Age-Related Associative Deficits are Absent with Nonwords

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We are grateful to Moshe Naveh-Benjamin for providing the stimuli for the words condition and helpful comments on an earlier report of this study, and to Laura Steel and Katherine Tyler for collecting the data for the words condition. This study was presented as a poster at the Cognitive Aging Conference, Atlanta, April 2010.

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Abstract

Words and nonwords were used as stimuli to assess item and associative recognition memory performance in young and older adults. Participants were presented with pairs of items and then tested on both item memory (old/new items) and associative memory (intact/recombined pairs). For words, older participants performed worse than young on item and associative tests but to a greater extent on the latter. In contrast, for nonwords, older participants performed equally worse than young on item and associative tests. This is the first study to demonstrate that a manipulation of stimulus novelty can alter age-related associative deficits.

Keywords: associative deficits, words, nonwords, aging, recognition memory

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It is well established that older adults show a general decline in memory performance when compared to young (e.g., Craik & Jennings, 1992). Furthermore, a variety of studies have shown that older adults have a specific impairment for associative memory (see Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995, for reviews). Thus older adults seem to experience particular difficulty in forming associations between items compared to remembering the items themselves, leading Naveh-Benjamin (2000) to propose an associative deficit hypothesis to explain age-related memory deficits. The focus in the current study is similarly on the comparison of age differences in item memory with age differences in associative memory. Note, however, the majority of studies demonstrating age-related associative deficits employ an item test for familiar information and an associative test for novel information. The current study therefore aimed to explore age differences in item vs. associative memory by directly manipulating the novelty of the memory stimuli.

Pre-Existing Knowledge

The greater age-related deficits observed for associations between items may be because inter-item associations are different to intra-item associations, namely, that they are completely new connections as opposed to pre-existing concepts reactivated. Indeed, this is the view proposed by Naveh-Benjamin, Hussain, Guez and Bar-On (2003) who stated that age-related associative deficits are most apparent in the formation of completely new associations. For example, a typical associative deficit memory measure is to present pairs of unrelated words and test for memory of the words themselves and also their pairings (e.g., Naveh-Benjamin, 2000, Exp. 2). The words (items) will have been seen by participants many times before and are therefore pre-existing in memory; however, the pairings of unrelated words are novel and unique associations. It would seem that superior item memory compared to associative memory may be due to reinforcement of item memory with pre-existing concepts. Therefore, it is hypothesized that older adults benefit more from pre-existing knowledge, resulting in reduced age deficits with item tests.

Several studies have demonstrated that age differences in associative memory are reduced when the associations are less novel. Naveh-Benjamin (2000, Exp. 4) and Naveh-Benjamin et al. (2003, Exp. 2) both showed a reduction in age differences for associative memory of semantically related words compared to semantically unrelated words. Likewise, Castel (2005) found that age differences in associating prices to products were reduced when the prices were normal market value compared to abnormal prices. Castel (2007) also found that age differences were smaller when remembering verbal associations between related objects and locations (e.g., hotels in the city) compared to unrelated objects and locations (e.g., nails in the bowl). Thus older adults seem able to use pre-existing knowledge to enhance associative memory, which reduces age differences. This conclusion also applies to at least one study of picture memory: Hess and Slaughter (1990) found that age differences were reduced when memorizing combinations of household objects in organized scenes compared with unorganized scenes. On the other hand, Gutchess and Park (2009) measured associative memory for objects situated in regular or irregular backgrounds (e.g., a cow in a farm or a laundry room). Regular combinations did not reduce age differences compared to irregular combinations when associating the objects to the backgrounds. With the exception of this last study with complex pictures, the literature generally indicates that memories formed with the support of pre-existing knowledge show reduced age differences.

Novel Stimuli

Several aging studies have demonstrated associative deficits in older adults with unfamiliar faces, which are novel stimuli (Bastin & Van der Linden, 2005; Bastin & Van der Linden, 2006; James, Fogler, & Tauber, 2008; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin et al., 2009; Rhodes, Castel, & Jacoby, 2008). Only four of these studies had comparable measures of both item and associative memory and were therefore able to demonstrate *larger* associative memory deficits than item memory deficits in older adults: Naveh-Benjamin et al. (2004; 2009) and Bastin and Van der Linden (2005) did not associate the faces to novel stimuli so only half of the stimuli were novel; Bastin and Van der Linden (2006) used pairs of unrelated faces, but item memory age differences were probably restricted by ceiling effects (proportion correct for item recognition was 0.93 for both young and older adults), making the comparison between item and associative memory age deficits difficult to interpret. A more important point is that none of these studies directly tested the effect of stimulus novelty on age-related associative deficits – that is, previous work did not compare both item and associative memory age differences between novel and familiar stimuli.

Of most relevance to the current study is Naveh-Benjamin (2000, Exp. 1), where word-nonword pairs produced age-related associative deficits: Age deficits in an associative memory test for word-nonword associations were significantly larger than age deficits in an item test, whether based on word or nonword recognition. Interestingly, the age-related associative deficit was smaller when nonwords were used as an item test compared to when words were used (age differences of .03, .23 and .36 for words, nonwords, and word-nonword associations, respectively), suggesting that the use of nonwords may have an influence on the size of age-related associative deficits.

The Current Study

In the current study, nonwords were used to remove the support of pre-existing knowledge for item memory. This would mean that when item memory and associative memory were compared, the memories formed would be equally novel across tests. Naveh-Benjamin et al. (2003, Exp. 2) reduced the novelty of associative memories by using semantically related words when comparing item and associative memory. The current study complements that design by *increasing* the novelty of the item memory measure in order to better compare it with the associative memory measure. In addition, the standard age-related associative deficits were reproduced with words for comparison to the nonwords data. Thus the study was designed to directly investigate the effect of stimulus novelty on age-related associative deficits.

Method

Participants

Twenty-four young adults (8 female, mean age = 21.0 years, mean education = 15.3 years) and 24 healthy older adults (15 female, mean age = 75.3, mean education = 13.0 years) took part in the words condition. Thirty young adults (18 female, mean age = 23.9, mean education = 15.5 years) and 30 healthy older adults (22 female, mean age = 74.3, mean education = 13.4 years) took part in the nonwords condition. Young adults were either volunteers or they participated in exchange for course credit. Older adults were recruited from the local community on a voluntary basis.

Materials and Procedure

In total, 476 different words (e.g., *contest*, *dancer*, *person*) were used in the words condition, varying from 3-11 letters in length (M = 6.30, SD = 1.11). They occurred with a mean frequency of use in the English language of 8.75 (SD = 1.74, range = 3.73-12.99), using log HAL frequency (Lund & Burgess, 1996). Also the words had 1.34 orthographic neighbors on average (*SD* = 1.91, range = 0-13).

For the nonwords condition, 90 pronounceable nonwords (e.g., *bligma*, *slanquil*, *tossens*) were selected from the English lexicon project (Balota et al., 2007). The nonwords were chosen for having no orthographic neighbors, 6-9 letters in length (*M* = 8.21, *SD* = 0.87), two syllables, and a high probability of being correctly identified as a nonword in a lexical decision task (*M* = 0.96, *SD* = 0.03, range = 0.90-1.00). Also, to ensure the nonwords were not too different to normal words, they were selected to have a long reaction time when being judged as nonwords in a lexical decision task (*M* = 883.11 ms, *SD* = 51.30).

Both the words and nonwords conditions used the same general procedure as that of Naveh-Benjamin (2000). Pairs of stimuli were sequentially presented on a computer screen and were followed by separate item and associative recognition memory tests. Participants were explicitly instructed to remember the stimuli and the associations between them for a later recognition test and they completed a short practice session before the main procedure. At encoding, pairs were presented in lower case in black font on a white background to the left and right of the center of a computer screen, with a clear separation between them. Stimulus order was randomized at both encoding and test. At test, stimuli were randomly assigned to either the item or associative tests. In addition, all word pairs were semantically unrelated.

For the words condition, each participant viewed 34 word pairs sequentially at a rate of one pair every 4 s. The first and last two pairs were buffers and memory was tested for the remaining 30 pairs. After presentation, there was a distracter task of counting backwards in threes for 60 s. Following this, the recognition tests commenced. The item test showed a single word on the screen which could be either an old word from the memory set or a completely new word; participants judged if the word was old or new. The item test had 40 trials, with 20 old words and 20 new words. The associative test showed either an old pair of words that was previously presented in the memory set or a recombined pair of words with one word from one pair and one word from another pair of the original memory set (preserving their left/right locations). The associative test had 20 trials, with 10 intact and 10 recombined pairs. The tests were counterbalanced so that half of the young and half of the older participants received the item test before the associative test and vice versa for the other half.

Pilot testing revealed that nonwords were more difficult to remember so they were presented slightly differently to avoid floor effects. Thus, 21 pairs of nonwords were shown sequentially at a rate of 5 s per pair, and then repeated a total of three times with the exact same order and rate. There was a 10-s gap between repetitions and participants were made explicitly aware that the same stimuli would be seen three times. In addition, two buffer nonwords were placed one at the very beginning and one at the very end of the repetition sequence; memory for these was not tested. After the memory set presentation, participants counted backwards in threes for 60 s, and then item and associative tests were conducted in the same way as for the words condition. With fewer stimuli presented, the item test consisted of 28 items (14 old and 14 new) and the associative test consisted of 14 pairs (7 intact and 7 recombined). The order of item and associative tests was again counterbalanced between participants.

Results

Data Preparation

From correct and erroneous recognition responses to old and new stimuli, signal detection measures of d' (performance sensitivity) and β (response bias) were computed for each participant (see Snodgrass & Corwin, 1988, for more detail). For analytical purposes, ln(β) was used; ln(β) provides a negative value for bias towards yes/seen-before responses and a positive value for bias towards no/not-seen-before, with zero indicating no response bias. Analyses were also conducted on the proportion of hits minus the proportion of false alarms but these produced qualitatively identical patterns of results.

Prior to the main analyses, the effects of test order were assessed. Participants receiving the item test before the associative test did not respond differently to participants receiving the associative test before the item test. Therefore, the following analyses were conducted without a test order factor.

Main Analysis

A 2 (Age: young, old) x 2 (Test: item, associative) x 2 (Stimuli: words, nonwords) repeated measures ANOVA was conducted on the d' data (see Figure 1 for means[1]). Age and stimuli were between-subjects factors and test was a within-subjects factor. Young participants performed better than older participants, $F(1, 104) = 49.56$, $MSE = 0.74$, $p < .001$, and item test performance was higher than associative test performance, $F(1, 104) = 177.11$, $MSE = 0.30$, $p < .001$. Performance was marginally higher in the nonwords condition than in the words condition, $F(1,104) = 3.56$, $MSE = 0.74$, $p = .06$, and there was an interaction between test and stimuli, $F(1, 104) = 16.70$, $MSE = 0.30$, $p < .001$, such that associative memory was similar for words and nonwords whereas item memory was higher for nonwords than for words. This was probably because nonwords had no pre-existing concepts in memory – when recognizing a nonword item there was no interference from pre-existing knowledge when making an old/new judgment.

Crucially, the three-way interaction between age, test, and stimuli was significant, $F(1, 104) = 4.35$, $MSE = 0.30$, $p < .05$, suggesting that associative deficits were significantly more evident in the words condition than in the nonwords condition. This was confirmed by separate

ANOVAs for each condition. With words, typical age-related associative deficits were present, as indicated by an age (young, older) by test type (item, associative) interaction, $F(1, 46) = 9.65$, $MSE = 0.19$, $p < .01$; older participants performed worse than young in both tests but to a greater extent in the associative test. With nonwords, this interaction was completely absent, $F < 1$, demonstrating no age-related associative deficit with the novel stimuli (i.e., older participants performed worse than young to the same extent on item and associative tests).

It could be argued that the absence of an associative deficit for nonwords is a consequence of floor effects in older adults. To explore this possibility, further analyses were conducted excluding participants performing at floor on associative tests as indicated by hit rates not exceeding false alarm rates. More older participants hit floor than young, so to ensure that exclusions were equivalent across age groups, all older participants performing at floor on the associative test were removed, and then the same number of young participants were also removed by selecting the worst associative performers (see Naveh-Benjamin et al., 2009, for a similar procedure). For nonwords, 12 out of 30 older participants (40%) did not perform above floor; for words, 5 out of 24 older participants did not perform above floor. In order to exclude the same proportion of participants from every condition, the worst 40% of associative test performers were removed from the words and nonwords data in both age groups. When the above analysis was repeated with the worst associative performers removed, the pattern of results was qualitatively identical, with the crucial three-way interaction increased in significance, $F(1, 60) = 7.39$, $MSE = 0.17$, $p < .01$. For words, age differences in d' were 0.88 for items and 1.54 for associations; for nonwords, age differences in d' were 0.86 for items and 0.71 for associations.

Response Bias

An Age x Test x Stimuli repeated measures ANOVA was also conducted on the ln(β) data (see Figure 2 for means). There was no main effect of age, $F < 1$. Responses were more biased towards no/not-seen-before for item than for associative tests, $F(1, 104) = 23.94$, $MSE = 0.29$, $p < .001$, and for words than for nonwords, $F(1, 104) = 17.57$, $MSE = 0.41$, $p < .001$. There was a Test x Stimuli interaction, $F(1, 104) = 8.59$, $MSE = 0.29$, $p < .01$, indicating that for nonwords, participants showed only a small bias for item and associative tests, but for words, there was a large bias towards no/not-seen-before responses in the item test but a less biased response in the associative test. The Age x Stimuli interaction was significant, $F(1, 104) = 5.13$, $MSE = 0.41$, $p < .05$, as young participants showed a larger difference in response bias between conditions than did older participants. Finally, the three-way interaction approached significance, $F(1, 104) = 3.84$, $MSE = 0.29$, $p = .05$. With the worst associative performers removed, the Age x Stimuli interaction was no longer significant, $p = .16$, and the three-way interaction completely disappeared, $F < 1$.

Task Difficulty

For a stronger test of the lack of age-related associative deficits with nonwords, we attempted to more closely match young and older adults on item memory performance by adjusting task difficulty. An additional 20 young participants (16 female, mean age = 19.9 years, mean education = 13.9 years) completed a slightly more difficult version of the nonwords condition: Instead of seeing the memory set three times, they only saw it twice. This successfully reduced their mean d' scores to 2.21 ($SD = 1.05$) and 0.73 ($SD = 0.82$) on item and associative tests, respectively. These data were compared to the original older participants' data where the memory set was seen three times, with a 2 (Age: young, old) x 2 (Test: item, associative) repeated measures ANOVA. Item test performance was higher than associative test performance,

$F(1, 48) = 85.64$, $MSE = 0.53$, $p < .001$. There was no longer any main effect of age, $F(1, 48) = 2.34$, $MSE = 0.95$, $p = .13$, and importantly still no interaction between age and test, $F < 1$.

Discussion

The current study provides evidence that young and older adults differentially remember familiar and unfamiliar stimuli. This difference in familiarity between words and nonwords can be seen as a difference in the amount of pre-existing knowledge related to the stimuli. The words condition produced typical age-related associative deficits, with age differences greater for associative memory than for item memory. However, when unfamiliar nonwords were used with the same types of memory tests, age differences were constant between associative and item memory. It is therefore suggested that age-related associative deficits with words are observed because the item test is for concepts supported by pre-existing knowledge while the associative test is for completely new concepts: Age differences on the item test for words are reduced compared to associative memory age differences because older participants can use pre-existing knowledge of the words to support memory formation. This view is shared by MacKay and Burke (1990), who proposed a commitment learning principle whereby age differences in memory formation are smaller when fewer new connections are required. In their chapter, they discussed a variety of evidence showing that older adults produce smaller age differences in word memory tasks when they can use pre-existing knowledge (referred to as engrainment learning) to support the encoding of information.

One issue regarding this explanation is that for the nonwords item test, the age difference was similar to that of the words item test despite a lack of pre-existing knowledge for nonwords. It could therefore be argued that older adults were not benefiting from pre-existing knowledge in the words item test as we would expect to see a larger age deficit in item memory when using the novel nonwords. Note, however, that the experimental design was not suited to such direct comparisons between the conditions; this is explored in more detail later in the discussion.

Alternatively, the data can be viewed in terms of dual process models of memory, which could account for the full pattern of results including the above issue. In dual process models, familiarity and recollection are considered as different memory processes (see Yonelinas, 2002, for review). Familiarity is seen as more automatic, providing a sense that a given stimulus has been encountered before following a recognition probe, whereas recollection is seen as controlled conscious retrieval of specific episodic experiences. Dual process models commonly assume that during recognition memory tasks, when the level of familiarity/unfamiliarity in memory is ambiguous, a further recollection based memory search is required before a response can be made (Yonelinas, 2002). Familiarity based processes are considered sufficient to complete an item test whereas associative tests are more reliant on recollection based processes (Healy, Light, & Chung, 2005; Old & Naveh-Benjamin, 2008).[2] This could explain why age deficits are often smaller for item tests than for associative tests because age deficits are typically smaller for recognition (familiarity based memory) than for recall (recollection based memory) (e.g., Craik & McDowd, 1987; Light, Prull, La Voie, & Healy, 2000; Naveh-Benjamin, 2000; Schonfield & Robertson, 1966). It may be the case that the nonwords condition of the current experiment differs from the words condition in terms of its relative reliance on familiarity vs. recollective processes. In particular, it seems more likely that recollection would contribute to associative memory for words than for nonwords because of the former’s greater pre-existing semantic knowledge. For example, unrelated word pairs such as *contest--dancer* may nevertheless evoke a specific mental image at encoding that can be recollected at test whereas nonword pairs such as *bligma--slanquil* are unlikely to do so. Thus age-related associative deficits would be larger with words than with nonwords. As can be seen in Figure 1, age differences were largest for associative memory with words but were smaller for item memory with words and both item and associative memory with nonwords. It may be that all of the tests are based largely on familiarity except for the words associative test.

A related point to note is that young adults are generally more likely than older adults to implement encoding strategies (e.g., Luszcz, Roberts, & Mattiske, 1990; Witte, Freund, & Sebby, 1990). However, it is possible that young adults are unable to implement an encoding strategy for associating nonwords as easily as for words. This may equate young and older adults on the implementation of encoding strategies because neither group is likely to incorporate an encoding strategy with nonwords. Thus, the nonwords condition may actually provide a 'purer' test of the associative deficit hypothesis.

Young and older participants showed similar patterns of response bias. However, the item test for words showed a bias towards no/not-seen-before whilst the other tests were relatively unbiased. This is noteworthy because it was the only test conducted that involved the recognition of concepts that were pre-existing in memory prior to the experiment. Participants may therefore have been less confident (and hence more cautious) in responding yes/seen-before in the words item memory test because pre-existing knowledge was available for both old *and* new words at test.

A potential problem with the current experimental design is that in the words condition, only one presentation of the memory set occurred but with nonwords there were three. This is problematic as it invalidates any direct comparison of overall performance levels between the two conditions; however, the comparison of age-related associative deficits remains valid. Overman and Becker (2009) observed that repetition of a memory set benefited both young and older participants for item memory but just young participants for associative memory. Similar studies of associative memory have shown that older adults benefit equally to young from repetition (Kornell, Castel, Eich, & Bjork, 2010) or less than young from repetition (Light, Patterson, Chung, & Healy, 2004). Several studies have also shown that young and old benefit equally from spacing compared to massed presentation of associative memory stimuli (e.g., Balota, Duchek, Sergent-Marshall, & Roediger, 2006; Benjamin & Craik, 2001; Logan & Balota, 2008). Therefore, the (spaced) repetition of the memory set in the current nonwords condition should have either increased age-related associative deficits or left them unchanged. This literature suggests that repetition is unlikely to account for the absence of age-related associative deficits with nonwords. In addition, the effect of repetition was analyzed by comparing the nonwords data from the young groups with two vs. three repetitions. There was a significant benefit from the additional repetition but this was equivalent for item and associative tests as indicated by no interaction between repetitions and test type, $F < 1$. Overall there are many studies demonstrating age-related associative deficits with different experimental parameters and there is no evidence to suggest that varying the numbers of repetitions, presentation rates, or memory set sizes would eliminate age-related associative deficits.

Finally, the present results raise an interesting issue of how to categorize an ‘item’. It could be argued that the nonword items required associative memory because participants had to associate the first syllable with the second syllable to remember each of them. Thus, the pattern of results could be explained in terms of associative deficits – the absence of age-related associative deficits with nonwords could be due to both ‘item’ and associative memory being ultimately associative in this case. However, such an explanation implies a reconsideration of what is meant by an item. Perhaps an item is not a unit of information that is presented and remembered but rather a unit of information that can be represented by a single pre-existing concept. Therefore, understanding age-related associative deficits could lead to insight into how pre-existing knowledge is used to encode memory and why this process is more robust against the aging process.

References

Balota, D. A., Duchek, J. M., Sergent-Marshall, S. D., & Roediger, H. L., III. (2006). Does expanded retrieval produce benefits over equal-interval spacing? Explorations of spacing effects in healthy aging and early stage Alzheimer's disease. *Psychology and Aging, 21*, 19-31.

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., et al. (2007). The English lexicon project. *Behavior Research Methods, 39*, 445-459.

Bastin, C., & Van der Linden, M. (2005). Memory for temporal context: Effects of ageing, encoding instructions, and retrieval strategies. *Memory, 13*, 95-109.

Bastin, C., & Van der Linden, M. (2006). The effects of aging on the recognition of different types of associations. *Experimental Aging Research, 32*, 61-77.

Benjamin, A. S., & Craik, F. I. M. (2001). Parallel effects of aging and time pressure on memory for source: Evidence from the spacing effect. *Memory & Cognition, 29*, 691-697.

Castel, A. D. (2005). Memory for grocery prices in younger and older adults: The role of schematic support. *Psychology and Aging, 20*, 718-721.

Castel, A. D. (2007). Aging and memory for numerical information: the role of specificity and expertise in associative memory. *Journal of Gerontology: Psychological Sciences, 62B*, P194-P196.

Craik, F. I. M., & Jennings, J. M. (1992). Human memory. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 51-110). Hillsdale, NJ: Lawrence Erlbaum.

Craik, F. I. M., & McDowd, J. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 474-479.

Gutchess, A. H., & Park, D. C. (2009). Effects of ageing on associative memory for related and unrelated pictures. *European Journal of Cognitive Psychology, 21*, 235-254.

Healy, M. R., Light, L. L., & Chung, C. (2005). Dual-process models of associative recognition in young and older adults: Evidence from receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*, 768-788.

Hess, T. M., & Slaughter, S. J. (1990). Schematic knowledge influences on memory for scene information in young and older adults. *Developmental Psychology, 26*, 855-865.

James, L. E., Fogler, K. A., & Tauber, S. K. (2008). Recognition memory measures yield disproportionate effects of aging on learning face-name associations. *Psychology and Aging, 23*, 657-664.

Kornell, N., Castel, A. D., Eich, T. S., & Bjork, R. (2010). Spacing as the friend of both memory and induction in young and older adults. *Psychology and Aging, 25*, 498-503.

Light, L. L., Patterson, M. M., Chung, C., & Healy, M. R. (2004). Effects of repetition and response deadline on associative recognition in young and older adults. *Memory & Cognition, 32*, 1182-1193.

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: Oxford University Press.

Logan, J. M., & Balota, D. A. (2008). Expanded vs. equal interval spaced retrieval practice: Exploring different schedules of spacing and retention interval in younger and older adults. *Aging, Neuropsychology, and Cognition, 15*, 257-280.

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior Research Methods, Instruments, & Computers*, *28*, 203-208.

Luszcz, M. A., Roberts, T. H., & Mattiske, J. (1990). Use of relational and item-specific information in remembering by older and younger adults. *Psychology and Aging, 5*, 242-249.

MacKay, D. G., & Burke, D. M. (1990). Cognition and aging: A theory of new learning and the use of old connections. In T. M. Hess (Ed.), *Aging and cognition: Knowledge organization and utilization* (pp. 213-263). North-Holland: Elsevier.

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

Naveh-Benjamin, M., Guez, J., Kilb, A., & Reedy, S. (2004). The associative memory deficit of older adults: Further support using face–name associations. *Psychology and Aging, 19*, 541-546.

Naveh-Benjamin, M., Hussain, Z., Guez, J., & Bar-On, M. (2003). Adult age differences in episodic memory: Further support for an associative-deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 826-837.

Naveh-Benjamin, M., Shing, Y. L., Kilb, A., Werkle-Bergner, M., Lindenberger, U., & Li, S-C. (2009). Adult age differences in memory for name-face associations: The effects of intentional and incidental learning. *Memory, 17*, 220-232.

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychology and Aging, 23,* 104-118.

Overman, A. A., & Becker, J. T. (2009). The associative deficit in older adult memory: Recognition of pairs is not improved by repetition. *Psychology and Aging, 24*, 501-506.

Rhodes, M. G., Castel, A. D., & Jacoby, L. L. (2008). Associative recognition of face pairs by younger and older adults: The role of familiarity-based processing. *Psychology and Aging, 23*, 239-249.

Schonfield, D., & Robertson, B. A. (1966). Memory storage and aging. *Canadian Journal of Psychology, 20*, 228-236.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*, 34-50.

Spencer, W. D., & Raz, N. (1995). Differential effects of aging on memory for content and context: A meta-analysis. *Psychology and Aging, 10*, 527-539.

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

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, *46*, 441-517.

Footnotes

[1]Means (and standard deviations) for hit rates minus false alarm rates for words were: young item = 0.60 (0.17), young associative = 0.51 (0.26), old item = 0.44 (0.14), old associative = 0.14 (0.17). For nonwords, they were: young item = 0.78 (0.13), young associative = 0.43 (0.29), old item = 0.58 (0.20), old associative = 0.19 (0.30).

[2] Note that the associative test was specifically designed to minimize reliance on familiarity in the recognition process: The associative recognition test always showed familiar (seen before) items in pairs and the test was to establish if the *combination* of those items was intact or recombined. Therefore intact and recombined test pairs would evoke similar levels of familiarity which, in line with dual process models, would require recollection processes to produce a correct response.

Figure 1. Young and older participants' d' memory performance for item and associative tests with words (left) and nonwords (right). Error bars represent ±1 standard error of the mean.

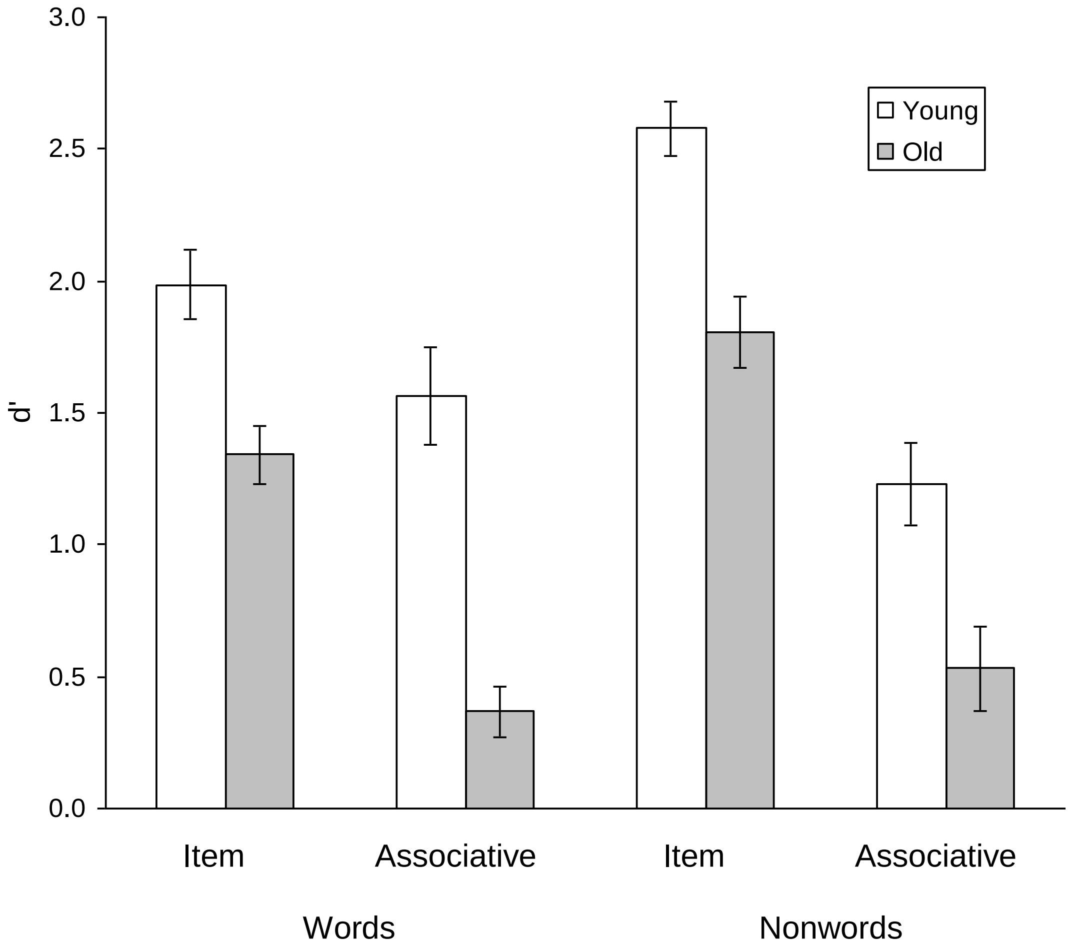

Figure 2. Young and older participants' response bias (ln(β)) for item and associative tests with words (left) and nonwords (right). Error bars represent ±1 standard error of the mean.