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Generation, Intentionality of Processing at Encoding and Retrieval, and Age-Related Associative Deficits

Katherine K. White

Centre College

Lise Abrams

University of Florida

Amy L. Byrd

College of Charleston

Please address correspondence to:
Katherine K. White, Ph.D.
Department of Psychology
Centre College
600 W. Walnut Street
Danville, KY 40422
(859) 238-5327
k.white@centre.edu

Abstract

This research tested age-related differences in the retrieval of self-generated new associations under conditions that required intentional or incidental processing. Under intentional or incidental encoding conditions, young and older adults generated new associations by producing a response to a two-letter stem paired with a cue/prime word (e.g., throne-mo_____). Memory for these new associations was tested under intentional or incidental retrieval conditions by pairing the word stem with the previous cue/prime word, its homophone partner, or a prime/cue not previously presented. Results indicated equivalent priming and cueing effects for both age groups in all conditions. These results suggest that generation of new associations can eliminate age-related associative deficits, even under intentional encoding and retrieval conditions that typically disadvantage older adults.

Generation, Intentionality of Processing at Encoding and Retrieval,

and Age-Related Associative Deficits

Research has consistently shown that older adults have more difficulty than young adults when asked to remember new associations, such as associations between previously unrelated words (e.g., Howard, 1991; Kausler, 1994; MacKay & Burke, 1990; Naveh-Benjamin, 2000). One explanation for these age-related associative deficits comes from the associative deficit hypothesis (ADH; Naveh-Benjamin, 2000) and the transmission deficit hypothesis (TDH; MacKay & Burke, 1990), which maintain that older adults have particular difficulty binding, or forming, connections between single units of information. For example, when the words *apple* and *letter* are paired together in an associative memory task, a new connection must be created between the stored representations in memory for *apple* and *letter*. Because this connection is new, it is weaker than connections between semantically-related words like *apple* and *pear* that have been repeatedly associated for many years (MacKay & Burke, 1990). In a series of studies examining age-related associative deficits, Naveh-Benjamin and colleagues (e.g., Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; for a meta-anaylsis, see Old & Naveh-Benjamin, 2008; see also Castel & Craik, 2003; Healy, Light, & Chung, 2005; Light, Patterson, Chung, & Healy, 2004) have shown that older adults' associative deficit occurs for a variety of associative stimuli (e.g., word-word pairs, word-nonword pairs, picture pairs, and name-face pairs) and tasks (e.g., recognition, cued recall, free recall).

One factor that appears to influence the amount of the age-related associative deficit is the type of processing performed at encoding and/or retrieval: Older adults appear to be more disadvantaged, compared to young adults, when using intentional relative to incidental processing. Intentional processing requires conscious use of memory, whereas incidental processing taps into memory indirectly. Both types of processing can be used either at encoding or at retrieval. For example, intentional encoding occurs when participants are instructed to learn associations for later retrieval, whereas incidental encoding occurs when participants are exposed to associations (e.g., through reading) but are not instructed to deliberately remember the material. Similarly, intentional retrieval occurs when participants are asked to either recognize or recall previously-learned associations, whereas incidental retrieval assesses memory without conscious attempts to recollect (e.g., reading aloud unrelated word pairs). Memory is demonstrated via priming, where people are faster to read word pairs that have been read previously than word pairs that have not been read. One purpose of the present research was to examine the relative importance of incidental and intentional processes at encoding versus retrieval in determining age-related deficits in associative memory. No previous research has included all four types of encoding-retrieval conditions using a task that only differs in the intentionality of processing at encoding and retrieval. Furthermore, we sought to determine whether age-related deficits in associative memory could be reduced by generating one’s own associations during encoding and retrieval.

Previous studies of associative memory have shown that *intentional* types of processing consistently produce age-related associative deficits, i.e., poorer memory for older adults than young adults (e.g., Java, 1996; Howard, Frye, & Brune, 1991; Light, La Voie, & Kennison, 1995, Experiment 3; Naveh-Benjamin, 2000; Naveh-Benjamin, Craik, & Ben-Shaul, 2002; Naveh-Benjamin, Craik, Guez, & Krueger, 2005). Intentional *retrieval* (i.e., free recall, cued recall, recognition) appears to be particularly detrimental to older adults, with even larger deficits found within intentional retrieval tasks that require self-initiated processing (e.g., free recall) compared to tasks that provide environmental support (e.g., recognition) (Craik, 1983, 1986; Craik & McDowd, 1987; Naveh-Benjamin, 2000; Rabinowitz, 1986). However, there are indicators that the type of *encoding* may also play a role in older adults' associative deficits. For example, Naveh-Benjamin (2000, Experiment 2) found that an age-related associative deficit in recognizing word-pair associations was reduced following incidental compared with intentional encoding. Furthermore, providing older adults with external support (e.g., multiple cues) at encoding can reduce age-related associative deficits (e.g., Bäckman, 1986; Craik & Jennings, 1992; Naveh-Benjamin, Brav, & Levy, 2007; Smith, Park, Earles, Shaw, & Whiting, 1998; Treat & Reese, 1976).

Although tasks that require intentional encoding and retrieval repeatedly show age-related associative deficits, the research regarding the impact of *incidental* processing on age-related associative deficits in less clear. Tasks using incidental encoding (e.g., Naveh-Benjamin, 2000), incidental retrieval (e.g., Howard et al., 1991), or both incidental encoding and incidental retrieval (e.g., Light et al., 1995; Light, Kennison, Prull, La Voie, & Zuellig, 1996; Spieler & Balota, 1996; White & Abrams, 2004a) show mixed results, with age invariance in some cases and age deficits in others (see also meta-analyses by La Voie & Light, 1994; Light, Prull, La Voie, & Healy, 2000). Nonetheless, the one constant finding is that age-related associative deficits are smaller following incidental retrieval than intentional retrieval (e.g., Balota & Duchek, 1989; Howard et al., 1991; Moscovitch, Winocur, & McLachan, 1986; Nilsson, Bäckman, & Karlsson, 1989; Rabinowitz, 1986). Using associative priming tasks, both young and older adults showed similar decreases in naming times, suggesting that incidental retrieval[1] reduces, if not eliminates, age-related associative deficits (but see Spieler & Balota, 1996, for an exception). Unfortunately, because naming is measured by latency to respond, direct comparisons to intentional retrieval tasks that measure accuracy of retrieval (i.e., via free or cued recall) are not possible.

One incidental retrieval task that is comparable to intentional cued recall is the word-stem completion test. Two unrelated words are paired at encoding (e.g., apple-letter), and retrieval of the association is tested by pairing the prime (apple) with the initial letter of the target followed by a blank line (l_____). Participants are asked to complete the word stem with the first word that comes to mind, making no reference to remembering previous associations. Under this type of incidental retrieval, young and older adults typically show equivalent amounts of associative priming, i.e., retrieving the target more often relative to pairs that had not been previously presented, demonstrating that new associations have been formed and retrieved (e.g., Howard et al., 1991; White & Abrams, 2004a). This age equivalence contrasts with the age-related deficits that are found with the analogous task of intentional retrieval, cued recall, where participants are asked to think back and try to produce the word that had been previously paired with the prime. However, most associative priming studies have not included a comparable intentional retrieval condition, and the ones that do did not assess the differential impact of intentional vs. incidental encoding.

In all of the previously-described experiments, the associations were provided by the experimenters, rather than generated by the participants. Research on the generation effect (i.e., better memory for items and associations that were generated versus read at encoding; Slamecka & Graf, 1978) shows that older adults' associative memory is enhanced following self-generated associations compared to experimenter-provided associations. This generation effect is exhibited when intentional encoding is followed by either intentional or incidental retrieval (Java, 1996) and when incidental or intentional encoding are followed by intentional retrieval (Troyer, Häfliger, Cadieux, & Craik, 2006). However, these studies involved generation of semantically-related associations, leaving a question as to whether generation can facilitate associative memory when the associations are unrelated. Evidence for beneficial generation effects during encoding on associative priming comes from White and Abrams (2004a). Young and older adults generated their own target to an associate that was paired with a word stem that could not be easily completed with a strong semantic associate (e.g., beach-l_____). At retrieval, participants saw a homophone of the encoding associate (e.g., beech), a semantic associate (e.g., sand), or an orthographically similar but unrelated word (e.g., batch) paired with the same word stem (e.g., l_____), and were asked to provide the first word that came to mind that completed the word stem. Both young and older adults showed equivalent amounts of associative priming in the phonological and semantic conditions. However, this study only used incidental encoding and incidental retrieval, conditions which generally exhibit much smaller associative deficits for older adults. Given that age-related associative deficits are much greater under conditions of intentional processing, the present experiment explored whether generating one's own association during encoding could help older adults to overcome their associative deficits when intentional encoding and/or retrieval was required.

The present study used a paired word-stem completion paradigm (e.g., Graf & Schacter, 1985) to measure memory for new associations. Participants formed a new association by generating a target response to a two-letter stem (e.g., *mo*____) that was preceded by an unrelated associate (e.g., *throne*). Young and older adults completed the stems following either incidental or intentional encoding instructions and were later tested for their memory of the target word under incidental or intentional retrieval conditions. During the retrieval phases, participants saw the same prime/cue[2] that was provided during encoding (e.g., *throne*, repeated prime/cue), a homophone of the encoding associate (e.g., *thrown*, phonological prime/cue)[3], or an orthographically-similar word (e.g., *thrive*, unrelated prime/cue). Associative priming (incidental retrieval) and associative cued recall (intentional retrieval) were observed if the two-letter word stem (e.g., *gl*____) was completed with same word that was generated during encoding. By keeping task conditions constant and only varying the type of processing at encoding and retrieval, it is possible to make more direct claims about what types of processing reduce age-related associative deficits.

Method

Participants

A total of 224 adults (112 young adults, 112 older adults) participated in this experiment, with 56 young and 56 older adults in each of the incidental and intentional encoding conditions. The young adults included 79 females and 33 males, ranged in age from 18 to 29 (M = 19.78 years, SD = 2.13), were obtained from the undergraduate population at the College of Charleston, and completed this experiment for either partial course credit or extra credit. The older adults included 60 females and 52 males, ranged in age from 60 to 90 (M = 72.32 years, SD = 6.31) and consisted of volunteers from the community. All participants completed the following background information forms and questionnaires: (a) a participant questionnaire asking for age, education, ethnicity, native language, health status, and current medications; (b) a 25-item vocabulary test, and (c) forward and backward digit span tests to assess working memory. In addition, older adults were also given the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) to assess any cognitive impairment or dementia.

Materials

During the encoding phase of the experiment, participants were presented with a word-stem completion task using 48 homophone pairs identical to those used in White and Abrams (2004a)[4]. To facilitate the formation of new associations, these homophones were paired with two-letter stems that did not elicit any preexisting semantically related response (e.g., *throne-mo*_____), and the same two-letter stem was presented during encoding and retrieval phases. Each of these word pairs had at least 10 different plausible completions, and each was pilot tested on 51 young adults to ensure the absence of any semantically-related response. Furthermore, for all homophones that were represented in the University of South Florida Free Association Norms (62%) (Nelson, McEvoy, & Schreiber, 1998), no homophone had an associate that started with the two letter stem with which it was paired. In addition to the 48 experimental word-stem pairs, 24 nonhomophone "filler" word-stem pairs were presented between every two homophones. These encoding phase fillers were included to reduce the likelihood that participants would notice that the retrieval word-stems were also encountered during encoding, an awareness that could contaminate the incidental retrieval test. Encoding phase fillers were only presented during encoding and not presented during retrieval.

Because one member of each homophone pair (e.g., *throne*) was always presented during encoding, the prime/cue type variable was defined by the relationship between the encoding prime/cue and the retrieval prime/cue (repeated, phonological, unrelated). In the repeated condition, participants saw the same prime/cue that they saw during encoding, paired with the same word stem (e.g., *throne-mo*____). In the phonological condition, participants saw a homophone of the encoding prime/cue, paired with the same word stem (e.g., *thrown-mo*_____). In the unrelated condition, participants saw a word unrelated in meaning to the encoding prime/cue, paired with the same word stem (e.g., *thrive-mo*_____). The unrelated primes/cues were matched as closely as possible to the encoding homophone in a number of variables: first letter (always shared), number of syllables (always shared), length (within one letter, $M_{encoding\ homophone}$ = 4.42, $M_{unrelated\ prime/cue}$ = 4.44), and word frequency ($M_{encoding\ homophone}$ = 9.93, $M_{unrelated\ prime/cue}$ = 10.78; Zeno, Ivens, Milliard, & Duvvuri, 1995).

The incidental and intentional retrieval tasks each included half of the word stems that participants saw during the learning phase. Word-stem pairs were counterbalanced across both retrieval type and prime/cue type so that each pair was represented equally often in both incidental and intentional retrieval conditions, as well as across repeated, phonological, and unrelated prime/cue types. Thus, each participant saw each word-stem pair in only one retrieval phase (e.g., incidental) and in only one prime/cue type (e.g., repeated). Of the 24 word-stem pairs seen during each retrieval phase, eight were repeated primes/cues, eight were phonological primes/cues, and eight were unrelated primes/cues.

Upon completion of the experiment, participants were verbally administered a post-experimental questionnaire intended to assess any knowledge they had of the relationship between primes/cues and target words.

Apparatus

In order to control stimulus presentation, all stimuli were presented on Pentium III 350 MHz IBM-compatible computers with 17-inch monitors using a program written in Visual Basic 5.0.

Design & Procedure

The experimental design consisted of four independent variables, with age group (young adults, older adults) and encoding type (incidental, intentional) as between-participants variables and retrieval type (incidental, intentional) and prime/cue type (repeated, phonological, unrelated) as within-participants variables. The dependent variable was the percent of time the word stems were completed with the same target word during encoding and retrieval.

A flowchart summarizing the experimental procedure is illustrated in Figure 1. Participants were first asked to read the instructions on the computer screen, which were then reiterated verbally and participants were given a chance to ask questions. Participants in the incidental encoding condition were told to read the word and complete the stem with the first word that comes to mind and completes the stem. They were also given an example (e.g., *cookie-up____*) to help clarify the task. Because of the incidental nature of this encoding task, there was no indication of a later memory test. Participants in the intentional encoding condition were given the same instructions and example but were also told to try to remember the first word along with their generated response as a word pair because they may later be asked to recall the pairs. Participants in both conditions then saw the 48 experimental word stems, as well as the 24 encoding filler word stems. The word-stem pairs appeared on the screen for a maximum of 4 seconds or until a response was made, and there was a 1 second pause in between word pairs.

At the end of the encoding phase, participants in both encoding conditions saw a new set of instructions on the screen that corresponded to the incidental retrieval task. In order to ensure that participants were unaware that their memory was being tested, they were told they would be completing a "pronunciation task". This task included reading aloud some words and generating other words and therefore participants were asked to speak clearly and to try to focus on their pronunciation. In order to further disguise the task, the primes and word stems were not presented on the screen at the same time. Of the words they read aloud, 24 were primes (eight in each condition), and the other 36 were non-homophone filler words that ranged in length from two to four syllables and were included to further support the nature of the pronunciation task.

Participants saw either one or two filler words, followed by a prime (repeated, phonological or unrelated), followed by its word-stem target. For the word-stem generation task, participants were asked to simply pronounce the first word that came to mind and began with the given letters. Each stimulus (incidental retrieval filler, prime, word stem) remained on the screen until a response was made or four seconds elapsed. One second elapsed between the offset of one stimulus and the onset of the next stimulus.

In order to maintain the incidental nature of the incidental retrieval task and to reduce explicit contamination (e.g., Bowers & Schacter, 1990), incidental retrieval always preceded intentional retrieval. Once the incidental retrieval task was completed, all participants proceeded to the intentional retrieval task, where they were told that they were now going to be tested on their ability to recall their responses from the first task. They were asked to read aloud a cue word that may or may not help them to retrieve the earlier generated word and to then try to give their earlier response to the word stem. If participants were unable to recall their previous response, they were told to make their best guess. Participants then saw the other 24 cues (eight in each condition) that were not presented in the incidental retrieval phase, and that corresponded to 24 of the word stems presented in the encoding phase. In order to maintain consistency of presentation with the incidental retrieval task, the cue was presented prior to the word stem, and remained on the screen until it was read by the participant or four seconds elapsed. Then, the word stem was presented for a maximum of four seconds or until a response was made. Because the purpose of the explicit retrieval task did not need to be disguised, there were no fillers.

The fourth and last task was performed in order to ensure that the associations created in the first task were in fact *new* associations and not preexisting ones. Participants were presented with the prime/cue and their response from the encoding task, and were asked to rate the relationship between the two words on a scale ranging from 1 (no relationship) to 5 (strongly related.

Once the entire experiment was completed, all participants were given the post-experiment questionnaire to assess their knowledge of the experiment, followed by a written and verbal debriefing.

Results

Of the 224 participants, nine young adults and 12 older adults were excluded from data analysis because they did not follow directions (e.g., did not pay attention to the prime word during the encoding phase), admitted to suppressing their first response, had below a 25 on the MMSE, or reported having detailed knowledge about the experiment's purpose during the post-experiment questionnaire. In addition to these participant exclusions, items were removed from analyses when a response was given to the word-stems that did not begin with the correct letters (0.6% for young, 1% for older) or when a target word was not produced for the encoding word stem (2.2% for young, 1.2% for older).

Demographics

Table 1 presents the means and standard deviations for the demographic characteristics of those 203 participants included in analyses. These participants included 74 young females, 29 young males, 55 older females, and 45 older males. Independent samples *t* tests indicated that young adults had fewer years of education, t (197) = 7.50, $p < .001$, and lower vocabulary scores, t (199) = 191.87, $p < .001$, than older adults. Young and older adults did not differ on self-reported health, $p > .220$, forward digit span, $p > .126$, or backward digit span, $p > .583$.

Main Analyses

A 2 (age group: young, older adults) x 2 (encoding type: incidental, intentional) x 2 (retrieval type: incidental, intentional) x 3 (prime/cue type: repeated, phonological, unrelated) repeated measures analysis of variance (ANOVA) was performed by participants (F_1) and by items (F_2) on the proportion (converted to percentages when reporting means) of time the word stems were completed with the same target word (subsequently referred to as "target production") during encoding and retrieval[5] (see Table 2). A main effect was found for prime/cue type, F_1 (2, 398) = 11.73, MSE = .03, p < .001, F_2 (2, 94) = 9.78, MSE = .03, p < .001. Participants had greater target production following repeated primes/cues (M_1 = 47.3%, SD = 19.9%) than phonological primes/cues (M_1 = 43.3%, SD = 19.5%), p_1 < .002, p_2 < .008, and unrelated primes/cues (M_1 = 41.3%, SD = 19.9%), p_1 < .001, p_2 < .001, which did not differ, p_1 > .107, p_1 > .132. A main effect of retrieval type, F_1 (1, 199) = 83.33, MSE = .04, p < .001, F_2 (1, 47) = 116.97, MSE = .03, p < .001, indicated that target production was greater when retrieval was intentional (M_1 = 48.9%, SD = 20.2%) rather than incidental (M_1 = 39.0%, SD = 19.5%). Main effects were not found for age group, F_1 (1, 199) = 1.56, MSE = .07, p > .213, F_2 (1, 47) = 2.49, MSE = .03, p > .122, or encoding type, F_1 < 1, F_2 (1, 47) = 1.17, MSE = .02, p > .284.

An interaction between encoding type and prime/cue type emerged, F_1 (2, 398) = 2.92, MSE = .03, p < .055, F_2 (2, 94) = 3.38, MSE = .03, p < .038 (see Figure 1). The pattern for incidental encoding mimicked the overall prime/cue type main effect, with greater target production following repeated primes than phonological primes, p_1 < .001, p_2 < .001, and unrelated primes, p_1 < .001, p_2 < .012, which did not differ, p_1 > .631, p_2 > .503. For intentional encoding, both repeated and phonological cues showed greater target production than unrelated cues, p_1s < .012, p_2s < .009, with no difference in target production between repeated and phonological cues, p_1 > .374, p_2 > .583.

There was also a significant Age Group x Retrieval Type interaction, F_1 (1, 199) = 7.45, *MSE* = .04, $p < .007$, F_2 (1, 47) = 9.07, *MSE* = .03, $p < .004$, which was moderated by a significant Age Group x Encoding Type x Retrieval Type interaction, F_1 (1, 199) = 7.69, *MSE* = .04, $p < .006$, F_2 (1, 47) = 10.12, *MSE* = .02, $p < .003$ (see Figure 2). Further investigation of this three-way interaction revealed a significant Age Group x Retrieval Type interaction for incidental encoding, F_1 (1, 200) = 15.19, *MSE* = .04, $p < .001$, F_2 (2, 94) = 4.13, *MSE* = .03, $p < .019$, where older adults had greater incidental target production than young adults, $p_1 < .036$, $p_2 < .015$, but young adults had greater intentional target production than older adults, $p_1 < .016$, $p_2 > .131$. In contrast, there was not an Age Group x Retrieval Type interaction for intentional encoding, $F_1 < 1$, F_2 (2, 94) = 3.46, *MSE* = .03, $p < .035$, although there was a significant effect of retrieval type, F_1 (1, 202) = 26.99, *MSE* = .05, $p < .001$, F_2 (2, 94) = 599.08, *MSE* = .06, $p < .001$, with greater target production when the retrieval task was intentional than when it was incidental. There was also an effect of age group within intentional encoding (marginal in the participant analysis), F_1 (1, 200) = 2.75, *MSE* = .07, $p < .099$, F_2 (1, 47) = 4.74, *MSE* = .04, $p < .035$, with young adults having slightly better target production than older adults. No other interactions were significant, p_1s > .093, p_2s > .089.

Analyses Using Only Associations Self-Reported as New

Following completion of the intentional retrieval task, participants were provided with the primes/cues that they had seen and the targets that they had produced during encoding and were asked to rate the relatedness of these two items. Young and older adults were relatively similar in their self-reported ratings of association strength/relatedness (see Table 3). In order to determine if truly new associations behaved differently from all associations in this experiment, we performed the same Age Group x Encoding Type x Retrieval Type x Prime/Cue Type

ANOVA using only those items that participants had rated as being completely unrelated (a rating of 1 on the 5-point scale). This analysis produced the same main effects and interactions as the main analysis, suggesting that the results cannot be due to age differences in using preexisting knowledge to encode the new associations.

Discussion

Previous research has documented an age-related associative deficit, where older adults have exacerbated difficulty in encoding and retrieving new associations between previously unrelated words (e.g., Howard, 1991; Kausler, 1994; MacKay & Burke, 1990; Naveh-Benjamin, 2000), but these new associations were always experimenter-provided. The present experiment found that use of self-generated associations, without preexisting semantic relationships, eliminated age-related associative deficits, independent of incidental and intentional processing conditions. Both young and older adults demonstrated new association formation, evidenced by associative priming (incidental retrieval) and associative cued recall (intentional retrieval) following repeated primes/cues relative to unrelated primes/cues. Furthermore, older adults benefited from repetition of primes/cues to the same extent as young adults. These findings are intriguing because the reduction in age-related associative deficits occurred for all four encoding-retrieval conditions. Even when both encoding and retrieval required intentional processing, conditions which typically disadvantage older adults (e.g., Java, 1996; Light et al., 1995; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2002; Naveh-Benjamin et al., 2005), older adults were able to exhibit associative priming/cued recall to the same degree as young adults. The present experiment demonstrated that generation does not need to be linked to semantics (Java, 1996; Troyer et al., 2006), but that the process of producing one’s own association can strengthen the new connection between previously unrelated words. These findings complement theoretical accounts, where older adults are deficient at forming new connections (TDH) or binding together individual representations (ADH), suggesting that generation facilitates this binding process. It is worth noting that, as with many aging studies, these findings may only apply to relatively high-functioning older adults as were tested here. Future research might investigate whether generation can offset associative age deficits in a sample of older adults with lower levels of cognitive functioning, such as those with impaired frontal lobe functioning.

These findings cannot be attributed to older adults producing associates that were somehow related episodically (e.g., having a personally-relevant connection between the two words). By analyzing only those associations that participants rated as entirely unrelated, we were able to ensure that the new associations were truly novel for both young and older adults. However, failing to account for this possibility in other studies may be one explanation for the inconsistencies in repetition priming of new associations, where age differences sometimes emerge (e.g., Spieler & Balota, 1996; Light et al., 2000). Some tasks may allow young adults (more than older adults) to utilize pre-existing knowledge structures to help encode the new experimenter-provided association. For example, if provided with the pair *apple-letter*, young adults may be more adept at linking these words together by remembering a specific episode when they ate an apple while writing a letter.

New association formation was also demonstrated via phonological associates, where using a homophone as a prime/cue resulted in greater target production than unrelated primes/cues. However, phonological facilitation was only found (for both young and older adults) when encoding was intentional. Given the tenuous strength of a new association, it seems plausible that conscious effort to encode it would be necessary for a cue that was not lexically identical to facilitate retrieval. Under these circumstances, it is interesting to note that phonological facilitation occurred after only a single encoding trial, suggesting that the connections that older adults are forming are at least strong enough to facilitate retrieval of that association when given a similar-sounding cue. Whether these new associations remain strong over time has yet to be determined.

Although young and older adults equally benefited from generation in facilitating the retrieval of new associations, there were some age differences with respect to the influences of specific encoding-retrieval conditions, independent of new association formation. Older adults had slightly less overall target production than young adults following intentional encoding, independent of the type of processing done at retrieval. This finding is consistent with research showing that intentional encoding will put older adults at a disadvantage unless given additional external support (e.g., time to study, multiple cues) (e.g., Craik & Jennings, 1992; Howard et al., 1991; Naveh-Benjamin et al., 2007; Rogers, Hertzog, & Fisk, 2000; Treat & Reese, 1976). Possible explanations for this age-related disadvantage in intentional encoding include older adults using less efficient strategies than young adults (Light & LaVoie, 1993), possibly due to deficits in frontal lobes and strategic processing (Moscovitch, 1992), older adults having trouble using self-initiated processes when forming new associations (Craik, 1986), or the activation of stereotype threat when older adults are aware that they are using their memory (e.g., Hess, Auman, Colcombe, & Rahhal, 2003; Rahhal, Hasher, & Colcombe, 2001; although no research has determined how stereotype threat affects memory under incidental conditions).

In contrast, when encoding was incidental, the type of processing used at retrieval influenced older adults' target production. Intentional retrieval put older adults at a disadvantage, producing fewer targets relative to young adults, a finding that is consistent with a larger literature showing age deficits when intentional retrieval is required (e.g., Naveh-Benjamin, 2000; Light et al., 1995). Despite the benefits of generating one's own association, this reduction in older adults' overall target production suggests that older adults might need additional contextual support or retrieval strategies to facilitate their memory when deliberate processing is required at retrieval. This is not the case when retrieval is incidental, where older adults' target production was greater than that of young adults. One possibility for finding an age-related advantage under entirely incidental conditions is that generation is especially beneficial to older adults. However, it is worth noting that this age difference may also be due to young adults doing poorly (rather than older adults doing better), as young adults' target production was the lowest under incidental encoding-incidental retrieval, relative to the other conditions. Another possibility is that since memory strategies are not used when both encoding and retrieval are incidental, more varied responses can emerge in response to the word stem. Since young adults have greater verbal fluency than older adults (at least when asked to free associate to a semantic category; e.g., Auriacombe, Fabrigoule, Lafont, Amieva, Jacqmin-Gadda, & Dartigues, 2001; Kozora & Cullum, 1995), young adults may have been more likely to give a variety of responses, rather than producing the same response twice, when intentional strategies are not required.

In summary, this experiment demonstrated that generating one's association can eliminate age-related deficits in associative memory, even under conditions where intentional processing is required at encoding or at retrieval, which normally results in age-related associative deficits (e.g., Java, 1996; Howard et al., 1991; Light et al., 1995; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2002, 2005). Self-generated associations, rather than experimenter-provided associations, allow older adults to not only effectively form new connections, but to also maintain this connection over a period of several minutes. Furthermore, independent of new associations, the differential influences of incidental and intentional processing on older adults' overall production of targets suggest that encoding processes may be more critical for older adults when encoding is intentional, whereas retrieval processes may be more critical when encoding is incidental, especially under conditions where there is no additional environmental or contextual support (e.g., elaborative associations, extra time) during encoding (e.g., Craik, 1986).

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Author Notes

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Footnotes

1. The use of “retrieval” when referring to associative priming includes tasks that require the retrieval of part of a word (as in word-stem completion) as well as tasks that require naming of a prime-target pair.
2. For clarity, we use “prime” when referring to incidental retrieval because a prime is not used consciously, and we use “cue” when referring to intentional retrieval because a cue is used as a memory aid.
3. The phonological condition was included to extend the findings of White and Abrams (2004a), which is the only study that has examined age differences in associative priming when associations were self-produced at encoding and retrieval.
4. We controlled for homophone dominance by always presenting the subordinate homophone during encoding and the dominant homophone during retrieval. By using this set of homophones, we were also able to control for any cohort differences in homophone dominance since these homophones have been normed equivalently for young and older adults on dominance (White & Abrams, 2004b).
5. In the case that the participant and item analyses were inconsistent (i.e., one was significant and the other was not), we followed the outcome of the participant analysis. This decision was made because the focus of this experiment was on the participants, not them items, and because we had a much larger participant sample than item sample. Thus, in cases where the item analysis was significant but the participant analysis was not, follow-up tests were not conducted.

Table 1

Demographic Characteristics for Young and Older Adults

	Group					
	Young Adults			Older Adults		
Variable	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*
Age	101	19.86	2.05	99	72.10	6.29
Education (years)*	101	13.86	1.51	98	16.14	2.61
Vocabulary* (max = 25)	101	14.31	2.88	100	19.30	3.10
Forward digit	101	7.14	1.27	99	6.86	1.30
Backward digit	101	4.82	1.21	99	4.72	1.48
Health (max = 10)	100	7.63	1.42	99	7.89	1.54
MMSE (max = 30)				98	27.87	1.36

Note. Asterisks indicate significant differences between the age groups, $p < .05$. Participants who were missing data from particular characteristics were excluded from that analysis.

Table 2

Means (and Standard Deviations) for the Percent of Time Young and Older Adults Produced a Target Word at Retrieval as a Function of Encoding Type and Prime/Cue Type

	Incidental Encoding		Intentional Encoding	
Age Group	Incidental Retrieval	Intentional Retrieval	Incidental Retrieval	Intentional Retrieval
Young Adults				
Repeated	38.4 (20.5)	54.9 (20.5)	44.4 (19.1)	55.1 (18.6)
Phonological	33.8 (16.1)	50.6 (20.5)	40.9 (20.4)	51.4 (18.2)
Unrelated	33.3 (20.7)	50.6 (21.7)	39.6 (21.7)	45.8 (22.6)
Older Adults				
Repeated	43.6 (18.1)	52.7 (21.9)	36.8 (22.1)	52.0 (17.8)
Phonological	39.8 (19.9)	40.3 (17.8)	43.2 (18.0)	46.6 (22.0)
Unrelated	39.4 (18.7)	44.2 (19.2)	33.9 (16.9)	43.2 (16.3)

Note: “Repeated”, “Phonological”, and “Unrelated” represent the three prime/cue types.

Table 3

Young and Older Adults' Ratings (%) of the Relatedness of Their Generated Encoding Associations.

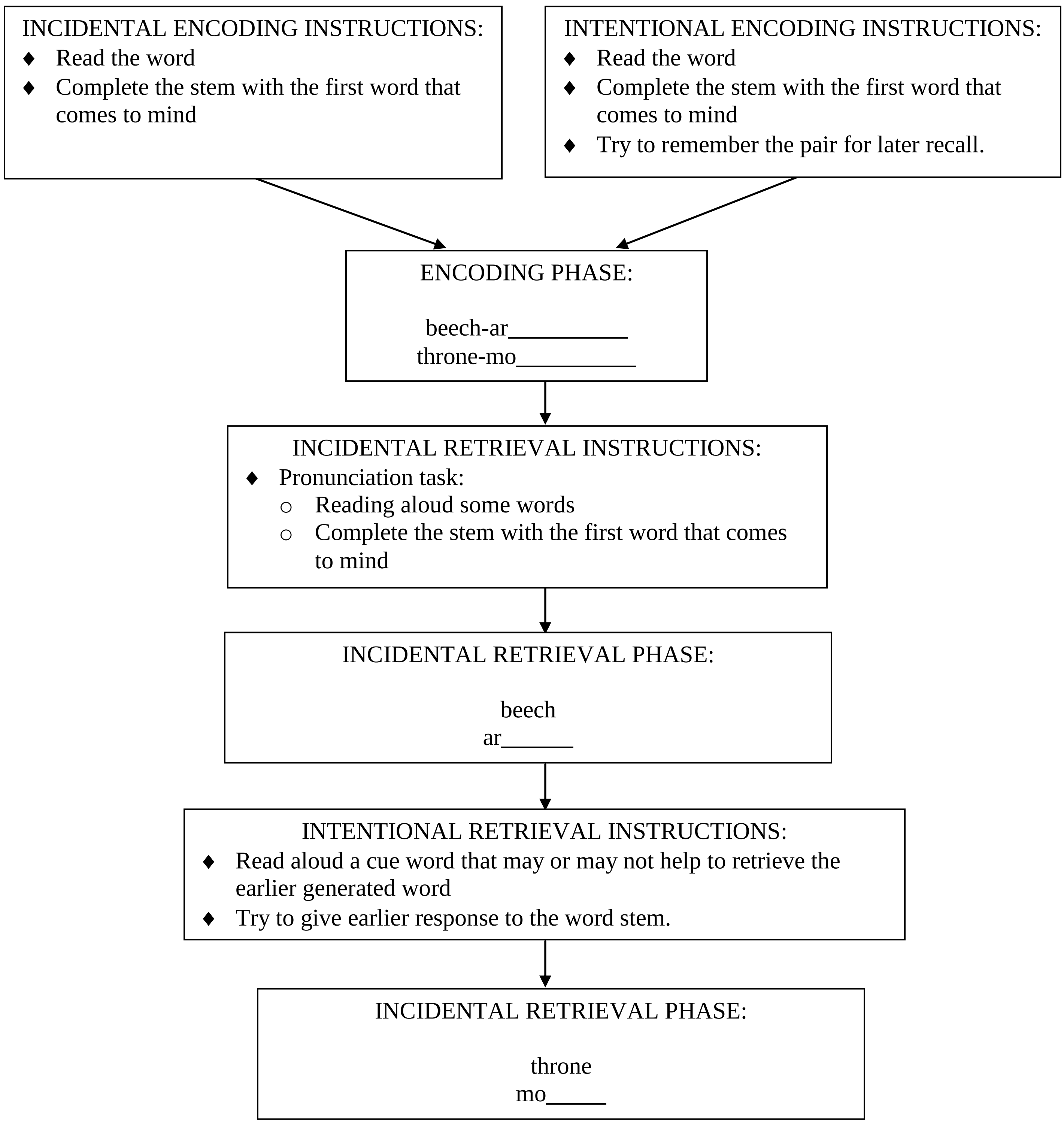
Age Group	Rating of 1 (no relationship)	Rating of 2	Rating of 3	Rating of 4	Rating of 5 (strongly related)
Young	60.5	11.1	10.9	9.3	8.2
Older	62.9	6.5	12.6	8.1	9.9

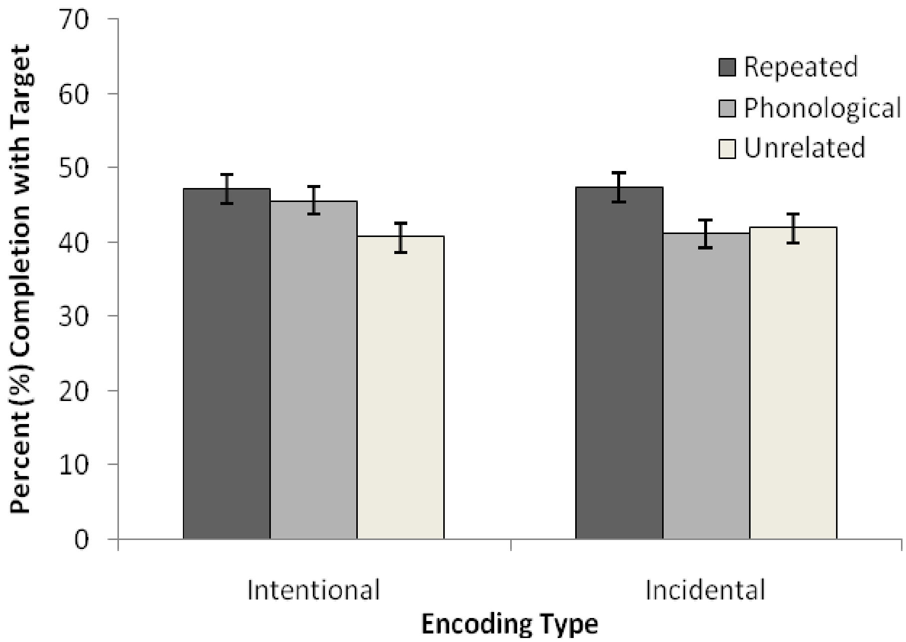
Figure Captions

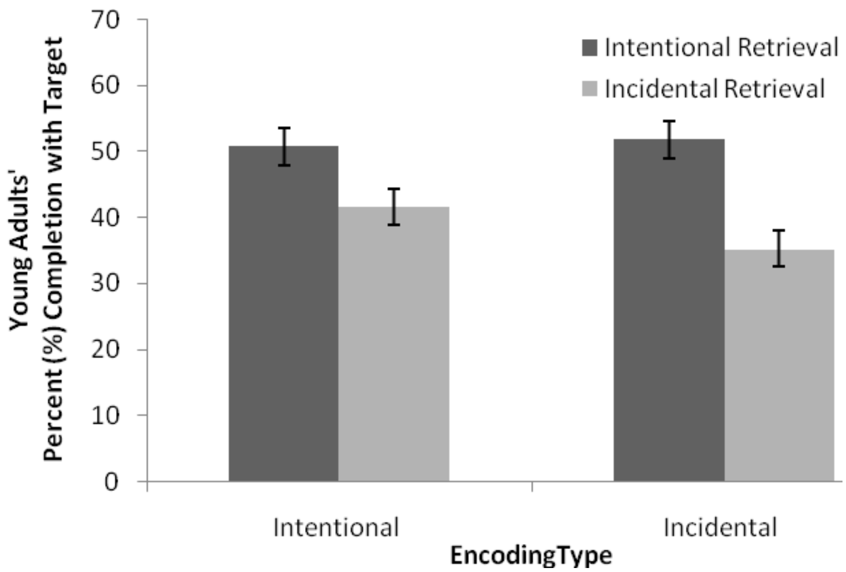
Figure 1. This flowchart illustrates the experimental procedure with a summary of instructions for each encoding and retrieval phase, as well as example paired word stems.

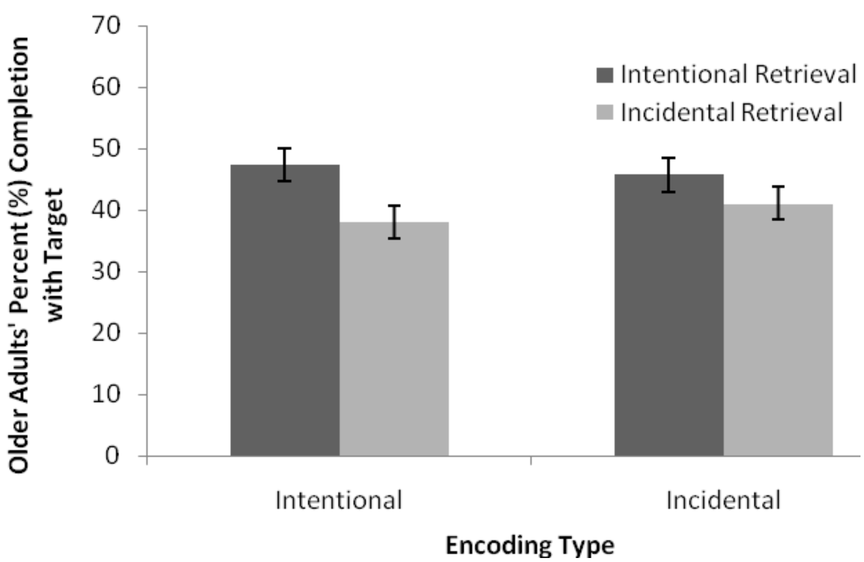
Figure 2. Mean percent of time the target word was produced at retrieval as a function of encoding type and prime/cue type.

Figure 3. Mean percent of time young (top) and older (bottom) adults produced the target word as a function of encoding type and retrieval type.


INCIDENTAL ENCODING INSTRUCTIONS:
♦ Read the word
♦ Complete the stem with the first word that comes to mind
INTENTIONAL ENCODING INSTRUCTIONS:
♦ Read the word
♦ Complete the stem with the first word that comes to mind
♦ Try to remember the pair for later recall.
ENCODING PHASE:
beech-ar___________
throne-mo___________
INCIDENTAL RETRIEVAL INSTRUCTIONS:
♦ Pronunciation task:
○ Reading aloud some words
○ Complete the stem with the first word that comes to mind
INCIDENTAL RETRIEVAL PHASE:
beech
ar_______
INTENTIONAL RETRIEVAL INSTRUCTIONS:
♦ Read aloud a cue word that may or may not help to retrieve the earlier generated word
♦ Try to give earlier response to the word stem.
INCIDENTAL RETRIEVAL PHASE:
throne
mo______


70
60
50
40
30
20
10
0
Percent (%) Completion with Target
Repeated
Phonological
Unrelated
Intentional
Incidental
Encoding Type


70
60
50
40
30
20
10
0
Young Adults'
Percent (%) Completion with Target
Intentional Retrieval
Incidental Retrieval
Intentional
Incidental
EncodingType


70
60
50
40
30
20
10
0
Older Adults' Percent (%) Completion
with Target
Intentional Retrieval
Incidental Retrieval
Intentional
Incidental
Encoding Type