thank Larry for patiently helping me to develop my abilities to think critically and to ask interesting questions. I would also like to thank Roddy Roediger and Dave Balota for their feedback and suggestions regarding this and other lines of research. Both have been extremely helpful in pointing out ways to improve the interpretation and presentation of my research and in sharpening my thinking about many issues. Thanks are also owed to Rachel Teune who assisted with the current experiments and many other preliminary experiments. Her helpful feedback and attention to detail has undoubtedly improved the quality of data collection. I also express appreciation to the various organizations that have funded my research including: the Binational Science Foundation, the McDonnell Foundation, and the National Institution on Aging. Finally, I would like to thank my family, especially Sara Estle, for their encouragement and support throughout the entire process. It would have been much more difficult to complete this project without them.

Table of Contents

List of Tables

List of Figures

Introduction

Research has shown that specific types of memory performance decline with age (e.g., Balota, Dolan, & Duchek, 2000; Craik & Jennings, 1992; Kausler, 1994). One situation in which older adults sometimes show memory impairment is under conditions of proactive interference (e.g., Hay & Jacoby, 1999; Jacoby, Debner, & Hay, 2001; for a review, see Kausler, 1994). Proactive interference (PI) occurs when the learning of previous information impairs memory for new information. For example, at the end of the workday, one may return to a parking location in which they typically park even though one has parked in a different location that day. Instances such as this occur when one has formed a strong habit of returning to the typical location as a result of repeatedly parking in that location. Consequently, when one does not remember parking in a different location, one is more likely to return to the typical location (Hay & Jacoby, 1996). Although previous learning often impairs memory for new information, as in the example of the changed parking location (for reviews, see Anderson & Neely, 1996; Crowder, 1976), research has also shown that it can facilitate memory performance when the new information is sufficiently similar (cf. Barnes & Underwood, 1959; Postman, 1964). An example of this can be found in educational settings when new concepts build upon previously learned concepts, such as in science courses. Does the similarity of materials facilitate memory performance by reminding one of previous learning? If so, do remindings and their effects on memory performance differ for young and older adults?

The primary aim of the current experiments was to examine how the similarity of materials modulates the effects of previous learning on memory for new information, and whether there are age differences in such effects. Age differences in the effects of previous learning on memory for new information were examined in a PI situation using paired associate methods conforming to A-B, A-D paradigms. Briefly, A-B, A-D paradigms can be used to examine the effects of previous learning of an initial list of stimulus-response word pairs (A-B) on the memory for pairs on a second list in which some responses have been changed (A-D). These effects are measured by assessing memory performance for the responses presented on the second list (D), and comparing it to performance in a control condition in which different responses are not paired with a common stimulus across lists (e.g., A-B, C-D).

In establishing the rationale for the current experiments, I consider evidence from two literatures that describe experiments designed to examine interference mechanisms (i.e., literatures on interference and transfer effects). Evidence from both of these literatures is relevant because experiments from each are thought to tap into similar underlying processes. Before introducing the current experiments, I provide brief overviews of the literature on interference effects, transfer effects, and aging, as well as age-related differences in the effectiveness of mediators in facilitating memory performance. I then discuss a *remindings* framework that is potentially useful for explaining the facilitative effects of previous learning in PI situations.

Interference and Aging

Interference theory was originally proposed as an account of forgetting (for reviews, see Anderson & Neely, 1996; Crowder, 1976). A common notion is that older adults' poorer memory for recent information is due to their heightened susceptibility to the effects of interference (see, e.g., Lustig, May, & Hasher, 2001; Welford, 1958). Early studies of age differences in interference effects were typically set in retroactive interference (RI) paradigms which examined the effects of new learning on memory for previously learned information. For example, in a study by Cameron (1943), young and older adults both repeatedly studied three-digit numbers on which they were tested following a one-minute retention interval. During the retention interval, the experimental group completed a backward spelling task, whereas the control group rested. Results revealed poorer memory performance for the experimental than control group with the difference being greater for older than young adults. These results were taken as evidence that memory performance was hurt by RI from the interpolated task, and that older adults were more susceptible to the effects of RI.

Although Cameron's results seem to provide evidence for age-related differences in susceptibility to RI, the validity of this evidence is questionable. An important problem that was overlooked was that young and older adults were not equated on their learning of the original information. Some believe that original learning must be equated to assess age differences in interference effects because young adults encode information more effectively than older adults under equivalent learning conditions (see Kausler, 1994). Thus, older adults' poorer memory performance may be due to their lower level of original learning, instead of a heightened susceptibility to interference.

To address the problem of differences in original learning, several studies that used the paired associate method were designed to equate original learning between young and older adults (e.g., Gladis & Braun, 1958; Hulicka, 1967; Wimer & Wigdor, 1958). In these studies, participants were presented with two lists of paired associates. In the first list, A-B stimulus-response pairs were learned to a criterion of N errorless trials.

Next, A-D pairs were learned in a second list. The idea was that the learning of two response terms (B, D) in association with one stimulus (A) created interference. At the time of test, stimuli were presented and participants were told to recall responses from the first list (B). RI effects were indexed as the extent to which memory performance in A-B, A-D conditions was lower than in control conditions in which participants only learned A-B pairs.

The results from some of these initial studies revealed that age differences in RI were no longer present after equating young and older adults' original learning. For example, in a study by Wimer and Wigdor (1958), young and older adults in the experimental condition learned A-B pairs to a criterion of one errorless trial, and then learned A-D pairs to a criterion of two errorless trials. Participants were then tested on their memory for the B response terms when presented with the stimuli on a test that occurred 15 minutes after learning of A-B pairs. Control participants were given the same task as participants in the experimental condition with the exception that the controls completed a distractor task for 15 minutes following A-B learning. Results revealed that memory performance was higher in the control than experimental group and that the magnitude of this effect did not differ for young and older adults. Thus, young and older adults did not appear to differ in their susceptibility to interference.

Based on these findings, one could conclude that older adults are not more susceptible to interference than young adults. However, note that older adults required twice as many trials to criterion in A-B learning than did young adults. This difference in exposure to materials leaves open the possibility that the lack of age differences in interference effects is due to item selection effects. That is, it is likely that older adults overlearned some of the A-B pairs which artifactually eliminated age differences. Further, the conclusion regarding age differences in interference effects becomes more complicated by the finding that older adults do show stronger effects of RI when both young and older adults are given the same amount of limited practice on the A-B list (e.g., Hulicka, 1967, Experiment 2). In addition, older adults do sometimes show heightened RI even when their original learning is matched with young adults (e.g., Arenberg, 1968b; Kay, 1951; Suci, Davidoff, & Brown, 1962; Traxler, 1973). Given the methodological difficulties in these studies, one can at most conclude that there are moderate age differences in the effects of interference (Kausler, 1994).

One way to explain the differences in the effects of interference brought about by differences in original learning is to examine these effects in the context of a dual process model. Dual process models hold that there are cognitively controlled and automatic forms of memory (e.g., Jacoby & Dallas, 1981; Mandler, 1980). Cognitively controlled processes are slow and deliberate, and give rise to detailed recollections along with the subjective experience of awareness. In contrast, automatic processes are fast, effortless, and unavailable to conscious awareness. Older adults' poorer memory performance has been attributed to a deficit in recollection as evidenced by their poorer performance in direct tests of memory that are require heavy use of controlled forms of memory such as free recall (for reviews, see Craik & Jennings, 1992; Hultsch & Dixon, 1992). In contrast, few age differences have been found on indirect tests of memory that often reflect little use of controlled forms of memory such as word stem completion tasks (for reviews, see Light, Prull, La Voie, & Healy, 2000; Kausler, 1994).

Evidence for age differences in controlled forms of memory (i.e., recollection) in a PI situation was reported by Hay and Jacoby (1999). In their studies, PI was examined using a paired associate method conforming to a version of the classic A-B, A-D paradigm. However, their paradigm differed from the studies of RI described above in several ways. The first way that it differed was that PI was examined instead of RI. Another difference was that the experiments contained A-B, A-B items, in which stimulus and response terms were repeated across lists, in addition to A-B, A-D items. A final difference was that on the first list, stimuli were presented and participants were told to produce an associated response by guessing. After a response was produced, participants were presented with either an A-B or A-D pair. The proportion of A-B and A-D pairs presented was manipulated probabilistically such that in a congruent condition, A-B pairs were presented 75% of the time, and in an incongruent, A-B pairs were presented 25% of the time. This was done to vary the extent to which learning in the first list facilitated or interfered with memory performance for critical A-D items presented in the second list.

The logic of Hay and Jacoby's probabilistic manipulation followed on the process dissociation framework developed by Jacoby (1991). Briefly, the process dissociation procedure (PDP) allows one to estimate the contributions of controlled and automatic processes to memory performance by comparing conditions in which these processes operate in concert or in opposition. The congruent condition represents a situation in which these processes operate in concert, whereas controlled and automatic processes are set in opposition in an incongruent condition. The proportion of typical responses in each condition can be submitted to the PDP equations to estimate the contributions of each component process (for a detailed description of these equations, see Jacoby, 1991, 1998). Thus, the contributions of recollection and more automatic forms of memory, such as familiarity, can be compared for young and older adults.

Results from Hay and Jacoby (1999) revealed that with typical intentional learning instructions in which participants were not provided with any particular encoding strategies, older adults were more likely to report the typical response from List 1 for incongruent items than were young adults. That is, older adults were more likely to make an intrusions error from the first list. Older adults also tended to produce the typical response less often on congruent items, which is consistent with the notion that older adults show lower levels of original learning when study is equated for both age groups. However, the PDP analysis revealed that the age related deficit was more specific than just a difference in original learning. Results showed that older adults had a deficit in recollection. Process estimates of recollection were lower for older than young adults, whereas automatic process estimates did not differ between age groups. These results provided evidence for age difference in the effects of interference, and, more important, accounted for this difference in terms of a difference in the use of controlled forms of memory.

Taken together, the results from the studies of RI and PI provide some evidence that older adults are more susceptible to interference effects than are young adults. In addition to these studies that have largely focused on PI and RI, results from studies of transfer effects in paired-associate learning also provide some support for this claim. Transfer tasks are similar to tasks used to examine PI and RI in that they make use of the A-B, A-D paradigm and they are all thought to reflect similar underlying processes.

However, transfer effects are indexed by comparing the rate of learning, as measured by the number of trials taken to reach a criterion level of performance on A-D items presented in a second list, to that of a control group. Nonetheless, transfer effects are often described in terms of interference theory just as are PI and RI effects.

Transfer effects can differ in size and direction. In paired-associate learning, negative transfer effects refer to impaired learning of the second list of pairs due to the presentation of the first A-B list. In contrast, positive transfer effects are obtained when learning of A-B pairs in the first list produces increased memory performance for pairs in the second list. Thus, negative transfer effects can be thought of as similar to PI effects, even though the measures are slightly different. Transfer effects can also differ in their generality. Some transfer effects are specific to particular items, as in the case of A-B, A-D pairs. In contrast, other transfer effects are nonspecific and have effects at the list level (across items). As mentioned earlier, it has long been thought that older adults are more susceptible to interference than young adults (e.g., Ruch, 1934). If this is true, then one would expect larger specific negative transfer effects in A-B, A-D paradigms for older than young adults.

To test for age differences in negative transfer, young and older adults' rate of learning A-D pairs in A-B, A-D paradigms were compared in two studies. In one study, Arenberg (1967a) found that the number of trials to reach a criterion level of learning did not differ between an A-B list that was learned first and an A-D list that was learned second for older adults. In contrast, young adults learned a list of A-D pairs in a second list in fewer trials than they needed to learn an A-B list that was presented first. In another study, Hulicka (1967) found a tendency for older adults to need more trials to learn an A-D list presented second as compared to an A-B list that was presented first, while young adults learned the A-D list in fewer trials than the A-B list. The interactions observed in these two studies suggest that older adults are more susceptible to the influence of interference; however, the effects in these studies were quite small. Moreover, these studies did not include the appropriate A-B, C-D control conditions to account for effects of nonspecific transfer. That is, it is unclear whether age differences were due to greater nonspecific positive transfer for young adults or greater specific negative transfer for older adults.

In a study by Freund and Witte (1976), age differences were compared in an A-B, A-D transfer task that included the appropriate control conditions. Young and older adults first learned A-B pairs to a criterion of one errorless trial. Next, both groups received four learning trials of A-D and C-D (control) pairs. Results revealed specific negative transfer effects that did not differ for young and older adults across the four learning trials. This lack of an age difference is similar to the earlier findings of no age differences in RI.

Although there is only limited evidence for older adults' heightened susceptibility to the effects of interference in conventional A-B, A-D transfer tasks, other variants of these procedures have revealed more convincing results. For example, Lair, Moon, and Kausler (1969) created interference pre-experimentally by taking related A-B word pairs (e.g., table-chair, fast-slow) that were not presented to participants and re-pairing them in a to-be-remembered A-Br list (e.g., table-slow, fast-chair). The rates of learning were then compared for participants who received the A-Br pairs and controls who received the same response terms paired with stimuli that were not related to any of the responses

(C-B). Results revealed a slower learning rate for those who received the re-paired list as compared to controls. More important, the difference in learning rate between experimental participants and controls was larger for older than middle aged participants. In addition, Kliegel and Lindenberger (1988) conducted similar experiments in which an A-B list was presented prior to successive A-Br lists and found that older adults were again more susceptible to interference effects than young adults. These results were taken as evidence that age-related differences in the effects of interference are most detectable under conditions of extreme interference.

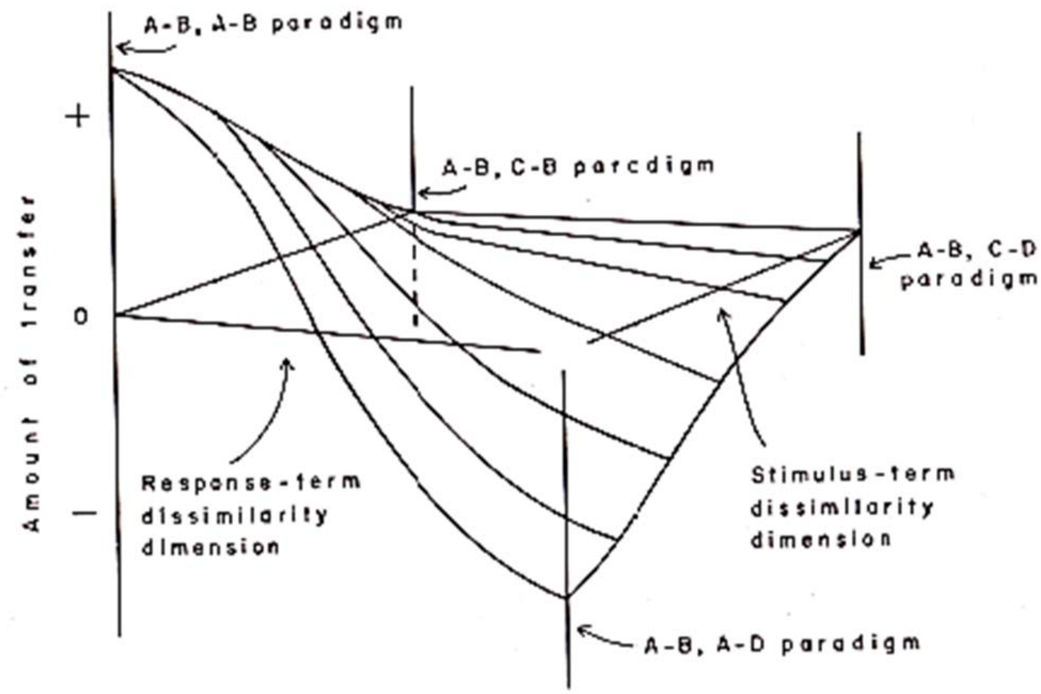
In another version of the A-B, A-D transfer task, Winocur and Moscovitch (1983) examined age differences in performance. The rate of learning the second list was compared for an experimental group that was presented with a list of A-B items followed by a list of A-D items, and a control group that only studied a list of A-D items. The materials in their study differed from other studies in that the stimuli (A) were associatively related to the responses in each list (B and D), and the responses were related to one another (e.g., army-battle, army-soldier). Results revealed poorer performance on A-D items for the experimental group than the control group. In addition, this effect was larger for older than young adults, showing that older adults were more susceptible to the effects of interference. However, the interpretation of these results is complicated because the relationship among items makes it likely that more than just interference was operating Also, the lack of an A-B, C-D control condition did not allow for a test of nonspecific transfer effects. Nonetheless, these results suggest that older adults performed more poorly than young adults under conditions of interference.

Taken together, the literatures on PI, RI, and transfer effects provide evidence that older adults are more susceptible to the effects of interference than young adults in many situations. However, this susceptibility may depend on the level of interference and the nature of the materials used. In addition, differences in original learning may point to differences in the bases used for responding for each age group. In particular, the finding that older adults have lower levels of original learning may be, in part, due to less effective use of controlled processes. In this vein, considering the influence of controlled and automatic processes on performance in PI situations may provide a better explanation of age differences in memory performance. Further, the use of controlled processes might also function to produce facilitation effects in these interference paradigms, which could mask the effects of interference more for young than older adults. I now turn to studies that have shown facilitation effects produced by additional learning events.

Aging and Mediation

As mentioned above, transfer effects can be either positive or negative. That is, previous learning can either facilitate or interfere with new learning. Of particular interest in early studies of transfer was the role of similarity in the direction of transfer effects. To understand how similarity modulates transfer effects, Osgood (1949) developed a formal model on the basis of results from studies using the paired associate method (see Figure 1). The paired associate method was useful for investigating transfer because one could control the similarity of stimuli and responses in each learning event. Osgood's analysis of existing data revealed that positive transfer effects (i.e., facilitation) were obtained to the extent that stimuli and responses overlapped in each list, with the extreme case being an A-B, A-B paradigm in which stimuli and responses were identical in each list. In contrast, negative transfer effects (i.e., interference) increased with dissimilarity between responses, such as in the A-B, A-D paradigm. Finally, no transfer was found in situations in which there was no similarity between stimuli and responses (i.e., A-B, C-D paradigms). Thus, facilitation occurred to the extent that responses were similar, whereas interference occurred to the extent that responses were dissimilar.

Figure 1. Osgood's (1949) transfer and retroaction surface (adapted from Crowder, 1976).



Facilitation effects that arise from the similarity or association between responses in versions of A-B, A-D paradigms have been found in several studies. For example, Barnes and Underwood (1959) examined the "fate" of first list responses in A-B, A-D and A-B, A-B' paradigms. In their A-B, A-D paradigm, there were no associations between responses in each list. In contrast, the A-B, A-B' paradigm contained responses that were highly similar (e.g., afraid, scared). In both paradigms, participants first learned the A-B list to a criterion of one errorless trial and then learned the second list for 1, 5, 10, or 20 trials. Following presentation of the second list, participants were given a modified modified free recall (MMFR) test in which they were presented with the stimulus terms and instructed to write down responses from both lists in the order that they came to mind.

Results revealed that recall performance on responses from both lists was better for the A-B, A-B' group than the A-B, A-D group, which is consistent with the prediction of Osgood's (1949) model. Further, in both paradigms, the number of responses recalled from the first list decreased across trials on the second list, whereas the reverse was true for the number of responses recalled from the second list. However, this interaction was more pronounced for the A-B, A-D paradigm than the A-B, A-B' paradigm. These results were taken as evidence that the learning of unrelated responses in the second list of the A-B, A-D paradigm extinguished, to some extent, the previous learning of the A-B pairs. More important, the results also indicated that the learning of A-B' pairs was mediated by the response term from the first list (B). That is, participants remembered the B response term during learning of the A-B' pairs which resulted in chained associations (A-B-B'). Thus, at the time of test, memory for the B term in association with the A term facilitated recall of the B' term. Additional evidence for the mediation account could be seen in that B terms were more often recalled prior to B' terms. Importantly, this mediation account held that the associations were formed automatically and were driven exclusively by the associations between responses.

In a similar vein, the associations between responses were shown to play an important role in the production of positive transfer effects in a study by Postman (1964). The aim of his study was to examine changes in transfer effects across successive learning trials as a function of the associations among terms. Four paradigms were used in which the A-B list was presented first, and the second list was either A-D, C-D, A-B', or A-Br. Postman was specifically interested in whether mediation would be used more often in A-B, A-D situations in which responses were unrelated as a function of experience across blocks of trials. In his experiment, participants learned the A-B list to 7/8 of an errorless trial, and the second list was presented for five study-test trials. This sequence occurred three times with new materials in each set. At the time of test, participants were given a version of the MMFR procedure used by Barnes and Underwood (1959) to evaluate changes in the use of mediational associations (e.g., A-B-D).

Not surprising, results revealed that memory performance for second list responses (collapsed across the five trial blocks) was best in the A-B' group followed by the C-D, A-D, and A-Br groups, respectively. Results from the MMFR test revealed evidence for mediation in the A-B' condition in that the conditional probability of recalling the second list response given that the first list response was produced always exceed the unconditional probability of recalling the second list response. In addition, this conditional probability increased across sets and reached .95 by the third set. Finally, results revealed a tendency towards an interaction between recall performance for conditionalized and unconditionalized data and the set on which performance was tested for the A-D and A-Br groups showing that: performance on the first set was lower for conditionalized than unconditionalized data, performance on the second set was similar for both types of data, and performance on the third set was higher for conditionalized than unconditionalized data. These results suggest that the use of mediational chains increased with experience in the task. More important, participants were able to use mediation even when responses in each list were unrelated as in the A-D and A-Br groups.

The role of mediation in recall in A-B, A-D paradigms was further examined in a study by Dallet and D'Andrea (1965). They examined both transfer and RI effects by measuring the rate of learning the second list and by testing recall of responses from the first list, respectively. The critical manipulation was that one group of participants was encouraged to use a mediation strategy to integrate responses from the second list with those presented in the first list, whereas another group was encouraged to unlearn responses from the first list prior to the learning the second list (akin to directed forgetting). Results revealed that encouraging the use of a mediation strategy did not increase the rate of List 2 learning relative to the unlearning instructions. In contrast, responses from the first list were recalled better in the mediation group than in the unlearning group, and participants in the mediation group reported using mediators more often than those in the unlearning group. The latter results suggest that mediation plays a role in facilitating recall when multiple responses are associated with a common stimulus. However, it is unclear why transfer did not benefit from mediation instructions. Perhaps transfer did not benefit from mediational instructions because the measure was not sensitive enough to detect the effects of a manipulation of task instructions.

Despite the finding that instructions to use mediation did not benefit transfer in the study by Dallet and D'Andrea (1965), the other results from the mediation studies still suggest that mediation plays a facilitative role in situations that also produce interference. Of relevance to the current study is whether these effects differ for young and older adults. To examine age differences in transfer effects, Freund and Witte (1976) used four paired associate paradigms in which the first list included A-B items, and the second list included A-D, C-D, A-B'$_{high}$ (high similarity between responses), or A-B'$_{low}$ (low similarity between responses) items. Results revealed positive transfer for both young and older adults on A-B, A-B'$_{high}$ items. In addition, negative transfer effects were obtained for A-B, A-D items both groups. Finally, on A-B, A-B'$_{low}$ items, young adults showed significant negative transfer effects, whereas older adults only showed a non-significant trend towards negative transfer. The finding of age differences in negative transfer effects for A-B, A-B'$_{low}$ items has been attributed to a mediational deficit in older adults (see Kausler, 1994). However, mediational deficits have seldom been examined in the context of A-B, A-D paradigms.

Research on age differences in the proficiency of mediators has instead been conducted primarily within the context of paired-associate learning in paradigms using only one study list. In these studies, participants learn a list of paired associates and are later tested on the responses when given the stimuli. Mediator usage is often measured by asking participants to report mediators that were produced during study. Studies along these lines have revealed that older adults are less likely to produce mediators linking stimuli to responses (e.g., Dunlosky & Hertzog, 2001; Hulicka & Grossman, 1967; Rowe & Schnore, 1971). However, these differences are small and can be eliminated when older adults are given instructions to use mediators (e.g., Dunlosky & Hertzog, 1998, 2001; Treat & Reese, 1976). More recent work by Dunlosky, Hertzog, and Powell-Moman (2005) has shown that older adults' deficit in mediation is not due to a deficit in the production of mediators, but instead lies in their inability to recall mediators at the time of test. Deficits such as these are consistent with the notion that older adults are less able to engage in recollection (cf. Hay & Jacoby, 1999).

Taken together, the results from these studies indicate that the facilitative effects of previous learning can be obtained in transfer and RI situations. Moreover, it appears that these facilitative effects are driven by response similarity which has its effects through mediational chaining. As mentioned earlier, mediation was held to be an automatic associative process that is driven exclusively by the characteristics of the materials. However, evidence that mediation can be controlled strategically has also been shown (e.g., Dallet & D'Andrea, 1965; Postman, 1964). This distinction is important because it indicates that the associations between responses are important for producing facilitation effects in A-B, A-D paradigms, but it is possible that the magnitude of these effects can be modulated using controlled processes. In particular, one possibility is that facilitative effects are produced when participants are reminded of earlier responses when studying later responses that share a common stimulus. Further, this reminding may serve to integrate and organize information in a way that preserves the order in which the responses occurred. A reminding mechanism such as this would rely on both controlled and automatic processes and would explain age differences in memory performance under conditions of PI as being due to a deficit in recollection. I describe this reminding framework in more detail in the next section.

Remindings

Remindings are common events that happen in one's daily life. Remindings in their most basic form are instances when a current event cues retrieval of a previous event. For example, seeing a missed called from one's spouse could remind one that he is supposed to pick up their dog from the groomers that afternoon. Remindings can also occur at many levels of cognition as indicated by their presence in various areas of cognitive psychology. For example, remindings have been shown to play roles in concept learning (e.g., Ross, Perkins, & Tenpenny, 1990), problem solving (e.g., Ross, 1984), frequency judgments (Hintzman, 2010), and spacing effects (e.g., Benjamin & Tullis, 2010). Of most relevance to the current study, remindings have also been shown to play roles in temporal judgments (e.g., Winograd & Soloway, 1985) and PI effects (Wahlheim & Jacoby, submitted).

The role of remindings in temporal judgments and PI situations is that they serve to preserve the temporal order of information (e.g., Hintzman, in press). For example, Winograd and Soloway (1985) showed that recency judgments made for related pairs for which each item was presented individually in an earlier list were more accurate than judgments about unrelated pairs. The notion was that the relationship between the related items facilitated remindings. The mechanism by which remindings preserved the temporal order of the items was assumed to operate such that remembering that the later event (B) reminded one of the earlier event (A), which produced a memory for event B being the reminder of event A. Remembering which event was the reminder preserved the temporal order because the reminder necessarily occurs after the event that it brought to mind. In this vein, remindings can produce facilitation effects in A-B, A-D paradigms when one remembers that the term presented in the second list (D) reminded one of the term presented in the first list (B). Memory for the reminding preserves memory of the list membership of both responses.

A remindings account of facilitation effects in A-B, A-D paradigms differs from a mediation account in that mediation has been associated with automatic processes that are drive by pre-existing associations (e.g., Barnes & Underwood, 1959), whereas remindings are thought to involve both automatic as well as controlled processes (cf. Jacoby, 1974). Remindings also differ from mediation effects produced by presenting mediating pairs (B-C) following the learning of A-B pairs, which both occur prior to a recall test of C terms when presented with the A terms (for a review, see Hall, 1971). That is, the enhancement in recall performance brought about by reminding occurs as a result of the previous information being retrieved during new learning, whereas the enhancement produced by mediation is attributed to either associations alone or to the presentation of mediating pairs. The primary difference between remindings and mediation is that remindings can be directed to early events using controlled processes, whereas mediation, as it has been described in the context of A-B, A-D paradigms, is a relatively passive process that relies more on automatic associations.

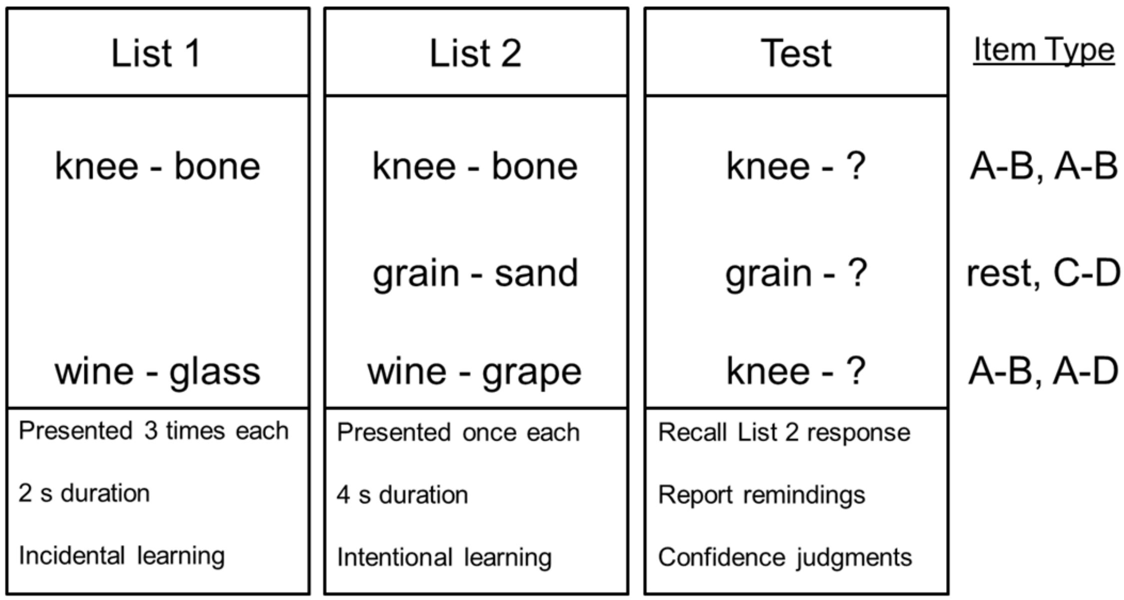
Recent work has shown that remindings can produce facilitation effects in A-B, A-D situations, and that they can also be cognitively controlled. Wahlheim and Jacoby (submitted) examined remindings in the context of a PI situation conforming to an A-B, A-D paradigm. Word pairs were used as materials, and the conditions in their experiments included: A-B, A-B items; rest, C-D (control items); and A-B, A-D items. In each of the pairs, there was a forward association from the stimulus to response (e.g., wine-grape). In addition, sets of pairs were created in which the stimulus term (wine) had two alternative responses that were perceptually similar (grape, glass). The two alternative responses were presented in separate lists for items in the A-B, A-D condition. An important point to note was that for A-B, A-D items, the bi-directional normative associative strength between B and D terms was low on average (.03), and the B and D terms were not related for most items. This is important because it indicates that if facilitative effects occurred, more than an automatic associative mechanism would be needed to account for the effects.

Wahlheim and Jacoby's procedure was similar to earlier A-B, A-D paradigms, with a few exceptions (see Figure 2 below). In the first list, A-B pairs were presented three times for 2 s each, and participants were simply told to read the pairs aloud (incidental learning instructions). There were no tests immediately following the presentation of List 1 items as was done in many of the earlier studies. In the second list, A-B, A-D, and C-D pairs were presented for 4 s each, and participants were told to study the pairs for an upcoming memory test (intentional learning instructions). They were also told that some pairs would be the same as in List 1 (A-B, A-B), some pairs would be new to List 2 (rest, C-D), and some pairs would have the same stimulus with a different response (A-B, A-D). Finally, participants were informed that noting items for which responses had changed (i.e., A-B, A-D items) would help them to remember the List 2 response.

At the time of test, participants were given stimuli as cues for recall of the responses presented in List 2. Importantly, participants were instructed to constrain their retrieval to responses that were presented in List 2. To measure the occurrence of remindings, participants were told to report whether another word came to mind prior to the response they recalled, after producing their response. Given that List 2 responses are assumed to make contact with List 1 responses when remindings occur, it was also assumed that remindings occurred for items on which List 1 responses were reported as coming to mind prior to participants' responses. List 1 responses should come to mind first in these instances because the integration of responses across lists would make both responses accessible when retrieval is constrained to List 2, and the accessibility of List 1 responses should be higher because they were presented more frequently than List 2 responses and because they were retrieved during List 2. Further, integration of the two responses via remindings should facilitate retrieval of List 2 responses because List 1 responses produced first would act as an additional retrieval cue for List 2 responses.

Wahlheim and Jacoby's measure of remindings differs from similar test procedures that assess recall of multiple responses such as the MMFR test described above. The primary difference between these measures is that the MMFR test does not require participants to constrain their retrieval to a particular list. Consequently, one cannot determine whether retrieval of responses from both lists is a product of an earlier reminding that integrated responses into one representation, or whether participants gained access to somewhat independent representations of responses from each list at the time of retrieval. In contrast, the production of List 1 responses prior to recall when participants are attempting to constrain their retrieval indicates that responses presented in List 1 were integrated with representations formed during List 2.

Figure 2. General procedure from Wahlheim and Jacoby (submitted).



Results from Wahlheim and Jacoby's experiments revealed that performance on A-B, A-D items was greater than performance on control items for items on which remindings were reported. This indicated that remindings produced facilitation effects in situations that commonly produce interference effects. In contrast, interference effects were obtained for A-B, A-D items when remindings were not reported as indicated by poorer performance as compared to control items. These results indicated that the list membership of the responses was preserved when participants used remindings to integrate responses from each list during List 2 study.

Evidence showing that remindings could be cognitively controlled was found by examining individual differences in their production. Hierarchical multiple regression analyses were used to examine the extent to which differences in general memory ability across participants accounted for difference in performance on A-B, A-D items. More important, these analyses were used to examine the extent to which individual differences in remindings accounted for variance in A-B, A-D performance across participants when controlling for differences in general memory ability. Results revealed that differences in general memory ability, indexed as performance on control items (rest, C-D) did account for a significant amount of variance in the recall of A-D items. However, remindings, indexed as the probability that a List 1 response came to mind first when attempting to retrieve List 2 responses on A-B, A-D items, accounted for a significant proportion of the variance in recall above and beyond general memory ability. These results indicate that individual differences in remindings can be cognitively controlled, and that participants may differ in the extent to which they strategically employ remindings to preserve the list membership of responses.

Wahlheim and Jacoby's remindings report procedure is a potentially important contribution to the investigation of age differences in transfer or PI effects. For example, consider that in the Freund and Witte (1976) study, age differences were limited in A-B, A-B'$_{low}$ groups in that older adults showed negative transfer, whereas young adults showed no transfer effects. One possibility is that the traditional transfer test procedure masked age differences in the effects of previous learning. Instead, the remindings report procedure would have allowed for an examination of differences in transfer effects as a function of whether remindings occurred. The lack of a difference found for young adults may have reflected a mixture of offsetting facilitation and interference effects, and these effects could be revealed by using the remindings report procedure.

In sum, remindings enhance memory performance in PI situations by preserving the temporal order of information. Remindings go beyond an account of facilitation effects based on normative associations by specifying a mechanism that underlies such effects. Wahlheim and Jacoby showed that remindings could occur even when the relationship between responses on A-B, A-D items was weak or when there was no relationship. In addition, results showed that there are individual differences in their occurrence. These results indicate that the associative strength between responses plays a role in eliciting remindings, but remindings are not exclusively due to associations. Instead, remindings can also be cognitively controlled, and this ability may differ as a function of age.

The extent to which individuals use remindings strategically should depend on their ability to recollect previous information. This possibility has implications for age differences in PI situations because older adults have been shown to have deficits in recollection (e.g., Hay & Jacoby, 1999; Jacoby, 1999; Jacoby, Debner, & Hay, 2001) and in their ability to bind associative information (e.g., Naveh-Benjamin, 2000). In addition, older adults have deficits in the ability to reflect on recently presented information (i.e., refreshing) resulting in poorer memory performance than young adults (e.g., Johnson, Reeder, Raye, & Mitchell, 2002). Finally, older adults have also been shown to have poorer memory for temporal order (e.g., McCormack, 1982). Although remindings may benefit memory performance for both age groups, older adults may use cognitively controlled remindings less often than young adults, because of the increased difficulty associated with attempting to engage in recollection. Thus, older adults may, in part, show poorer overall memory performance in PI situations because they do not employ controlled remindings to the same extent as do young adults.

The notion that remindings can be cognitively controlled also has implications for the subjective experience of their occurrence. Wahlheim and Jacoby (submitted) provided evidence that participants were aware of their remindings in the form of additional study time being taken for items on which remindings were reported relative to those on which remindings were not reported. In this vein, age differences in the awareness of remindings may exist because of older adults' deficit in controlled forms of memory. Given that older adults show more susceptibility to interference effects (e.g., Hay & Jacoby, 1999), one possibility is that they may not think that remindings are an effective means by which to facilitate memory performance. Alternatively, older adults have been shown to have intact metacognitive monitoring (e.g., Dunlosky & Connor, 1997), so they may be sensitive to the benefits of remindings.

Introduction to the Experiments

To examine the role of remindings in age differences in PI, two experiments were conducted using A-B, A-D paradigms that included Wahlheim and Jacoby's (submitted) remindings report procedure. Experiment 1 was designed to examine the effects of associations on the production of remindings and to examine age differences in remindings and their effects on memory performance. This experiment was designed to highlight the role of automatic associations in the production of remindings and differences in the extent to which remindings could be cognitively controlled. To anticipate, young and older adults benefitted from remindings, but older adults produced fewer remindings than young adults. The reduction in remindings for older adults pointed to the importance of controlled processes in the production of remindings. However, the results were preliminary in that the design did not control for age differences in original learning. Consequently, Experiment 2 was designed to verify the age differences while controlling for differences in original learning. Lastly, awareness of the effects of remindings was examined in both experiments by including confidence judgments at the time of test.

Experiment 1

The first aim of Experiment 1 was to examine the role of associations in the production of remindings. Previous research has shown that changing responses paired with common stimuli between lists (i.e., A-B, A-D) can produce either facilitation or interference effects depending on the strength of associations between responses (e.g., Barnes & Underwood, 1959). These differences may reflect differences in the probability that remindings occurred. In Experiment 1, the effects of associations on the probability of remindings were examined by varying the number of associations among stimulus and response terms across three conditions. These conditions included: a stimulus-response-response (SRR) association condition in which stimuli were associated with both responses and responses were associated with one another (e.g., agent-spy, detective), a stimulus-response only (SRO) association condition in which stimuli were associated with both responses but the responses were not associated with one another (e.g., nose-eye, snort), and an unrelated condition in which stimuli and responses were not associated with one another (e.g., inch-bacon, cost). If remindings underlie the facilitation effects observed when associations are present, then the probability of remindings should be higher when associations are present among terms. A second hypothesis is that remindings could increase with the number of associations present.

The second aim was to examine potential age differences in the production of remindings. Research has shown that the magnitude of facilitation effects on recall performance produced by associated responses tend to be smaller for older than young adults (e.g., Freund & Witte, 1976). In addition, older adults have been shown to have a deficit in recollection with intact use of automatic forms of memory. The finding that older adults produce facilitation effects when responses are related indicates that they are able to make use of automatic associations. However, the finding that the facilitation effects are smaller for older than young adults suggests that older adults make less use of controlled remindings than young adults. Thus, both age groups were expected to show higher probabilities of remindings when associations were present, but older adults were expected to produce fewer remindings than young adults.

The third aim was to examine participants' sensitivity to the effects of remindings using confidence judgments at the time of test. Older adults' metacognitive monitoring has been shown to be similar in accuracy to that of young adults (e.g., Dunlosky & Connor, 1997). One possibility is that young and older adults will both be sensitive to the benefits of remindings by showing higher confidence for items on which remindings occurred as compared to items on which remindings did not occur. However, older adults' memory performance has also been shown to suffer relative to young adults when multiple responses are available at the time of retrieval (cf. Hasher & Zacks, 1988). Thus, an alternative possibility is that older adults might judge their memory to be poorer when multiple responses come to mind at the time of test, whereas the reverse might be true for young adults.

The final aim was to examine whether remindings account for variance in performance on A-B, A-D items beyond the variance accounted for by general memory ability. Wahlheim and Jacoby (submitted) recently used hierarchical multiple regression to show that remindings account for variance in performance on A-B, A-D items beyond the variance accounted for by general memory ability alone. This was taken as evidence for individual differences in the controlled used of remindings. Similar analyses were used in Experiment 1 to verify that this pattern of results could be replicated for young adults and to examine whether it could be extended to older adults and to a different set of materials. The prediction was that individual differences in controlled remindings should be obtained for both groups when there are sufficient associations to produce remindings.

Method

Participants

Thirty-six young adults (26 women, 10 men, M_{age} = 19.3 years, age range: 18-22 years), and 36 older adults (27 women, nine men, M_{age} = 75.8, age range: 63-86 years) were recruited using the Washington University Department of Psychology participant pools for each respective age group. The compensation for young adults was course credit or $10 per hour, and the compensation for older adults was $10 per hour. The mean score on the Vocabulary subtest of the Shipley Institute of Living Scale (Shipley, 1986) was lower for young adults (M = 34.00, SD = 2.96) than for older adults (M = 36.11, SD = 2.08), $t(70) = -3.50$.

Design and Materials

The design was similar to that of Wahlheim and Jacoby (submitted) in that the same item types were used. A 3(Item type: A-B, A-B vs. rest, C-D (control) vs. A-B, A-D) X 3(Association: unrelated vs. stimulus-response only (SRO) vs. stimulus-response-response (SRR)) X 2(Age: young vs. older) mixed design was used. Item type and association were manipulated within-participants, and age was a between participants variable.

Materials consisted of 99 three-word sets (see Appendix). Each set contained a cue word (e.g., knee) and two responses (e.g., bone, bend). Three groups of 33 sets were created with each group representing one of the association conditions. In each association condition, the associative strength among members was indexed according to the Nelson, McEvoy, and Schrieber (1998) norms. For the unrelated items, there were no associations among members of the set (e.g., inch-bacon, cost). For the stimulus-response only (SRO) items, the average forward associative strength (FAS) from stimuli to responses (e.g., nose-eye, nose-snort) was .03 (*SD* = .02, range: .01-.09), and there was no association between responses (e.g., eye, snort). For the stimulus-response-response (SRR) items, the average FAS from stimuli to responses (e.g., agent-spy, agent-detective) was .03 (*SD* = .02, range: .01-.09), and the average forward and backward associative strengths between responses (e.g., spy, detective) were matched (*M* = .14, *SD* = .15, range: .01-.55). Each group of items in each association condition was matched on the associative strengths presented above.

The length of stimuli and responses in each group ranged from 3-8 letters and was matched across groups (*M* = 4.94, *SD* = .26). Word frequency was indexed according to the English Lexicon Project (ELP) database (Balota et al., 2007). Log HAL frequencies ranged from 4.73 to 14.73 and were matched for stimuli and responses across groups (*M* = 9.63, *SD* = .42). Each 33-set group was then divided into three 11-set subgroups matched on the dimensions described above. Of the 11 sets in each subgroup, 10 sets served as critical items and the remainders served as buffers against primacy and recency effects. Each subgroup was rotated through item type conditions and served equally often in each condition across experimental formats.

Item types were created by varying the relationship between pairs in List 1 and List 2. A-B, A-B items consisted of the same stimuli and responses in each list, control pairs (rest, C-D) were only presented in List 2, and A-B, A-D items had the same stimuli in each list, with the response being changed from List 1 to List 2. The assignment of responses to lists was counterbalanced such that each response in a set was presented equally often in each list across experimental formats. The counterbalancing of critical items and assignment of responses to list produced six experimental formats.

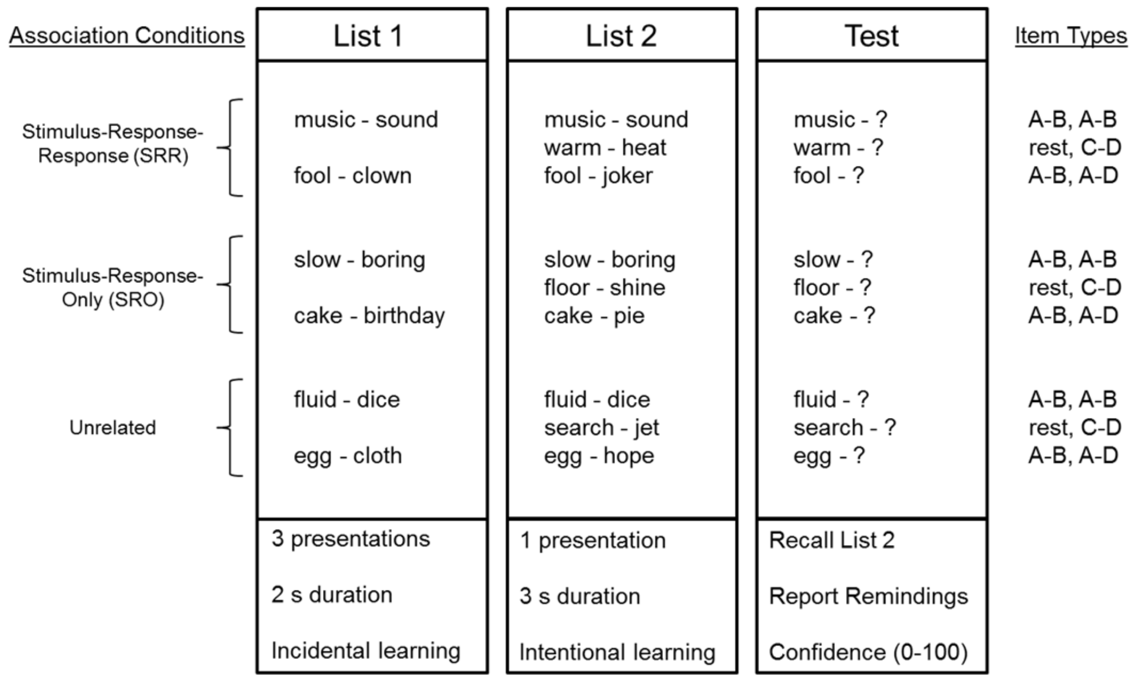
Procedure

The procedure consisted of three phases in the following order: List 1, List 2, and test. During List 1, 66 word pairs (e.g., agent-spy) were presented three times each resulting in 198 total presentations. Pairs were presented repeatedly to increase their memorability to a level that would allow for remindings in List 2. Each pair was presented for 2 s each followed by a 500 ms interstimulus interval (ISI). Thirty-three pairs were from each of the A-B, A-B, and A-B, A-D conditions. Participants were told to read the pairs aloud quickly and accurately, and they were given the cover story that we were interested in their reading times.

After participants read the words in List 1, they were given instructions for List 2. In List 2, 99 word pairs (33 per condition) were each presented once for 3 s, followed by a 500 ms ISI. The first three pairs were primacy buffers, and the last six pairs were recency buffers. The remaining 90 pairs were critical items. Participants were told to read the pairs aloud and to study them for an upcoming cued-recall test. Participants were also encouraged to note any similarities between List 2 pairs and pairs presented earlier in List 1. In the instructions, participants were told that some pairs would be the same in each list, some would be new to List 2, and others would have the same stimulus with a changed response. They were told that noticing items with changed responses would help them to remember the response from List 2.

At test, participants were first given a practice phase including nine items. Stimuli from the buffer pairs in List 2 were each presented individually with a question mark (e.g., knee - ?). Following practice, 90 critical items were presented as critical test items in the same manner. For each test item, participants were told to say the List 2 response aloud or to guess if they could not remember it. Following their response, they were asked to report whether another word came to mind prior to their response. Earlier pilot studies showed that participants sometimes reported two words coming to mind simultaneously. Consequently, participants were told that if this happened, they should first report the response they thought was from List 2 and report the other response as coming to mind first. The prompt "Did another word come to mind?" appeared, and participants clicked either "Yes" or "No" in boxes displayed below the prompt. When participants responded "Yes", they were asked to report the other word that came to mind. After indicating whether another response came to mind, participants rated their confidence in whether the response they recalled as being from List 2 was from that list on a scale from 0 (wild guess) – 100 (certain correct). All responses were recorded by an experimenter. A schematic of the design, materials, and procedure is displayed below in Figure 3.

Figure 3. Schematic of the design, materials, and procedure in Experiment 1.



Results and Discussion

The significance level in both experiments was set at alpha = .05.

Overall Recall Performance

The pattern of overall recall performance can be seen in Table 1. Results revealed that young adults outperformed older adults (.40 vs. .26), $F(1, 70) = 17.18$, $\eta_p^2 = .20$, and that age did not enter into any significant interactions. There was a significant effect of association, $F(2, 140) = 246.79$, $\eta_p^2 = .78$, showing that recall performance was higher for the SRO than SRR condition (.43 vs. .38), $t(71) = 4.82$, and higher for the SRR than unrelated condition (.38 vs. .17), $t(71) = 17.59$. There was also a significant effect of item type, $F(2, 140) = 243.21$, $\eta_p^2 = .78$, indicating that performance did not differ between the A-B, A-D and control conditions (.22 vs. .23), $t(71) = 1.67$, whereas performance was greater in the A-B, A-B condition than in the other conditions (.53), $ts(71) > 15.21$. These effects were qualified by a significant association X item type interaction, $F(4, 280) = 4.94$, $\eta_p^2 = .07$, showing that the advantage in performance for A-B, A-B relative to the mean of control and A-B, A-D items was greater in the SRO condition (.38) than in the SRR (.28) and the unrelated condition (.27), $ts(71) > 3.18$, with there being no difference between the SRR and unrelated conditions, $t < 1$. These results show that, as expected, memory performance was better for young than older adults. In addition, the presence of associations increased memory performance relative to when terms were completely unrelated. Finally, the finding that the SRO condition produced higher performance than the other conditions may have been because they were less difficult to remember even though word frequency was matched across conditions.

Table 1. *Probability of Correct Recall of List 2 Responses as a Function of Item Type, Associations, and Age: Experiment 1*

	Item Type		
Age X Association	A-B, A-B	Control	A-B, A-D
Young			
SRR	.65 (.04)	.34 (.03)	.36 (.03)
SRO	.74 (.04)	.40 (.04)	.35 (.03)
Unrelated	.47 (.05)	.15 (.02)	.12 (.02)
Older			
SRR	.48 (.04)	.21 (.03)	.22 (.03)
SRO	.63 (.04)	.25 (.04)	.22 (.03)
Unrelated	.23 (.05)	.03 (.02)	.03 (.02)

Note. Standard errors of the means are presented in parentheses.

Remindings

To explore the role of associations and age in the production of remindings, I first examined the extent to which participants reported that another response came to mind prior to the response that they recalled as a function of the type of response that was produced (see Table 2). The occurrence of remindings was indicated by the production of List 1 responses as the first to come to mind. Results revealed an effect of association, $F(2, 140) = 19.22$, $\eta_p^2 = .22$, showing that the probability of any response coming to mind first was higher for the SRR (.08) and SRO (.10) conditions than the unrelated condition (.05), $ts(71) > 4.69$, with there being no difference between the SRR and SRO conditions, $t(71) = 1.35$. There was also a significant effect of response, $F(2, 140) = 20.74$, $\eta_p^2 = .23$, indicating no difference in the probability of producing List 1 (.12) or extra-list (.10) responses, $t < 1$, with the probabilities of both being higher than the probability of producing a List 2 response as the other response (.01), $ts(71) > 5.86$. Note that the production of a List 2 response prior to the response resulted in incorrect recall. It is interesting that the probability that a List 2 response came to mind first was near zero in that interference theories might predict a higher frequency of these instances due to response competition at the time of retrieval.

The effect of response was qualified by a significant response X age interaction, $F(2, 140) = 4.00$, $\eta_p^2 = .06$. This interaction showed that young adults produced List 1 responses first (.16) more often than extra-list responses (.09), and extra-list responses more often than List 2 (.01) responses, $ts(35) > 2.19$. In contrast, older adults produced List 1 responses (.08) no more often than extra-list responses (.11), $t < 1$, and both responses were produced more often than List 2 responses (.01), $ts > 3.87$. Further, List 1 responses were produced more often by young than older adults (.16 vs. .08), $t(70) = 2.71$, whereas there was no difference in the production of List 2 and extra-list responses between age groups, $ts(70) < 1.61$. These results indicate that young adults reported remindings more often than older adults, and that both groups did not differ in their production of List 2 and extra-list responses. Although young adults reported more remindings than older adults, older adults still produced a reasonable number of responses that were not the List 1 alternatives. These results show that young adults' remindings were more constrained by the current task than were the remindings produced by older adults.

Finally, there was a significant association X response interaction, $F(4, 280) = 17.37$, $\eta_p^2 = .20$. List 1 responses were produced more often than extra-list responses in the SRR condition (.16 vs. .09), $t(71) = 2.74$, and in the SRO condition (.16 vs. .11), $t(71) = 1.74$ (*one-tailed*). In contrast, extra-list responses were produced more often than List 1 responses in the unrelated condition (.10 vs. .04), $t(71) = 2.75$. These results indicate that pre-existing associations are important for the production of remindings, but the extent to which the terms were associated in the present conditions did not seem to matter.

Table 2. *Probability of Responses Coming to Mind Prior to the Response Output on A-B, A-D items as a Function of Response Type, Associations, and Age: Experiment 1*

	Response Type		
Age X Association	List 1	List 2	Extra-List
Young			
SRR	.21 (.03)	.02 (.01)	.08 (.02)
SRO	.20 (.03)	.02 (.01)	.08 (.03)
Unrelated	.06 (.01)	.01 (.01)	.11 (.03)
Older			
SRR	.10 (.03)	.01 (.01)	.10 (.02)
SRO	.13 (.03)	.01 (.01)	.13 (.03)
Unrelated	.02 (.01)	.01 (.01)	.10 (.03)

Note. Standard errors of the means are presented in parentheses.

Recall Conditionalized on Remindings

The results from overall recall performance indicated no differences in performance between control and A-B, A-D items. To interpret performance for A-B, A-D items, recall was examined as a function of whether remindings were produced. Given that few participants produced at least one reminding in all of the association conditions, the following analyses compared performance for young and older adults as a function of item type separately for each association condition (see Table 3). This allowed for the maximum number of observations because the analyses included all instances in which a reminding was produced. Recall of A-B, A-D items was compared to that of control items to examine potential facilitation and interference effects. To anticipate, facilitation effects were obtained on A-B, A-D items for which remindings were reported (A-B, A-D_R), whereas interference effects were obtained when remindings were not reported (A-

B, A-D_{NR}). Follow-up analyses compared recall for A-B, A-D_R items to recall on A-B, A-B items to examine whether the facilitation effects produced by remindings differed in magnitude from those produced by repeating pairs across lists. Note that main effects of age are not reported in the following analyses because they are redundant with effects reported for overall recall performance above.

Table 3 shows that performance on A-B, A-D_R items was higher than performance on control items for both age groups in the SRR condition (.79 vs. .30), $F(1, 46) = 61.37$, $\eta_p^2 = .57$, and in the SRO condition (.67 vs. .34), $F(1, 42) = 35.89$, $\eta_p^2 = .46$. There was also a trend in the same direction in the unrelated condition (.30 vs. .12), $F(1, 18) = 2.46$, $\eta_p^2 = .12$. In contrast to A-B, A-D_R items, recall performance on A-B, A-D_{NR} items was lower than for control items for both age groups in the SRR condition (.20 vs. .30), $F(1, 46) = 9.19$, $\eta_p^2 = .17$, and in the SRO condition (.22 vs. .34), $F(1, 42) = 13.81$, $\eta_p^2 = .25$. There was also a non-significant trend in the same direction in the unrelated condition (.04 vs. .12), $F(1, 18) = 3.47$, $p = .08$, $\eta_p^2 = .16$. None of these effects interacted with age, Fs < 2.40, ps < .13. These results provide evidence that remindings facilitated recall performance, and that interference effects were obtained in the absence of remindings. Further, these results suggest that the presence of associations increased the facilitative effects of remindings because there were larger differences between A-B, A-D_R and control items for the condition in which associations were present (i.e., SRR and SRO) as compared to the condition in which there were no associations (i.e., unrelated).

The magnitudes of facilitation effects produced by remindings were compared to those produced by repeating pairs across Lists 1 and 2 by examining differences in recall performance for A-B, A-D_R and A-B, A-B items. The facilitation effects produced by remindings were larger than those produced by repetitions in the SRR condition in that performance on A-B, A-D_R items was higher than performance on A-B, A-B items (.78 vs. .64), $F(1, 46) = 4.81$, $\eta_p^2 = .10$. However, there was not a significant difference in the effects produced by remindings and repetitions in the SRO condition (A-B, A-B = .76 vs. A-B, A-D_R = .66), $F(1, 42) = 2.16$, $p = .15$, $\eta_p^2 = .05$. Finally, repetitions produced more facilitation than remindings in the unrelated condition as performance was significantly higher for the A-B, A-B than A-B, A-D_R items (.57 vs. .30), $F(1, 18) = 5.22$, $\eta_p^2 = .23$. None of these effects interacted with age, *F*s < 1. Together, these results indicate that remindings facilitate memory performance, and that the magnitude of such effects increases with the extent to which associations are present.

Table 3. *Probability of Correct Recall as a Function of Item Type, Remindings, Association, and Age: Experiment 1*

	Item Type			
Age X Association	A-B, A-B	Control	A-B, A-D_R	A-B, A-D_{NR}
SRR				
Young (N = 32)	.68 (.04)	.37 (.03)	.79 (.06)	.24 (.03)
Older (N =16)	.60 (.06)	.24 (.05)	.77 (.09)	.15 (.04)
SRO				
Young (N = 26)	.79 (.04)	.44 (.04)	.73 (.08)	.27 (.04)
Older (N = 18)	.74 (.04)	.23 (.05)	.60 (.09)	.16 (.05)
Unrelated				
Young (N = 15)	.60 (.08)	.17 (.05)	.30 (.11)	.08 (.05)
Older (N = 5)	.54 (.14)	.08 (.08)	.30 (.19)	.01 (.08)

Note. A-B, A-D_R = A-B, A-D items on which remindings were reported; A-B, A-D_{NR} = A-B, A-D items on which remindings were not reported. The number of participants who produced at least one reminding are displayed in parentheses next to each association condition. Standard errors of the means are presented in parentheses next to correct recall probabilities.

Confidence Judgments

Confidence in recall of List 2 responses was measured for all items to examine participants' sensitivity to differences in performance across conditions, and, more important, to determine if participants were sensitive to the effects of remindings. Confidence judgments were analyzed in the same manner as recall performance. That is, confidence in overall recall performance was analyzed first, and confidence conditionalized on remindings was examined second.

The pattern of overall confidence is presented in Table 4. There was a significant effect of age showing that young adults were more confident in their recall performance than were older adults (.47 vs. .36), $F(1, 70) = 10.94$, $\eta_p^2 = .14$. There was also a significant effect of association, $F(2, 140) = 168.15$, $\eta_p^2 = .71$, indicating that participants judged recall performance to be higher in the SRO than SRR condition (.51 vs. .44), $t(71) = 6.77$, and higher in the SRR than unrelated condition (.44 vs. .29), $t(71) = 15.26$. In addition, a significant effect of item type, $F(2, 140) = 185.14$, $\eta_p^2 = .73$, showed that participants judged performance to be higher for A-B, A-B than A-B, A-D items (.54 vs. .43), $t(71) = 9.07$, and higher for A-B, A-D than control items (.43 vs. .28), $t(71) = 12.06$.

The patterns of these judgments were consistent with actual recall performance with the exception that actual performance was not higher for A-B, A-D than control items. The inflated confidence on A-B, A-D items may reflect participants' reliance on multiple bases for their judgments. Both the effects of remindings and the familiarity of cues were likely used as bases for confidence for A-B, A-D items. This would produce higher confidence for A-B, A-D than control items because the facilitative effects of remindings would not be considered for judgments on control items, and A-B, A-D items in which cues were repeated across lists have higher cue-familiarity than the control items that were presented only once in List 2.

Finally, a significant association X item type X age interaction, $F(4, 280) = 2.73$, $\eta_p^2 = .04$, further qualified differences in the postdicted facilitation effects. The triple interaction indicated differences in the postdicted magnitudes of facilitation effects for A-B, A-B and A-B, A-D items for young and older adults across association conditions. The magnitudes of facilitation effects were computed in the following analyses by subtracting confidence for control items from confidence for A-B, A-B and A-B, A-D items. Young adults postdicted no difference in facilitation effects for A-B, A-B items across association conditions (SRR = .27, SRO = .28, Unrelated = .27), $ts(35) < 1$, and larger facilitation effects for A-B, A-D items in the SRR than unrelated condition (.20 vs. .11), $t(35) = 2.62$, with effects in the SRO condition being intermediate, but not significantly different from the SRR and unrelated conditions (.16), $ts(35) < 1.41$. In contrast, older adults postdicted larger facilitation effects for A-B, A-B items in the SRO than in the SRR condition (.33 vs. .23), $t(35) = 3.03$, and in the SRR as compared to the unrelated condition (.23 vs. .16), $t(35) = 2.02$, $p = .05$. Further, older adults postdicted no difference in facilitation effects for A-B, A-D items in the SRR and SRO conditions (.15 vs. .20), $t(35) = 1.50$, but larger facilitation effects for SRR and SRO conditions as compared to the unrelated condition (.06), $ts(35) > 2.42$. Given that a significant interaction of this sort was not obtained for recall performance, the more appropriate comparison between confidence and recall is that described above.

Table 4. *Confidence Judgments for Recall of List 2 Responses as a Function of Item Type, Associations, and Age: Experiment 1*

	Item Type		
Age X Association	A-B, A-B	Control	A-B, A-D
Young			
SRR	.61 (.03)	.34 (.03)	.54 (.03)
SRO	.69 (.03)	.41 (.03)	.57 (.03)
Unrelated	.49 (.04)	.22 (.02)	.33 (.03)
Older			
SRR	.49 (.03)	.26 (.03)	.41 (.03)
SRO	.62 (.03)	.29 (.03)	.49 (.03)
Unrelated	.31 (.04)	.15 (.02)	.21 (.03)

Note. Standard errors of the means are presented in parentheses.

Participants' sensitivity to the effects of remindings was assessed by examining confidence conditionalized on the occurrence of remindings (see Table 5). Analyses including both age groups were conducted separately for each association condition as was done for the conditionalized recall data. Effects of age are not reported here because of their redundancy with the effects reported in the analyses of overall confidence judgments above.

Sensitivity to the facilitative effects of remindings was examined by comparing confidence in A-B, A-D_R to control items, and sensitivity to the interference effects that occurred in the absence of remindings was examined by comparing A-B, A-D_{NR} to control items. Results revealed that both young and older adults were sensitive to the effects of remindings. Confidence was significantly higher for A-B, A-D_R than control items in the SRR condition (.75 vs. .32), $F(1, 46) = 87.68$, $\eta_p^2 = .66$, and in the SRO condition (.66 vs. .36), $F(1, 42) = 45.17$, $\eta_p^2 = .52$. There was also a non-significant trend in the same direction in the unrelated condition (A-B, A-D_R = .40 vs. control = .21), $F(1, 18) = 3.57$, $p = .08$, $\eta_p^2 = .17$. However, both age groups did not appear to be sensitive to the interference effects that occurred in the absence of remindings. Confidence was significantly higher for A-B, A-D_{NR} than control items in the SRR condition (.44 vs. .32), $F(1, 46) = 18.05$, $\eta_p^2 = .28$, the SRO condition (.54 vs. .36), $F(1, 42) = 56.41$, $\eta_p^2 = .57$, and the unrelated condition (.34 vs. .22), $F(1, 18) = 6.70$, $\eta_p^2 = .27$. There was also a significant age X item type interaction in the SRO condition, $F(1, 42) = 4.81$, $\eta_p^2 = .10$, indicating that older adults postdicted larger facilitation effects on A-B, A-D_{NR} items than young adults. However, this interaction must be interpreted with caution because it is being driven more by differences in performance than differences in confidence.

Table 5. *Confidence Judgments for Recall of List 2 Responses as a Function of Item Type, Remindings, Association, and Age: Experiment 1*

	Item Type			
Age X Association	A-B, A-B	Control	A-B, A-D_R	A-B, A-D_{NR}
SRR				
Young (N = 32)	.64 (.04)	.35 (.03)	.76 (.05)	.50 (.03)
Older (N =16)	.54 (.05)	.28 (.04)	.74 (.06)	.40 (.05)
SRO				
Young (N = 26)	.74 (.03)	.45 (.03)	.72 (.06)	.58 (.04)
Older (N = 18)	.68 (.04)	.26 (.04)	.60 (.07)	.50 (.04)
Unrelated				
Young (N = 15)	.57 (.06)	.23 (.03)	.34 (.09)	.38 (.05)
Older (N = 5)	.55 (.10)	.21 (.06)	.46 (.16)	.30 (.09)

Note. A-B, A-D_R = A-B, A-D items on which remindings were reported; A-B, A-D_{NR} = A-B, A-D items on which remindings were not reported. The number of participants who produced at least one reminding are displayed in parentheses next to each association condition. Standard errors of the means are presented in parentheses next to confidence judgments.

The finding that participants were more confident in their recall of A-B, A-D_{NR} than control items could suggest that participants believed that those items produced facilitation effects. However, interpretation of these differences in confidence is also complicated by differences in cue-familiarity between A-B, A-D items and control items of the sort described earlier. One possibility is that judgments on A-B, A-D items overestimated the magnitude of facilitation effects when remindings did occur and masked participants' sensitivity to deleterious effects of response competition when remindings did not occur. Consequently, tests in which cue-familiarity is taken into account are needed to examine participants' sensitivity to these effects more closely.

To control for cue-familiarity, confidence was compared between items for which the stimulus term (A) was presented an equal number of times across lists (i.e., A-B, A-B items, A-B, A-D_R items, and A-B, A-D_{NR} items). Confidence was first compared for A-B, A-D_R and A-B, A-D_{NR} items to verify that participants were sensitive to the facilitative effects of remindings. Sensitivity to the effects of remindings was indicated by higher confidence for A-B, A-D_R items. Results revealed that confidence was higher for A-B, A-D_R than A-B, A-D_{NR} items in the SRR condition (.75 vs. .45), $F(1, 46) = 47.92$, $\eta_p^2 = .51$, and in the SRO condition (.66 vs. .54), $F(1, 42) = 6.79$, $\eta_p^2 = .14$. However, there was no reliable difference in confidence for A-B, A-D_R and A-B, A-D_{NR} items in the unrelated condition (.40 vs. .34), $F < 1$. These results indicate that participants were sensitive to the facilitative effects of remindings in the SRR and SRO conditions, but they did not postdict such effects in the unrelated condition. These evaluations were largely consistent with actual performance.

Confidence was then compared for A-B, A-D_{NR} and A-B, A-B items to examine whether participants were sensitive to the deleterious effects of response competition when remindings did not occur. Sensitivity to these effects was indicated by confidence being higher for A-B, A-B than A-B, A-D_{NR} items. Results revealed that participants were sensitive to performance being worse for A-B, A-D_{NR} than A-B, A-B items. Confidence was significantly higher for A-B, A-B than A-B, A-D_{NR} items in: the SRR condition (.59 vs. .45), $F(1, 46) = 24.50$, $\eta_p^2 = .35$, the SRO condition (.71 vs. .54), $F(1, 42) = 50.14$, $\eta_p^2 = .54$, and the unrelated condition (.56 vs. .34), $F(1, 18) = 13.37$, $\eta_p^2 = .43$.

Finally, confidence was compared for A-B, A-D_R and A-B, A-B items to examine participants' sensitivity to differences in the magnitude of facilitation effects produced by remindings and repetitions. Participants postdicted that the facilitation effects produced by remindings were larger than those produced by repetitions in the SRR condition as indicated by higher confidence in A-B, A-D_R than A-B, A-B items (.75 vs. .59), $F(1, 46) = 12.21$, $\eta_p^2 = .21$. In addition, participants did not postdict any differences between A-B, A-D_R and A-B, A-B items in the SRO condition (.66 vs. .71), or in the unrelated condition (.40 vs. .56), Fs < 1.77. These postdictions were consistent with actual patterns of performance with the exception of the unrelated condition. However, note that recall in the unrelated condition was better for A-B, A-B than A-B, A-D_R items, and that the numerical difference in confidence judgments was in the same direction.

Taken together, these results provide evidence that participants were aware of the benefits conferred by remindings.

Individual Differences in Remindings

Individual differences in remindings were examined using hierarchical multiple regression. The model included age, general memory ability, and remindings as predictor variables with performance on A-B, A-D items as the outcome variable. Age was entered on the first step by dummy coding young and older adults. General memory ability was entered on the second step as the probability of correct recall on control items. Remindings were entered on the third step as the probability that a List 1 response was reported as coming to mind prior to the response that was output as being from List 2 on A-B, A-D items. An omnibus test of double interaction terms was entered on the fourth step (i.e., age X general memory, age X remindings, and general memory X remindings), and the triple interaction term was entered on the fifth step (i.e., age X general memory X remindings).

The changes in explained variance on each step for each association condition are displayed in Table 6. Results revealed that age and general memory explained significant proportions of unique variance in all three association conditions. Evidence for individual differences in remindings was found in the SRR and SRO conditions as indicated by significant changes in explained variance. However, remindings did not account for variance beyond general memory in the unrelated condition. There were no significant interactions. These results showed that there were individual differences in remindings when associations were present. The finding that remindings did not account for variance in A-B, A-D items in the unrelated condition is not surprising given that remindings rarely occurred in that condition. Together, these results provide evidence that associations are important for the production of remindings and that there were individual differences in their strategic use.

Table 6. *Changes in Explained Variance as a Function of Association: Experiment 1*

	Association		
	SRR	SRO	Unrelated
Step 1			
Age	.13**	.10*	.12**
Step 2			
General Memory	.18**	.30**	.26**
Step 3			
Remindings	.18**	.21**	.01
Step 4			
Double Interactions	.05	.02	.01
Step 5			
Triple Interaction	.00	.00	.01

Note. ΔR^2 are displayed above.
$^{**}p < .005$, $^{*}p < .05$.

Summary

Results from Experiment 1 showed that young adults outperformed older adults in terms of overall recall performance. In addition, overall recall performance was higher in the SRO condition than in the SRR condition. One possibility is that the lower performance in the SRR condition was due to interference produced by the associations between responses. This finding is noteworthy because a mediation account would predict that associations between responses would facilitate recall resulting in higher performance in the SRR than SRO condition. More important, these results provide more support for the remindings account of the observed facilitation effects.

Remindings were reported more often by young than older adults and when associations were present rather than absent. However, older adults still produced as many extra-list responses prior to the response they output as did young adults. These findings indicate that older adults have the ability to produce remindings, but their remindings may be less well constrained to the context of the experiment. This difference in the ability to constrain retrieval is consistent with the notion that older adults do not use controlled processes as effectively as do young adults. These results suggest that older adults engaged in controlled remindings less often than young adults. However, both groups were able to produce remindings on the basis of automatic associations as shown by higher probabilities of remindings when associations were presented in the SRR and SRO conditions as compared to when stimulus and response terms were completely unrelated. Finally, there was no difference in the probability of remindings between SRR and SRO conditions suggesting that the mere presence of associations between stimuli and responses were sufficient for the production of remindings, whereas associations between responses did not seem to matter.

Remindings also produced large facilitation effects that sometimes exceeded those produced by repeating items across lists. There was a trend indicating that the size of these facilitation effects did not differ between SRR and SRO conditions for young adults, but were lower in the SRO than SRR condition for older adults. These findings suggest that the facilitation effects produced by remindings for older adults might depend on the strength pre-existing associations between responses, which is consistent with the notion of an associative deficit in older adults (e.g., Naveh-Benjamin, 2000). To examine this possibility further, I only included only items that fit the constraints of the SRO condition in Experiment 2.

Finally, confidence judgments showed that both young and older adults were generally sensitive to the effects of remindings and to the interference effects that occurred in their absence. Remindings were also shown to be more specific than general memory ability as indicated by individual differences in their use. The finding of individual differences in remindings is important because it indicates that differences in the extent to which they are employed in a controlled manner exist within age groups. More interesting, these differences may point to differences in the extent to which people tend to integrate information during learning.

Experiment 2

Results from Experiment 1 showed that young adults produced more remindings than did older adults. These results were attributed to older adults making less use of controlled remindings than young adults. However, given that older adults showed poorer overall recall performance, an alternative possibility is that the difference in remindings may have been due to differences in the extent to which young and older adults could remember the List 1 items (i.e., original learning). Experiment 1 also revealed a trend showing that the facilitation effects produced by remindings were smaller for older adults when stimuli were related to responses, but responses were not associated (SRO condition) as compared to when all terms were associated (SRR condition). In contrast, young adults showed similar benefits of remindings in each condition. One possibility is that older adults have a reduced ability to establish relationships between unrelated responses when remindings occur, which is consistent with the notion of an age-related associative deficit (e.g., Naveh-Benjamin, 2000). These issues were examined in Experiment 2.

The first aim of Experiment 2 was to replicate the finding that young adults produced more remindings than did older adults while controlling for age differences in original learning. Original learning was measured by testing recall of List 1 items in the second list prior to presenting the corresponding List 2 study items. List 1 items were presented either twice or six times which resulted in original learning being equated for young and older adults in the two and six presentation conditions, respectively. In addition, level of original learning was also controlled by examining List 2 recall conditionalized on the accuracy of List 1 recall. Items on which List 1 recall was correct represent instances in which original learning was observed as being similar for young and older adults. If age differences in remindings are due to differences in the use of controlled forms of memory, then young adults should still show a higher probability of remindings when controlling for original learning in the two ways described above.

The second aim was to examine age differences in the facilitation effects produced by remindings when stimuli are related to responses but when responses are not related to one another (i.e., the SRO condition). In Experiment 2, all items were constructed to fit the constraints of the SRO condition of Experiment 1. If older adults require more support from pre-existing associations than young adults to derive the benefits of remindings, then the facilitation effects produced by remindings should be smaller for older than young adults.

The final aims were to verify that young and older adults are sensitive to the effects of remindings using confidence judgments, and to show that remindings are distinct from general memory ability using hierarchical multiple regression.

Method

Participants

Thirty-six young adults (25 women, 11 men, M_{age} = 19.3 years, age range: 18-23 years), and 36 older adults (25 women, 11 men, M_{age} = 78.5, age range: 65-89 years) were recruited using the Washington University Department of Psychology participant pools for each respective age group. The compensation for young adults was course credit or \$10 per hour, and the compensation for older adults was \$10 per hour. The mean score on the Shipley vocabulary test was lower for young adults (M = 34.17, SD = 2.38) than for older adults (M = 35.83, SD = 2.68), $t(70) = -2.79$.

Design and Materials

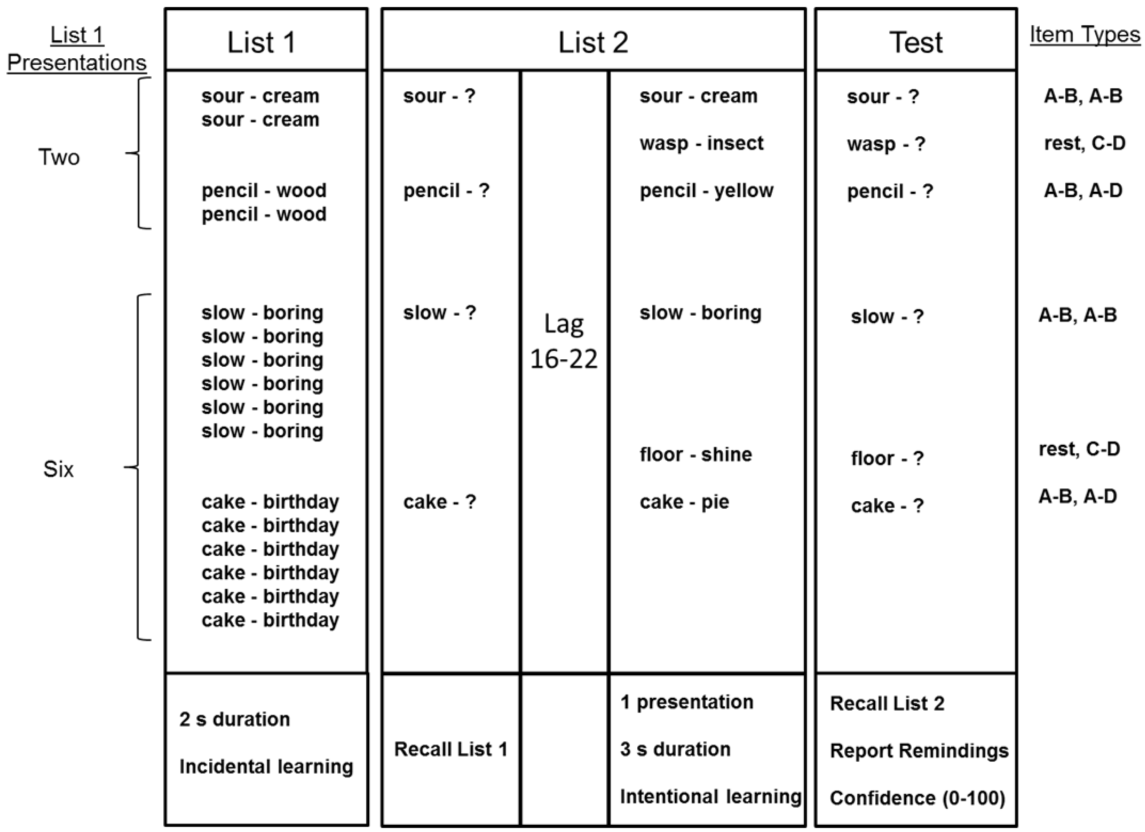
A 3(Item type: A-B, A-B vs. rest, C-D (control) vs. A-B, A-D) X 2(List 1 presentations: 2 vs. 6) X 2(Age: young vs. older) mixed design was used. Item type and List 1 presentations were manipulated within-participants, and age was a between-participants variable.

Materials consisted of three-word sets in which there were forward associations from stimuli to responses and no associations between responses (see Appendix), consistent with the SRO condition in Experiment 1 (e.g., nose-eye, snort). Ninety-six sets were divided into six groups of 16 sets. Each group contained 15 critical sets, and the remaining sets served as primacy and recency buffers. Each group was matched on average FAS from stimuli to responses (M = .04, SD = .02, range: .01-.10), and stimuli and responses in each group were matched on length (*M* = 4.94, *SD* = .26, range: 3-8 letters) as well as word frequency (*M* = 9.60, *SD* = 1.56, range: 1.11-14.35). Groups served equally often in each within-participant condition. The assignment of responses to lists was counterbalanced such that each response was presented equally often in each list across experimental formats. This resulted in 12 experimental formats.

Procedure

The procedure was identical to Experiment 1 with a few exceptions. During List 1, 64 word pairs were presented for 2 s each followed by a 500 ms ISI. Half of these pairs were presented twice and the other half were presented six times for a total of 256 presentations. In List 2, 96 word pairs were presented for 3 s each. Six pairs were used for primacy and recency buffers (two primacy, four recency), and the remaining 90 pairs were critical items. Memory for List 1 was tested during List 2 by presenting stimuli paired with question marks (e.g., nose - ?) prior to their corresponding List 2 pairs. The List 1 test items were printed in lowercase, white ink to match the format in which they were presented in List 1. Participants were told to recall the List 1 responses for these items. List 2 study items that corresponded to List 1 test items were then presented after a lag of 16-22 intervening items (*M* = 19.13, *SD* = 1.40). List 2 study items were capitalized and printed in yellow ink (e.g., NOSE-EYE) so that they could be distinguished from the List 1 test items. Participants were told to study these items for an upcoming memory test. On the final test, stimuli were capitalized and printed in yellow ink to match the format in which the items were studied in List 2 (e.g. NOSE - ?). Participants were told to recall the List 2 responses that had been presented in the same format. A schematic of the design, materials and procedure is presented below in Figure 4.

Figure 4. Schematic of the design, materials, and procedure in Experiment 2.



Results and Discussion

Overall List 2 Recall Performance

The pattern of overall recall performance for List 2 responses can be seen in Table 7. Given that control items were not subjected to the manipulation of List 1 presentations, comparisons among item types could not be made using an omnibus analysis of variance. Instead, three separate analyses were used to make the critical comparisons. To simplify the interpretation of the analyses the subscripts 2 and 6 were used to denote the number presentations that corresponded to each A-B item in List 1 (e.g., A-B_2, A-B = A-B, A-B items with two List 1 presentations; A-B_6, A-D = A-B, A-D items with six List 1 presentations, etc.)

Table 7. *Probability of Correct Recall of List 2 Responses as a Function of Item Type, List 1 Presentations, and Age: Experiment 2*

	Item Type		
Age X Presentations	A-B, A-B	Control	A-B, A-D
Young			
2 presentations	.81 (.03)	.38 (.02)	.46 (.03)
6 presentations	.86 (.03)	.38 (.02)	.40 (.03)
Older			
2 presentations	.55 (.04)	.21 (.02)	.25 (.02)
6 presentations	.64 (.04)	.21 (.02)	.18 (.02)

Note. Control items were not subjected to the List 1 presentation manipulation. Consequently, performance on control items is displayed twice for each age group (once for each presentation condition) for comparison with A-B, A-B and A-B, A-D items. Standard errors of the means are presented in parentheses.

First, overall age differences were examined by comparing performance for young and older adults averaged across item types. As found in Experiment 1, young adults outperformed older adults (.55 vs. .34), $t(70) = 7.24$. Second, the effects of varying List 1 presentations were examined by comparing performance on A-B, A-B and A-B, A-D items for young and older adults. Performance was higher on A-B, A-B than A-B, A-D items (.72 vs. .32), $F(1, 70) = 429.46$, $\eta_p^2 = .86$, and a significant item type X List 1 presentations interaction, $F(1, 70) = 25.98$, $\eta_p^2 = .27$, showed that performance was higher for A-B_6, A-B than A-B_2, A-B items (.75 vs. .68), $t(71) = 4.12$, whereas performance was higher for A-B_2, A-D than A-B_6, A-D items (.36 vs. .29), $t(71) = 3.73$. Third, the effects of repeating or varying responses between lists were examined by comparing performance on control items with A-B, A-B and A-B, A-D items separately for each List 1 presentations condition. Young adults' performance was higher for A-B_2, A-D items than for control items (.46 vs. .38), $t(35) = 2.79$. However, performance on the remaining A-B, A-D and A-B, A-B items did not differ from performance on control items, $ts(35) < 1.68$.

List 1 Recall Performance

As described in the introduction to Experiment 2, List 1 presentations were manipulated in attempt to equate levels of original learning of A-B, A-D items between age groups. Table 8 shows that overall List 1 recall performance was higher for young than older adults (.69 vs. .51), $F(1, 70) = 15.60$, $\eta_p^2 = .18$. Performance was also higher when items were presented six times as compared to twice (.70 vs. .50), $F(1, 70) = 168.39$, $\eta_p^2 = .71$. There was an unexpected item type X List 1 presentations interaction showing that the recall advantage for items presented six times was larger for those that eventually became A-B, A-B items (.73 vs. .49) rather than A-B, A-D items (.67 vs. .51), $F(1, 70) = 6.29$, $\eta_p^2 = .08$. It is unclear why this interaction was obtained given that the mean lags between List 1 tests and List 2 study items did not differ for the A-B_2, A-D and A-B_6, A-D items (18.56 vs. 18.31), $t < 1$, and because the assignment of items to conditions was counterbalanced. Finally, and most important, performance on eventual A-B, A-D items did not differ between young and older adults when List 1 responses were presented twice for young adults and six times for older adults (.59 vs. .59), $t < 1$.

Thus, the level of original learning was equated in these two conditions, which allowed for a more precise examination of age differences in remindings.

Table 8. *Probability of Correct Recall of List 1 Responses as a Function of Item Type, List 1 Presentations, and Age: Experiment 2*

	Item Type	
Age X Presentations	A-B, A-B	A-B, A-D
Young		
2 presentations	.59 (.04)	.59 (.04)
6 presentations	.82 (.03)	.75 (.04)
Older		
2 presentations	.40 (.04)	.43 (.04)
6 presentations	.64 (.03)	.59 (.04)

Note. Standard errors of the means are presented in parentheses.

Remindings

Table 9 displays the probabilities of words being reported as coming to mind prior to responses output as being from List 2 on A-B, A-D items. As in Experiment 1, remindings were defined as the probability of reporting that a List 1 came to mind first. Results revealed an effect of response type, $F(2, 140) = 55.99$, $\eta_p^2 = .44$, showing that List 1 responses were produced more often than extra-list responses (.22 vs. .15), $t(71) = 2.52$, and that extra-list responses were produced more often than List 2 responses (.15 vs. .01), $t(71) = 7.55$. An effect of age showed that more responses were reported as coming to mind first by young than older adults (.44 vs. .32), $t(70) = 2.56$. An age X response interaction, $F(2, 140) = 26.64$, $\eta_p^2 = .28$, qualified this effect by showing that young adults produced more List 1 responses than older adults (.32 vs. .12), $t(70) = 6.01$, whereas older adults produced more extra-list responses than young adults (.18 vs. .11), $t(70) = 2.27$. Young and older adults did not differ in the extent to which List 2 responses came to mind first (.01 vs. .02), $t < 1$. Finally, there was a List 1 presentations X response interaction, $F(2, 140) = 8.43$, $\eta_p^2 = .11$, showing that List 1 responses were produced more often with six than two List 1 presentations (.24 vs. .20), $t(71) = 3.12$, whereas the opposite was true for extra-list responses (six = .13 vs. two = .16), $t(71) = -2.01$. The production of List 2 responses did not differ as a function of List 1 presentations (.01 vs. .01), $t < 1$. Together these results indicated that young adults reported more remindings than older adults and that the probability of remindings increased with List 1 accessibility.

Table 9. *Probability of Responses Coming to Mind Prior to the Response Output on A-B, A-D Items as a Function of Response Type, List 1 Presentations, and Age: Experiment 2*

	Response Type		
Age X Presentations	List 1	List 2	Extra-List
Young			
2 presentations	.29 (.03)	.01 (.01)	.11 (.02)
6 presentations	.35 (.03)	.01 (.01)	.10 (.02)
Older			
2 presentations	.10 (.02)	.01 (.01)	.21 (.03)
6 presentations	.14 (.03)	.02 (.01)	.16 (.02)

Note. Standard errors of the means are presented in parentheses.

Age Differences in Remindings

Although the results above showed that young adults reported more remindings than older adults overall, the critical comparisons of age differences in remindings required controlling for differences in the level of original learning. This was accomplished in two ways. First, remindings were compared for young adults in the A-B_2, A-D condition and older adults in the A-B_6, A-D condition because List 1 recall performance did not differ between those conditions. Second, including a test of List 1 items allowed for a comparison of remindings when List 1 responses were correctly recalled. These items presumably represent instances in which the accessibility of List 1 responses was similar for young and older adults prior to the presentation of List 2 responses.

Results revealed that young adults reported more remindings than older adults when controlling for differences in original learning. This can be seen in Table 9 in that young adults reported more remindings in the A-B_2, A-D condition than older adults did in the A-B_6, A-D condition (.29 vs. .14), $t(70) = 3.78$. In addition, recall performance on the final test conditionalized on List 1 test accuracy revealed that young adults produced more remindings on items for which List 1 recall was correct than did older adults. Table 10 shows that for participants who produced at least one correct and one incorrect response on the test of List 1 items, remindings were reported more often when List 1 responses had been accurately recalled than when they had not (.31 vs. .02), $F(1, 63) = 174.90$, $\eta_p^2 = .74$, and that remindings were reported more often by young than older adults (.22 vs. .11), $F(1, 63) = 22.40$, $\eta_p^2 = .26$. More important, a significant age X List 1 accuracy interaction, $F(1, 63) = 31.91$, $\eta_p^2 = .34$, qualified these effects in showing that when List 1 responses were accurately remembered, young adults reported more remindings than older adults (.43 vs. .19), $t(63) = 5.28$, whereas there was no age difference in remindings reported when List 1 responses were not recalled (.01 vs. .03), *t*(63) = -1.58. Note that the rare occurrence of remindings when List 1 responses were not recalled on an earlier test is consistent with the idea that the accessibility of List 1 responses is critical for the occurrence of remindings.

Table 10.

Probability of List 1 Responses Coming to Mind Prior to the Response Output on A-B, A-D Items as a Function of List 1 Accuracy, List 1 Presentations, and Age: Experiment 2

	List 1 Accuracy	
Age X Presentations	Correct	Incorrect
Young (N = 32)		
2 presentations	.43 (.04)	.02 (.01)
6 presentations	.43 (.03)	.01 (.01)
Older (N = 33)		
2 presentations	.19 (.04)	.02 (.01)
6 presentations	.20 (.03)	.04 (.01)

Note. Standard errors of the means are presented in parentheses.

List 2 Recall Conditionalized on Remindings

As in Experiment 1, recall performance on A-B, A-D items was interpreted by examining performance conditionalized on the occurrence of remindings. Table 11 displays List 2 recall for the participants who produced at least one reminding in both List 1 presentation conditions. Given that the control condition was not subjected to the List 1 presentations manipulation, comparisons of recall on A-B, A-D and control items were made separately for List 1 presentation conditions. The order of comparisons followed that of Experiment 1. Age differences redundant with those reported for overall recall performance are not reported here.

Table 11. *Probability of Correct Recall of List 2 Responses as a Function of Item Type, Remindings, List 1 Presentations, and Age: Experiment 2*

	Item Type			
	A-B, A-B	Control	A-B, A-D_R	A-B, A-D_{NR}
Young (N = 34)				
2 presentations	.83 (.03)	.38 (.02)	.80 (.05)	.32 (.03)
6 presentations	.88 (.03)	.38 (.02)	.82 (.05)	.18 (.02)
Older (N = 19)				
2 presentations	.61 (.04)	.24 (.03)	.47 (.07)	.25 (.04)
6 presentations	.68 (.04)	.24 (.03)	.48 (.07)	.16 (.03)

Note. A-B, A-D_R = A-B, A-D items on which remindings were reported; A-B, A-D_{NR} = A-B, A-D items on which remindings were not reported. The number of participants who produced at least one reminding are displayed in parentheses next to each association condition. Performance on control items is presented twice for each age group because those items were not subjected to the List 1 presentations manipulation. Standard errors of the means are presented in parentheses next to correct recall probabilities.

The potential benefits of remindings were examined first. An initial analysis revealed that recall performance on A-B, A-D_R items did not differ between the two and six List 1 presentation conditions for either age group (.63 vs. .65), $F < 1$. These results indicated that the number of List 1 presentations did not impact the benefits of remindings on recall performance. However, young adults showed higher recall on A-B, A-D_R items than older adults (.81 vs. .48), $F(1, 51) = 20.43$, $\eta_p^2 = .29$, indicating that remindings benefitted recall performance more for young than older adults. This suggestion was examined further by comparing differences in recall of A-B, A-D_R and control items for young and older adults. Performance on A-B, A-D_R items was collapsed across List 1 presentation conditions because recall performance did not differ between those conditions. Results revealed higher performance on A-B, A-D_R than control items for both age groups (.64 vs. .31), $F(1, 51) = 105.21$, $\eta_p^2 = .67$. Further, a significant interaction showed that remindings produced a larger difference in performance between A-B, A-D_R and control items for young adults (.81 vs. .38) than for older adults (.48 vs. .24), $F(1, 51) = 8.61$, $\eta_p^2 = .14$. These results replicate Experiment 1 in showing that remindings facilitated performance on A-B, A-D items. More interesting, perhaps, was that the magnitude of facilitation effects did not differ as a function of number of presentations in List 1; however, remindings facilitated recall more for young than older adults when the responses were not associated.

The potential negative consequences of response competition created by changing responses between lists on A-B, A-D items in the absence of remindings were examined next. An initial analysis revealed that recall was higher when List 1 responses were presented twice as compared to six times for both age groups (.28 vs. .17), $F(1, 51) = 14.31$, $\eta_p^2 = .22$. Consequently, differences in recall performance between A-B, A-D_{NR} and control items were examined separately for each List 1 presentation condition using analyses that included both age groups. Results revealed that for the analysis that included A-B, A-D items with two List 1 presentations, performance did not differ from control items, $F < 1$. In contrast, the same comparison in the analysis that included A-B, A-D items with six List 1 presentations revealed that performance was lower than on control items for both age groups (.17 vs. .31), $F(1, 51) = 29.98$, $\eta_p^2 = .37$. Although older adults showed lower overall performance as compared to young adults (.20 vs. .28), *F*(1, 51) = 7.46, η_p^2 = .13, the interference effects observed were larger for young than for older adults (see Table 10), *F*(1, 51) = 5.38, η_p^2 = .10. These results show that in the absence of remindings, interference effects were not obtained when List 1 responses were presented twice, whereas interference effects were obtained when List 1 response were presented six times.

The magnitude of the facilitation effects produced by remindings was again compared to those produced by repeating items across lists by examining differences in recall performance between A-B, A-D_R and A-B, A-B items for young and older adults. Results revealed that overall recall performance was higher for A-B, A-B than A-B, A-D_R items (.75 vs. .64), *F*(1, 51) = 15.19, η_p^2 = .23. This effect was qualified by a significant age X item type interaction, *F*(1, 51) = 4.76, η_p^2 = .09, showing that young adults' recall performance did not differ for A-B, A-B and A-B, A-D_R items (.86 vs. .81), *t*(33) = 1.68, whereas older adults' recall performance was higher for A-B, A-B than A-B, A-D_R items (.65 vs. .48), *t*(18) = 3.10. These results show that the magnitude of facilitation effects produced by remindings and repetitions did not differ for young adults, whereas repetitions produced larger facilitation effects than remindings for older adults.

Confidence Judgments

Confidence judgments were examined in a manner similar to that in Experiment 1. Confidence was first examined for all items (Table 12) and then for items conditionalized on remindings (Table 13). The analyses of overall confidence were the same as those used to examine overall recall performance. First, confidence was higher for young than older adults (.59 vs. .49), *t*(70) = 3.30. Second, analysis of the effects of List 1 presentations revealed that confidence was higher for A-B, A-B than A-B, A-D items (.66 vs. .58), $F(1, 70) = 55.21$, $\eta_p^2 = .44$, and higher when List 1 items were presented six times as compared to twice (.64 vs. .60), $F(1, 70) = 16.54$, $\eta_p^2 = .19$. Third, analysis of the effects of repeating or varying responses between lists showed that confidence was higher for all A-B, A-B and A-B, A-D items than control items, $ts(35) > 8.47$.

Table 12. *Confidence Judgments for Recall of List 2 Responses as a Function of Item Type, List 1 Presentations, and Age: Experiment 2*

	Item Type		
Age X Presentations	A-B, A-B	Control	A-B, A-D
Young			
2 presentations	.70 (.03)	.43 (.02)	.61 (.02)
6 presentations	.73 (.03)	.43 (.02)	.65 (.02)
Older			
2 presentations	.58 (.03)	.36 (.02)	.51 (.02)
6 presentations	.62 (.03)	.36 (.02)	.55 (.03)

Note. Control items were not subjected to the List 1 presentation manipulation. Consequently, confidence on control items is displayed twice for each age group. Standard errors of the means are presented in parentheses.

Overall confidence judgments were somewhat consistent with patterns of actual recall performance; however, there were some exceptions. Recall performance was higher when A-B, A-D items included two rather than six List 1 presentations, but the pattern of confidence was in the opposite direction. This likely reflects the difference in cue familiarity produced by additional repetitions of A-B items in List 1. In addition, recall of A-B_2, A-D items was higher than control items, whereas confidence for A-B, A-D items in both List 1 presentations conditions was higher than for control items. This difference also likely reflects differences in cue familiarity due to stimuli being repeated across lists for A-B, A-D items, but not for control items. This difference might also reflect sensitivity to the facilitative effects of remindings that occurred for some of the A-B, A-D items.

Sensitivity to the effects of remindings was directly examined by conditionalizing analyses of confidence on the occurrence of remindings on A-B, A-D items (Table 13). As in Experiment 1, sensitivity to the facilitation effects produced by remindings was examined by first comparing A-B, A-D_R to control items, and sensitivity to the interference effects that occurred in the absence of remindings was examined by first comparing A-B, A-D_{NR} to control items.

Table 13. *Confidence Judgments for Recall of List 2 Responses as a Function of Item Type, Remindings, List 1 Presentations, and Age: Experiment 2*

	Item Type			
	A-B, A-B	Control	A-B, A-D_R	A-B, A-D_{NR}
Young (N = 34)				
2 presentations	.71 (.03)	.43 (.02)	.79 (.03)	.54 (.02)
6 presentations	.74 (.02)	.43 (.02)	.82 (.03)	.57 (.02)
Older (N = 19)				
2 presentations	.63 (.05)	.38 (.04)	.60 (.06)	.48 (.03)
6 presentations	.65 (.05)	.38 (.04)	.61 (.07)	.56 (.04)

Note. A-B, A-D_R = A-B, A-D items on which remindings were reported; A-B, A-D_{NR} = A-B, A-D items on which remindings were not reported. The number of participants who produced at least one reminding are displayed in parentheses next to each association condition. Confidence on control items is presented twice for each age group because those items were not subjected to the List 1 presentations manipulation. Standard errors of the means are presented in parentheses next to confidence judgments.

Preliminary examination of confidence on A-B, A-D_R items revealed no differences between List 1 presentations conditions for either age group, $F < 1$. Consequently, confidence on A-B, A-D_R items was collapsed across List 1 presentation conditions for comparison with control items. Results revealed that confidence was higher for A-B, A-D_R than control items (.71 vs. .40), $F(1, 51) = 159.24$, $\eta_p^2 = .76$, and this difference was larger for young than older adults, $F(1, 51) = 8.79$, $\eta_p^2 = .15$. Although confidence on A-B, A-D_R items did not differ between List 1 presentations conditions, confidence on A-B, A-D_{NR} items did reveal differences. Confidence on A-B, A-D_{NR} items was higher when there were six rather than two List 1 presentations (.57 vs. .51), $F(1, 51) = 7.27$, $\eta_p^2 = .13$, and this effect did not interact with age, $F(1, 51) = 2.15$, $\eta_p^2 = .04$. Together, these results show that participants were sensitive to the facilitative effects of remindings. However, as in Experiment 1, this analysis did not reveal sensitivity to interference effects produced by the absence of remindings, perhaps due to differences in cue familiarity.

To control for differences in cue familiarity across item types, only items for which the stimulus term (A) had been repeated between lists (i.e., A-B, A-B and A-B, A-D items) were included in the following analyses. The comparisons made between item types were the same as those made in the corresponding analysis of results from Experiment 1. Sensitivity to the facilitative effects of remindings was examined while controlling for cue familiarity by comparing confidence on A-B, A-D_R and A-B, A-D_{NR} items. Results revealed that confidence was higher for A-B, A-D items on which remindings were reported (.71 vs. .54), $F(1, 51) = 63.48$, $\eta_p^2 = .56$. In addition, there was a significant item type X age interaction, $F(1, 51) = 15.04$, $\eta_p^2 = .23$, showing that this difference was larger for young (.81 vs. .56), $t(33) = 13.63$, than older adults (.61 vs. .52), $t(18) = 1.87$ (*significant with a one-tailed test*). These results are consistent with actual performance in that recall was higher for A-B, A-D_R than A-B, A-D_{NR} items, and young adults showed larger facilitation effects than older adults.

Confidence was then compared for A-B, A-D_{NR} and A-B, A-B items to examine sensitivity to the interference effects produced in the absence of remindings while controlling for cue familiarity. Results showed that participants were indeed sensitive to interference effects in that confidence was higher for A-B, A-B than A-B, A-D_{NR} items (.68 vs. .54), $F(1, 51) = 113.17$, $\eta_p^2 = .69$. However confidence was also higher on items for which List 1 pairs were presented six times as compared to twice (.63 vs. .59), $F(1, 51) = 6.93$, $\eta_p^2 = .12$, which again can be attributed to differences in cue familiarity.

Finally, sensitivity to differences in facilitation produced by repetitions and remindings was examined by comparing confidence on A-B, A-D_R and A-B, A-B items. Young adults postdicted facilitation effects produced by remindings to be larger than those produced by repetitions, whereas older adults postdicted no difference in the size of the facilitation effects. This was shown by an item type X age interaction, $F(1, 51) = 6.25$, $\eta_p^2 = .11$, in which confidence for young adults was higher for A-B, A-D_R than A-B, A-B items (.81 vs. .72), $t(33) = 4.13$, whereas older adults' confidence trended in the reverse direction (.61 vs. 64), $t < 1$. These judgments were inconsistent with actual performance in that there was no difference in facilitation effects produced by repetitions and remindings for young adults, and remindings produced smaller facilitation effects than repetitions for older adults.

Individual Differences in Remindings

Individual differences in remindings were examined using hierarchical multiple regression with the same variables and order of entry as in Experiment 1. The changes in explained variance on each step for each List 1 presentation condition are displayed in Table 14. Results revealed that age and general memory explained significant proportions of unique variance in both List 1 presentation conditions. Evidence for individual differences in remindings was also found in both List 1 presentation conditions as indicated by significant changes in explained variance. There were no significant interactions. These results replicate results from Experiment 1 in showing individual differences in remindings when associations were present.

Table 14. *Changes in Explained Variance as a Function of List 1 Presentations: Experiment 2*

	List 1 Presentations	
	Two	Six
Step 1		
Age	.31**	.34**
Step 2		
General Memory	.09**	.18**
Step 3		
Remindings	.17**	.11**
Step 4		
Double Interactions	.02	.01
Step 5		
Triple Interaction	.01	.01

Note. ΔR^2 are displayed above.
**$p < .005$, *$p < .05$.

Summary

As in Experiment 1, results from Experiment 2 showed that recall performance was higher for young than older adults. More important, the probability of remindings was also higher for young than older adults, even when controlling for the level of original learning. These results are consistent with the suggestion that age differences in remindings are due to differences in the use of controlled forms of memory, because older adults showed fewer remindings when the associations among items was held constant across age groups. In addition, the facilitative effects of remindings were larger for young than older adults, which is consistent with the idea that the benefits of remindings depend more heavily on the pre-existing associations between responses for older adults. Along these lines, remindings produced facilitation effects that were similar in magnitude to those produced by repetitions for young adults, whereas repetitions produced larger facilitation effects than remindings for older adults. Also, as in Experiment 1, both young and older adults were generally sensitive to the facilitation effects produced by remindings and the interference effects that occurred in the absence of remindings. Finally, individual differences in the controlled use of remindings were revealed in that the probability of remindings varied across participants, even though there were no associations between responses. Further, the variability in remindings predicted differences in final recall performance on A-B, A-D items beyond differences in general memory ability, showing remindings to be a more specific memory strategy.

General Discussion

Results from the current experiments showed that remindings produced facilitation effects in PI situations, and that interference effects were obtained only in the absence of remindings. Young adults produce more remindings than older adults, and both groups produced more remindings when associations were present rather than absent. Remindings enhanced memory performance for both age groups, but older adults showed fewer benefits when responses were not associated. Remindings were shown to be more specific than general memory ability, and individual differences in their use provided evidence that they could be cognitively controlled. Finally, both age groups were sensitive to the effects of remindings.

Remindings in Paired-Associate Learning

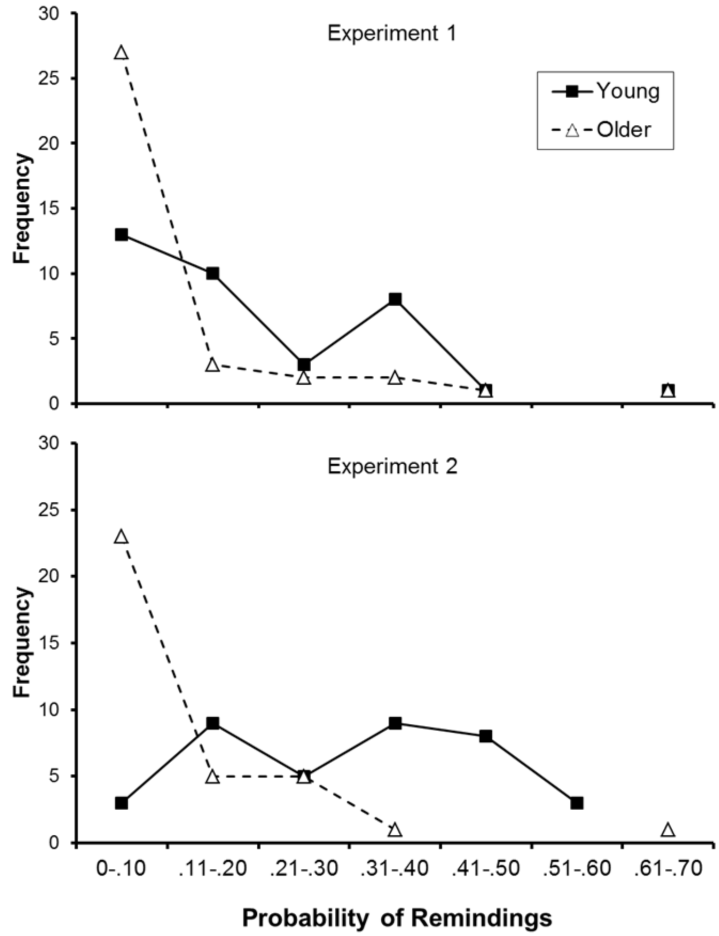
As pointed out by Wahlheim and Jacoby (submitted), results showing facilitation and interference effects in A-B, A-D paradigms converge with results from earlier studies on interference effects in paired-associate learning. For example, Barnes and Underwood (1959) showed that facilitation or interference effects could be obtained in a retroactive memory situation by varying the associations between responses. In addition, Postman (1964) showed that associations were important for producing positive transfer, but positive transfer could also be produced in the absence of associations when participants were given several experiences with the task. The current results go a step further by showing that associations have their effects on memory performance through the production of remindings, and that remindings can also occur when responses are not associated via controlled retrieval processes. Thus, facilitation effects in A-B, A-D paradigms can result from controlled and automatic remindings.

Considering the influence of remindings in the context of A-B, A-D paradigms also provides insight into age differences in the effects of interference. For example, Freund and Witte (1976) showed that when responses were low associates, older adults showed negative transfer whereas young adults' performance did not differ from a control group. These results might be due differences in the production of remindings for young and older adults. Specifically, older adults may have produced fewer remindings than young adults, resulting in poorer performance relative to controls. In addition, this difference points to age differences in the use of controlled remindings because the same items were presented to each group, likely producing similar influences of automatic associations. Finally, age differences in interference effects could be examined more precisely in future studies by accounting for differences in remindings and their effects in conditions that produce interference.

Individual Differences in Remindings

Individual differences in the probability of remindings were found in the current experiments, which is consistent with the results of Wahlheim and Jacoby (submitted). Figure 5, displayed below, shows that there was variability in the probability of remindings, and this variability was greater for young than older adults. This variability may indicate differences in people's general ability to integrate information. If so, individual differences in remindings may correlate with other measures that assess integration of information.

Figure 5. *Individual differences in the probability of remindings as a function of age in Experiments 1 (top panel) and 2 (bottom panel). Remindings from Experiment 1 included only the SRR and SRO conditions because there were no differences in remindings between these two conditions and because few remindings were produced in the unrelated condition.*



An example of correlated measures thought to tap into integration processes was shown by Potts and Peterson (1985) in that performance on a linear ordering task in which participants were required to integrate real world knowledge with relational information about artificial terms learned in the lab correlated well with performance on a lexical decision task that was considered a measure of comprehension. For the lexical decision task, participants read stories including conceptual information about unfamiliar animals and their environment (e.g., a rare flightless bird from New Zealand called the *tahake* and its primary predator, the *stoat*). To examine the extent to which participants were able to integrate these new concepts into their semantic networks using a lexical decision task, the unfamiliar terms from the stories appeared along with familiar words that were unrelated to the story context as well as pronounceable nonwords. In addition, the context in which the words appeared was varied to be consistent or inconsistent with the critical unfamiliar words (e.g., *tahake, stoat*). Context was primed by presenting only non-critical words in the initial blocks prior to presenting the critical words in later blocks. In a story context condition, the words in the initial blocks were taken from the story, whereas in a nonstory context condition, the initial words were not included in the story.

The extent to which new concepts were integrated with pre-existing knowledge in the lexical decision task was revealed by faster reaction times to critical unfamiliar words in the story context condition than in the nonstory context condition. In addition, results showed that this difference was larger for participants who failed to use real word knowledge on a linear ordering task than for those who did use real world knowledge, indicating that both measures tapped into the integration of new information with existing knowledge. Finding correlations such as these between remindings and other tasks that tap into integration processes would provide more support for the notion that remindings serve to integrate and organize information. Further, the finding that remindings are produced less often by older adults might point to a deficit in integration and organizational processes.

Age Differences in Organization

Age differences in organization have been examined in a variety of tasks using many different measures. Organization is commonly measured in tasks in which participants study lists of exemplars from various categories by examining the extent to which exemplars from the same category are clustered together during recall (e.g., Roenker, Thompson, & Brown, 1971). This type of organization has been referred to as categorical organization, and there is mixed evidence regarding whether age differences exist because there is little consensus about which measure of organization is most appropriate (Kausler, 1994). However, studies of subjective organization have shown more convincing evidence for age differences in organization.

Subjective organization refers to participants' ability to establish relationships among unrelated items resulting in unitized representations (e.g., Tulving, 1962). A study by Witte, Freund, and Sebby (1990) showed that young adults had higher subjective organization scores in free recall of unrelated items than older adults across five measures of organization. This showed that young adults could more effectively establish relationships between unrelated items than older adults. These results are consistent with the finding in the current experiments that older adults benefitted less from remindings than young adults when responses were unrelated (i.e., the SRO condition). In addition, these results suggest that older adults are less likely to organize information in a way that facilitates recall as effectively as done by young adults even when they are reminded, which is consistent with the notion of an age-related associative deficit (e.g., Naveh-Benjamin, 2000).

Given that measures of categorical organization do not always converge, measures of subjective organization seem more appropriate for examining age differences in organizational processes. The findings that older adults show less subjective organization and that they benefit less from remindings when responses are unrelated indicate that remindings tap into organizational processes. In this vein, a remindings measure might be useful as an alternative measure of subjective organization because individual differences in remindings were shown to correlate positively with memory performance, which is the same way that measures of organization correlate with memory performance.

Age Differences in Order Memory

Remindings enhance memory performance in PI situations because they preserve the temporal order of responses. The finding that older adults produced fewer remindings than young adults in the current experiments explains age differences in performance in these situations and is consistent with research showing age-related deficits in memory for temporal order. For example, McCormack (1982) showed that young adults made more accurate recency judgments than older adults, and the magnitude of these effects did not differ as a function of the lag between items. In addition, Zacks (1982) found that older adults performed worse than young adults in a "keeping track" task in which participants studied multiple category exemplars and were asked to recall the most recently presented exemplar when given a category label at test. Zacks also found that these age differences could be attributed to differences in the use of active versus passive strategies. Specifically, older adults used active strategies less often then young adults. Given that memory for temporal order is preserved by remindings (e.g., Winograd & Soloway, 1985), the results from these studies provide evidence for a remindings deficit in older adults. Further, the notion that this deficit can be attributed to differences in the use of active strategies is consistent with the possibility suggested earlier that older adults engage in controlled remindings less often than young adults. This possibility should be tested in future studies.

Evidence showing that age related deficits in remindings can be attributed to differences in the use of controlled processes can also be found in the literature on memory differences between amnesics and healthy adults. The impairments in memory performance suffered by amnesics often have larger deleterious effects on controlled as compared to automatic processes (e.g., Schacter, 1987). This has been shown in studies examining differences in recognition memory and memory for temporal order. For example, Hirst and Volpe (1982) found no difference in recognition memory for unrelated news events between amnesics and healthy adults, presumably because recognition memory decisions could be based largely on automatic processes (i.e., familiarity). However, healthy adults' memory for temporal order was equal to their recognition memory, whereas amnesics performance on recency judgments was at chance. These results suggest that healthy adults were able to use controlled remindings to preserve the temporal order of the events, whereas amnesics were not able to do so. Together, results from the aging and amnesic literatures are consistent with the notions that remindings preserve temporal order and that remindings can be cognitively controlled.

Remindings, Metacognition, and Memory Training

A common theme in the metacognition literature is that people monitor the accuracy of their memories and then control future actions on the basis of their monitoring (e.g., Nelson & Narens, 1990). As mentioned earlier, older adults have been shown to monitor their memory performance as accurately as young adults. However, despite their intact monitoring ability, older adults show a deficit in their ability to use that information to control future behaviors (e.g., Dunlosky & Connor, 1997). One possibility is that older adults may be aware of the benefits of remindings, but they do not initiate controlled remindings as often as do young adults. This possibility has implications for training regimens aimed at improving older adults' memory performance under conditions of interference.

Training interventions aimed at improving older adults' memory performance have done so by increasing the extent to which their memory decisions are based on controlled processes such as recollection (e.g., Jennings & Jacoby, 2003). Similarly, training older adults to use controlled remindings may improve their performance in tasks that produce interference effects. Recent work by Jacoby, Wahlheim, Rhodes, Daniels, and Rogers (2010) has shown that the effects of PI could be diminished through experience with PI and feedback. In a follow-up study, Wahlheim and Jacoby (2011) replicated these effects with young adults and showed that the underlying mechanisms were enhanced encoding and retrieval processes that served to increase reliance on recollection as a basis for retrieval and for metacognitive judgments. Enhanced recollection was shown to constrain retrieval to the appropriate source of information more effectively which produced better list differentiation.

Results such as these are consistent with the notion that PI effects can be diminished by encapsulating distinct learning events (e.g., Szpunar, McDermott, & Roediger, 2008). However, it is also possible that effective integration of events could have similar effects when remindings preserve the temporal order of information. Future studies should be designed to examine the interplay between list differentiation produced by encapsulation and list integration produced by remindings in diminishing the effects of PI. Studies such as these may be informative as to which is a more effective means by which to diminish older adults' susceptibility to interference effects.

Concluding Comments

Age differences in memory performance have been investigated by comparing young and older adults' performance in various memory tasks. Although this approach has improved our understanding of the specific types of age differences that exist, it has had the unfortunate effect of producing many accounts to explain differences in each task. A more parsimonious approach to understanding age differences in memory performance would be to establish unifying constructs that can account for differences across a variety of tasks. The current experiments take a step in this direction by showing that age differences in remindings can explain differences in performance in tasks designed to investigate interference effects, memory for temporal order, organization, etc. Future research should continue along these lines so as to explore the role that remindings play in various memory tasks and in age differences in memory in general.

References

Anderson, M. C., & Neely, J. H. (1996). Interference and inhibition in memory retrieval. In E. L. Bjork & R. A. Bjork (Eds.), *Handbook of perception and cognition (2nd ed.): Memory* (pp. 237-313). San Diego, CA: Academic Press.

Arenberg, D. (1967a). Regression analyses of verbal learning on adult age differences at two anticipation intervals. *Journal of Gerontology, 22*, 88-91.

Arenberg, D. (1968b). Retention of time judgment in young and old adults. *Journal of Gerontology, 23*, 35-40.

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

Balota, D. A., Watson, J. M., Duchek, J. M., & Ferraro, F. R. (1999). Cross-modal semantic and homographic priming in healthy young, healthy old, and in Alzheimer's disease individuals. *Journal of the International Neuropsychological Society, 5*, 626-640.

Barnes, J. M., & Underwood, B. J. (1959). "Fate" of first-list associations in transfer theory. *Journal of Experimental Psychology, 58*, 97-105.

Benjamin, A. S., & Ross, B. H. (in press). The causes and consequences of reminding. In A. S. Benjamin (Ed.), *Successful remembering and successful forgetting: A Festschrift in honor of Robert A. Bjork.* New York, NY: Psychology Press.

Benjamin, A. S., & Tullis, J. (in press). What makes distributed practice effective? *Cognitive Psychology.*

Cameron, D. E. (1943). Impairment at the retention phase of remembering. *Psychiatric Quarterly, 17*, 395-404.

Craik, F. I. M., & Jennings, J. M. (1992). Human memory. In T. A. S. Fergus I. M. Craik (Ed.), The handbook of aging and cognition. (pp. 51-110): Lawrence Erlbaum Associates, Inc, Hillsdale, NJ, US.

Crowder, R. G. (1976). *Principles of learning and memory.* Hillsdale, NJ: Erlbaum.

Dallett, K. M., & D'Andrea, L. (1965). Mediation instructions versus unlearning instructions in the A-B, A-C paradigm. *Journal of Experimental Psychology, 69*, 460-466.

Dunlosky, J., & Connor, L.T. (1997). Age differences in the allocation of study time account for age differences in memory performance. *Memory & Cognition, 25*, 691-700.

Dunlosky, J., & Hertzog, C. (1998). Aging and deficits in associative memory: What is the role of strategy production? *Psychology and Aging, 13*, 597-607.

Dunlosky, J., & Hertzog, C. (2001). Measuring strategy production during associative learning: The relative utility of concurrent versus retrospective reports. *Memory & Cognition, 29*, 247-253.

Dunlosky, J., Hertzog, C., & Powell-Moman, A. (2005). The contribution of mediator-based deficiencies to age differences in associative learning. *Developmental Psychology, 41*, 389-400.

Ebert, P. L., & Anderson, N. D. (2009). Proactive and retroactive interference in young adults, healthy older adults, and older adults with amnestic mild cognitive impairment. *Journal of the International Neuropsychological Society, 15*, 83-93.

Freund, J. S., & Witte, K. L. (1976). Paired-associate transfer: Age of subjects, anticipation interval, association value, and paradigm. *American Journal of Psychology, 89*, 695-705.

Gladis, M., & Braun, H. (1958). Age differences in transfer and retroaction as a function of intertask response similarity. *Journal of Experimental Psychology, 55*, 25-30.

Hall, J. F. (1971) *Verbal learning and retention.* Philadelphia, PA: Lippincott.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. G. Bower (Ed.), The psychology of learning and motivation (Vol. 22, pp. 193-225). San Diego, CA: Academic Press.

Hay, J. F., & Jacoby, L. L. (1999). Separating habit and recollection in young and older adults: Effects of elaborate processing and distinctiveness. *Psychology and Aging, 14*, 122-134.

Hintzman, D. L. (in press). Research strategy in the study of memory: Fads, fallacies, and the search for the "coordinates of truth." *Perspectives on Psychological Science.*

Hintzman, D. L. (2004). Judgment of frequency versus recognition confidence: Repetition and recursive reminding. *Memory & Cognition, 32*, 339-350.

Hintzman, D. L., Summers, J. J., & Block, R. A. (1975a). Spacing judgments as an index of study-phase retrieval. *Journal of Experimental Psychology: Human Learning and Memory, 1*, 31-40.

Hulicka, I. M., & Grossman, J. L. (1967). Age-group comparisons for the use of mediators in paired associate learning. *Journal of Gerontology, 22*, 46-51.

Hulicka, I. M. (1967). Age differences in retention as a function of interference. *Journal of Gerontology, 22*, 180-184.

Hultsch, D. F., & Dixon, R. A. (1989). Learning and memory and aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of psychology and aging. 3rd. ed.*. New York: Van Nostrand Reinhold.

Hirst, W., & Volpe, B. T. (1982). Temporal order judgments with amnesia. *Brain and Cognition, 1*, 294-306.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*, 306-340.

Jacoby, L. L. (1974). The role of mental contiguity in memory: Registration and retrieval effects. *Journal of Verbal Learning and Verbal Behavior, 13*, 483-496.

Jacoby, L. L. (1999). Ironic effects of repetition: Measuring age-related differences in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*, 3-22.

Jacoby, L. L., Debner, J. A., & Hay, J. F. (2001). Proactive interference, accessibility bias, and process dissociations: Valid subjective reports of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 686-700.

Jacoby, L. L., Wahlheim, C. N., Rhodes, M. G., Daniels, K. A., & Rogers, C. S. (2010). Learning to diminish the effects of proactive interference: Reducing false memory for young and older adults. *Memory & Cognition, 38*, 820-829.

James, W. (1890). *Principles of psychology.* Dover.

Jennings, J. M., & Jacoby, L. L. (2003). Improving memory in older adults: Training recollection. *Neuropsychological Rehabilitation, 13*, 417-440.

Johnson, M. K., Reeder, J. A., Raye, C. L., & Mitchell, K. J. (2002). Second thoughts versus second looks: An age-related deficit in reflectively refreshing just-activated information. *Psychological Science, 13*, 64-67.

Kausler, D. H. (1994). *Learning and Memory in Normal Aging.* New York: Academic Press.

Kay, H. (1951). Learning of a serial task by different age groups. *Quarterly Journal of Experimental Psychology, 3*, 166-183.

Kliegl, R., & Lindenberger, U. (1988, April). *Age related intrusion errors in cued recall.* Paper presented at the Second Cognitive Aging Conference, Atlanta, GA.

Lair, C. V., Moon, W. H., & Kausler, D. H. (1969). Associative interference in the paired-associate learning of middle-aged and old subjects. *Developmental Psychology, 1*, 548-552.

Light, L. L., Prull, M. W., La Voie, D. J., & Healy, M. R. (2000). Dual-process theories of memory in old age. In T. J. Perfect & E. A. Maylor (Eds.) *Models of cognitive aging* (pp. 238-300). New York, NY: Oxford University Press.

Lustig, C., May, C. P., & Hasher, L. (2001). Working memory span and the role of proactive interference. *Journal of Experimental Psychology: General, 130*, 199-207.

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review, 87*, 252-271.

McCormack, P. D. (1982). Temporal coding and study-phase retrieval in young and elderly adults. *Bulletin of the Psychonomic Society, 20*, 242-244.

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 26*, 1170-1187.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. http://www.usf.edu/FreeAssociation/.

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and some new findings. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 26, pp. 125-173). San Diego: Academic Press.

Osgood, C. E. (1949). The similarity paradox in human learning: A resolution. *Psychological Review, 56*, 132-143.

Postman, L. (1964). Studies of learning to learn II. Changes in transfer as a function of practice. *Journal of Verbal Learning and Verbal Behavior, 3*, 437-447.

Potts, G. R., & Peterson, S. B. (1985). Incorporation versus compartmentalization in memory for discourse. *Journal of Memory and Language, 24*, 107-118.

Roediger, H. L., & Karpicke, J. D. (2006a). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science, 1*, 181 – 210.

Roenker, D. L., Thompson, C. P., & Brown, S. C. (1971). Comparison of measures for the estimation of clustering in free recall. *Psychological Bulletin, 76*, 45-48.

Rowe, E. J., & Schnore, M. M. (1971). Item concreteness and reported strategies in paired-associate learning as a function of age. *Journal of Gerontology, 26*, 470-475.

Schacter, D. L. (1987). Memory, amnesia, and frontal lobe dysfunction. *Psychobiology, 15*, 21-36.

Suci, G. H., Davidhoff, M. D., & Brown, J. C. (1962). Interference in short-term retention as a function of age. In C. Tibbitts & W. Donahue (Eds.), *Social and psychological aspects of aging.* New York: Columbia University Press.

Szpunar, K. K., McDermott, K. B., & Roediger, H. L. (2008). Testing during study insulates against the buildup of proactive interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 1392-1399.

Traxler, A. J. (1973). Retroactive and proactive inhibition in young and elderly adults using an unpaced modified free recall task. *Psychological Reports, 32*, 215-222.

Treat, N. J., & Reese, H. W. (1976). Age, imagery, and pacing in paired-associate learning. *Developmental Psychology, 12*, 119-124.

Tulving, E. (1962). Subjective organization in free recall of "unrelated words." *Psychological Review, 69*, 344-354.

Wahlheim, C. N., & Jacoby, L. L. (2011). Experience with proactive interference diminishes its effects: Mechanisms of change. *Memory & Cognition, 39*, 185-195.

Wahlheim, C. N., & Jacoby, L. L. (submitted). Proactive effects of memory: The role of remindings.

Welford, A. T. (1958). *Aging and human skill.* Oxford: Oxford University Press.

Wimer, R. E., & Wigdor, B. T. (1958). Age differences in retention of learning. *Journal of Gerontology, 13*, 291-295.

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

Winograd, E., & Soloway, R. M. (1985). Reminding as a basis for temporal judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 262-271.

Witte, K. L., Freund, J. S., & Sebby, R. A. (1990). Age differences in free recall and subjective organization. *Psychology and Aging, 5*, 307-309.

Woodworth, R. S. (1938). *Experimental psychology.* New York: Henry Holt.

Zacks, R. T. (1982). Encoding strategies used by young and elderly adults in a keeping track task. *Journal of Gerontology, 37*, 203-211.

Appendix: Materials and Association Information

S = Stimulus; R1 = Response 1; R2 = Response 2;

FAS = Forward associative strength (Nelson et al., 1998).

Italicized items were used as buffers.

Stimulus-Response-Response Items (SRR): Experiment 1

Stimulus	Response 1	Response 2	FAS (S to R1)	FAS (S to R2)	FAS (R1 to R2)	FAS (R2 to R1)
reward	*gift*	*give*	0.04	0.04	0.04	0.03
envy	*admire*	*like*	0.03	0.05	0.29	0.02
blanket	*pillow*	*sheet*	0.06	0.05	0.02	0.03
diet	coke	soda	0.01	0.03	0.16	0.19
agent	detective	spy	0.01	0.02	0.07	0.07
inform	teach	instruct	0.02	0.01	0.07	0.53
normal	average	regular	0.07	0.08	0.02	0.04
golf	grass	green	0.01	0.03	0.36	0.25
earn	gain	lose	0.02	0.02	0.38	0.05
empty	can	jar	0.01	0.03	0.05	0.08
fabric	sew	yarn	0.02	0.02	0.01	0.07
fame	wealth	money	0.02	0.07	0.31	0.05
fool	clown	joker	0.05	0.02	0.01	0.09
globe	map	atlas	0.01	0.03	0.02	0.53
bake	broil	fry	0.05	0.02	0.03	0.02
learn	think	smart	0.02	0.02	0.02	0.01
music	sound	noise	0.02	0.02	0.36	0.15
relax	nervous	stress	0.01	0.01	0.03	0.01
risk	dare	challenge	0.05	0.03	0.06	0.03
scratch	pain	hurt	0.02	0.03	0.55	0.52
apart	close	far	0.03	0.08	0.12	0.09
warm	heat	cool	0.02	0.06	0.05	0.02
confess	lie	truth	0.05	0.05	0.29	0.26
fun	beach	sun	0.05	0.06	0.15	0.06
debate	talk	speech	0.06	0.01	0.02	0.28
host	server	waiter	0.02	0.03	0.47	0.11
harvest	plant	grow	0.01	0.02	0.11	0.07
bargain	shop	store	0.02	0.02	0.39	0.18
join	connect	attach	0.01	0.01	0.02	0.09
mistake	forgive	sorry	0.01	0.01	0.05	0.05
gang	fight	war	0.09	0.08	0.06	0.14
quest	trip	travel	0.01	0.01	0.07	0.06
year	date	calendar	0.07	0.03	0.06	0.31

Stimulus-Response Only Items (SRO): Experiment 1

Stimulus	Response 1	Response 2	FAS (S to R1)	FAS (S to R2)	FAS (R1 to R2)	FAS (R2 to R1)
peace	*free*	*sign*	0.01	0.01	0.00	0.00
night	*moon*	*train*	0.02	0.02	0.00	0.00
bus	*ride*	*city*	0.06	0.03	0.00	0.00
tiger	cage	kitten	0.01	0.01	0.00	0.00
sand	ocean	pebble	0.02	0.02	0.00	0.00
square	root	dance	0.01	0.02	0.00	0.00
slow	boring	motion	0.01	0.01	0.00	0.00
doctor	health	help	0.02	0.03	0.00	0.00
nose	eye	snort	0.03	0.02	0.00	0.00
church	service	bell	0.02	0.03	0.00	0.00
floor	shine	hard	0.04	0.07	0.00	0.00
ball	park	bounce	0.02	0.06	0.00	0.00
sour	cream	dough	0.03	0.02	0.00	0.00
coffee	table	bean	0.02	0.05	0.00	0.00
gun	fire	holster	0.04	0.03	0.00	0.00
pearl	jewelry	harbor	0.03	0.05	0.00	0.00
fantasy	desire	island	0.02	0.08	0.00	0.00
ugly	horrid	plain	0.01	0.01	0.00	0.00
cake	birthday	pie	0.09	0.07	0.00	0.00
blow	pop	torch	0.02	0.03	0.00	0.00
door	jam	house	0.02	0.01	0.00	0.00
smooth	skin	silk	0.06	0.06	0.00	0.00
baby	cute	bottle	0.05	0.05	0.00	0.00
maple	sugar	oak	0.03	0.04	0.00	0.00
pencil	wood	yellow	0.02	0.02	0.00	0.00
wine	glass	grape	0.04	0.06	0.00	0.00
blue	ink	velvet	0.01	0.01	0.00	0.00
army	boots	strength	0.02	0.02	0.00	0.00
number	phone	amount	0.06	0.03	0.00	0.00
mouse	hole	cheese	0.05	0.07	0.00	0.00
watch	tick	view	0.01	0.01	0.00	0.00
mountain	rocky	dew	0.03	0.02	0.00	0.00

Unrelated Items: Experiment 1

Stimulus	**Response 1**	**Response 2**	**FAS (S to R1)**	**FAS (S to R2)**	**FAS (R1 to R2)**	**FAS (R2 to R1)**
olive	*unfair*	*tennis*	0.00	0.00	0.00	0.00
uncle	*hatch*	*mail*	0.00	0.00	0.00	0.00
gravel	*clerk*	*armor*	0.00	0.00	0.00	0.00
debt	faith	exit	0.00	0.00	0.00	0.00
heaven	stitch	saddle	0.00	0.00	0.00	0.00
key	tail	weekend	0.00	0.00	0.00	0.00
labor	subtle	toilet	0.00	0.00	0.00	0.00
market	virus	sincere	0.00	0.00	0.00	0.00
shelter	thumb	rare	0.00	0.00	0.00	0.00
atom	poem	exam	0.00	0.00	0.00	0.00
inch	bacon	cost	0.00	0.00	0.00	0.00
art	hour	pork	0.00	0.00	0.00	0.00
maze	court	turtle	0.00	0.00	0.00	0.00
fluid	dice	shelf	0.00	0.00	0.00	0.00
tour	opera	fail	0.00	0.00	0.00	0.00
mummy	rescue	study	0.00	0.00	0.00	0.00
prey	quiet	paddle	0.00	0.00	0.00	0.00
zone	thief	sphere	0.00	0.00	0.00	0.00
skinny	ghost	harmony	0.00	0.00	0.00	0.00
kid	worker	delay	0.00	0.00	0.00	0.00
highway	nurse	imagine	0.00	0.00	0.00	0.00
mix	regret	coin	0.00	0.00	0.00	0.00
mild	infant	rose	0.00	0.00	0.00	0.00
disc	bucket	toe	0.00	0.00	0.00	0.00
proof	remove	robot	0.00	0.00	0.00	0.00
search	jet	update	0.00	0.00	0.00	0.00
lick	credit	seldom	0.00	0.00	0.00	0.00
egg	cloth	hope	0.00	0.00	0.00	0.00
oath	flavor	predict	0.00	0.00	0.00	0.00
liquid	police	smile	0.00	0.00	0.00	0.00
parent	meet	flip	0.00	0.00	0.00	0.00
card	soul	budget	0.00	0.00	0.00	0.00

Stimulus-Response Only Items (SRO): Experiment 2

Stimulus	Response 1	Response 2	FAS (S to R1)	FAS (S to R2)	FAS (R1 to R2)	FAS (R2 to R1)
badge	*officer*	*courage*	0.06	0.05	0.00	0.00
river	*bend*	*boat*	0.05	0.06	0.00	0.00
slow	*boring*	*motion*	0.01	0.01	0.00	0.00
ball	*bounce*	*park*	0.06	0.02	0.00	0.00
number	*amount*	*phone*	0.03	0.06	0.00	0.00
fact	*theory*	*evidence*	0.02	0.02	0.00	0.00
sour	cream	dough	0.03	0.02	0.00	0.00
hint	guess	secret	0.09	0.09	0.00	0.00
smooth	silk	skin	0.06	0.06	0.00	0.00
city	street	building	0.05	0.04	0.00	0.00
treasure	pirate	fortune	0.02	0.02	0.00	0.00
wasp	insect	nest	0.01	0.01	0.00	0.00
bullet	hole	proof	0.04	0.03	0.00	0.00
book	worm	study	0.06	0.06	0.00	0.00
lock	chain	secure	0.03	0.04	0.00	0.00
pencil	wood	yellow	0.02	0.02	0.00	0.00
oven	toast	heat	0.01	0.04	0.00	0.00
square	root	dance	0.01	0.02	0.00	0.00
road	drive	travel	0.04	0.03	0.00	0.00
quiet	peace	library	0.03	0.03	0.00	0.00
sand	ocean	pebble	0.02	0.02	0.00	0.00
mess	neat	hall	0.04	0.02	0.00	0.00
wool	cotton	lamb	0.07	0.06	0.00	0.00
forever	young	long	0.06	0.05	0.00	0.00
rich	power	famous	0.02	0.02	0.00	0.00
towel	rack	shower	0.03	0.08	0.00	0.00
author	editor	poet	0.02	0.03	0.00	0.00
media	camera	radio	0.03	0.01	0.00	0.00
plastic	rubber	wrap	0.04	0.03	0.00	0.00
disagree	opinion	anger	0.01	0.03	0.00	0.00
soup	bowl	sandwich	0.04	0.09	0.00	0.00
wine	grape	glass	0.06	0.04	0.00	0.00
market	flea	price	0.01	0.01	0.00	0.00
pyramid	ancient	desert	0.01	0.04	0.00	0.00
train	plane	whistle	0.05	0.05	0.00	0.00
lamp	bulb	post	0.05	0.03	0.00	0.00
nature	trail	plant	0.02	0.02	0.00	0.00
clever	trick	wise	0.04	0.03	0.00	0.00
west	north	wild	0.03	0.03	0.00	0.00
swim	float	exercise	0.05	0.03	0.00	0.00
respect	earn	dignity	0.02	0.02	0.00	0.00
journey	voyage	vacation	0.01	0.01	0.00	0.00
picnic	blanket	grass	0.01	0.01	0.00	0.00
silent	movie	night	0.02	0.07	0.00	0.00
pocket	knife	wallet	0.05	0.05	0.00	0.00
mystery	murder	unknown	0.06	0.06	0.00	0.00
mist	steam	spray	0.04	0.06	0.00	0.00
crown	head	queen	0.08	0.08	0.00	0.00
cough	throat	medicine	0.05	0.01	0.00	0.00
angel	wings	saint	0.04	0.04	0.00	0.00
hear	music	speak	0.02	0.03	0.00	0.00
gun	fire	holster	0.04	0.03	0.00	0.00

Stimulus	Response 1	Response 2	FAS (S to R1)	FAS (S to R2)	FAS (R1 to R2)	FAS (R2 to R1)
pearl	jewelry	harbor	0.03	0.05	0.00	0.00
bubble	blow	soap	0.03	0.04	0.00	0.00
shelter	storm	safety	0.02	0.02	0.00	0.00
nose	sneeze	eye	0.02	0.03	0.00	0.00
silly	clown	giggle	0.03	0.02	0.00	0.00
floor	shine	hard	0.04	0.07	0.00	0.00
limp	hurt	walk	0.07	0.04	0.00	0.00
sweater	blouse	winter	0.05	0.05	0.00	0.00
mind	think	body	0.08	0.06	0.00	0.00
dentist	cavity	drill	0.02	0.06	0.00	0.00
shadow	shade	doubt	0.03	0.03	0.00	0.00
computer	screen	machine	0.03	0.04	0.00	0.00
robbery	mask	criminal	0.02	0.03	0.00	0.00
start	engine	over	0.03	0.02	0.00	0.00
maple	sugar	oak	0.03	0.04	0.00	0.00
disturb	noise	upset	0.03	0.03	0.00	0.00
walnut	almond	squirrel	0.04	0.05	0.00	0.00
paint	picture	house	0.04	0.06	0.00	0.00
unfair	cheat	justice	0.04	0.05	0.00	0.00
victory	champion	battle	0.03	0.01	0.00	0.00
military	base	uniform	0.01	0.05	0.00	0.00
heart	attack	throb	0.08	0.02	0.00	0.00
cage	trap	lion	0.03	0.04	0.00	0.00
baby	cute	bottle	0.05	0.05	0.00	0.00
church	bell	service	0.03	0.02	0.00	0.00
curb	cement	edge	0.03	0.03	0.00	0.00
schedule	list	routine	0.03	0.03	0.00	0.00
imagine	create	pretend	0.03	0.02	0.00	0.00
chalk	dust	eraser	0.10	0.03	0.00	0.00
apron	maid	chef	0.03	0.01	0.00	0.00
carpet	tile	vacuum	0.01	0.01	0.00	0.00
early	bird	dawn	0.06	0.02	0.00	0.00
strong	hold	will	0.02	0.01	0.00	0.00
oil	change	slick	0.04	0.05	0.00	0.00
cake	pie	birthday	0.07	0.09	0.00	0.00
group	meeting	therapy	0.03	0.02	0.00	0.00
cloud	white	nine	0.08	0.06	0.00	0.00
riot	crowd	police	0.02	0.03	0.00	0.00
world	map	round	0.03	0.09	0.00	0.00
harvest	farm	grain	0.05	0.03	0.00	0.00
gamble	chance	cards	0.03	0.03	0.00	0.00
morning	glory	sleep	0.03	0.03	0.00	0.00
coffee	table	bean	0.02	0.05	0.00	0.00
moment	instant	truth	0.03	0.02	0.00	0.00