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Age Differences in Memory for Meaningful and Arbitrary Associations: A Memory Retrieval Account

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Older adults typically show poor associative memory performance relative to younger adults. This age-related effect, however, is mediated by the meaningfulness of the materials used, such that age differences are minimized with the use ofinformation that is consistent with prior knowledge. While this effect has been interpreted as facilitative learning through schematic support, the role of memory retrieval on this effect has yet to be explored. Using an associative memory paradigm that varied the extent of controlled retrieval for previously studied meaningful or arbitrary associations, older and younger adults in the present study retrieved realistic and unrealistic grocery item prices in a speeded, or in a slow, more control-based retrieval condition. There were no age differences in memory for realistic (meaningful) prices in either condition; however, younger adults showed better memory than older adults for unrealistic prices in the controlled retrieval condition only. These results suggest that age differences in memory for arbitrary associations can, at least partly, be accounted for by age reductions in strategic, controlled retrieval.

Keywords: associative memory, aging, controlled retrieval

Older adults typically show reduced episodic memory relative to younger adults (e.g., Craik, 1986; Hoyer & Verhaeghen, 2006). This age difference has been attributed, in part, to difficulties integrating or binding individual elements of a to-be-remembered episode into a single cohesive unit (i.e., "associative memory deficits"; e.g., Chalfonte & Johnson, 1996; Lyle, Bloise, & Johnson, 2006; Mitchell, Johnson, Raye, & D'Esposito, 2000; Naveh-Benjamin, 2000). Research has demonstrated, however, that older adults do not have reduced memory on all associative memory tasks. Instead, performance of older adults is moderated by the meaningfulness of the materials used and their consistency with prior knowledge, such that age differences are minimized for naturally co-occurring elements compared with unrelated, arbitrary units (e.g., unrelated word or face-name pairs).

An example of this effect of meaningfulness or prior knowledge is the finding that older and younger adults show equivalent associative memory for semantically related word pairs relative to random, unrelated pairs (Naveh-Benjamin, 2000; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005; Patterson, Light, Van Ocker, & Olfman, 2009). Similarly, on source memory tasks, both age groups show similar performance when arbitrary pairings are given an important versus unimportant context (May, Rahhal, Berry, & Leighton, 2005; Rahhal, May, & Hasher, 2002), or when information about a person matches versus mismatches a stereotype (Mather, Johnson, & De Leonardis, 1999). Most relevant to the current study, older adults are poorer than younger adults in learning the association between a familiar product and an unrealistic price for that product, although they are not at a disadvantage when the price is a realistic one that is consistent with prior knowledge (Castel, 2005; see also Mohanty, Naveh-Benjamin, & Ratneshwar, 2016).

These findings have traditionally been explained as facilitative learning through "schematic support," or enhanced learning from well-established forms of knowledge (e.g., Bartlett, 1932; Brewer & Treyens, 1981). That is, existing knowledge may aid in the incorporation and organization ofincoming information that is consistent with it, resulting in a boost to older adults' learning and memory (e.g., Castel, 2005, 2007; McGillivray & Castel, 2010; Mohanty et al., 2016; see Umanath & Marsh, 2014 for a discussion). While this argument is consistent with findings suggesting

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that older adults generally rely on prior knowledge across a range of tasks (Umanath & Marsh, 2014), it is possible that age-related differences in retrieval can also account for older adults' worse memory for arbitrary relative to meaningful associations. Older adults show worse performance on strategy-based memory retrieval tasks that demand high levels of control, relative to those that demand lower levels of control (e.g., Dywan & Jacoby, 1990; Jennings & Jacoby, 1993). Recollection processes involved in these tasks, such as memory search, elaboration of retrieval cues, suppression of competitors, and postretrieval monitoring (Moscovitch, 1994; Yonelinas, 2002) all show decrements with age (e.g., Healey, Ngo, & Hasher, 2014; Light, Patterson, Chung, & Healy, 2004).

Evidence of retrieval difficulties in associative learning and memory tasks comes from studies using a pair recognition task. These tasks typically include pairs seen previously in the experiment (often called intact) and pairs that use old items that are recombined. Relative to younger adults, older adults show similar hit rates for intact pairs and poorer performance on recombined pairs, suggesting retrieval difficulties (Castel & Craik, 2003; Cohn, Emrich, & Moscovitch, 2008; Healy, Light, & Chung, 2005). Similarly, when the task is to distinguish between old word pairs (regardless of whether intact or recombined) and pairs containing at least one new word, older and younger adults show similar accuracy and response speed advantages when responding to intact compared with recombined old word pairs (Cohn et al., 2008).

Research using implicit and/or speeded retrieval tasks also suggests the possibility that associative deficits may occur at retrieval. Using an implicit associative recognition task in which participants made speeded associative judgments about unrelated objects (whether they are together smaller than a referent object), Dew and Giovanello (2010) found equal associative priming for repeated intact pairs relative to recombined pairs in older and younger adults. By contrast, typical age differences in associative memory were seen when an explicit associative recognition task was used (see also Naveh-Benjamin, Shing, Kilb, Werkle-Bergner, Lindenberger, & Li, 2009). We note particularly that speeded responding as used in the Dew and Giovanello (2010) study is widely thought to limit the use of strategic retrieval and increase reliance on familiarity or on more automatic retrieval processes (Yonelinas, 2002).

Taken together, the described studies suggest that age-related deficits in controlled, strategic retrieval may contribute to older adults' reduced associative memory for arbitrary associations. In the current study, we investigate the role of memory retrieval on age differences in associative memory for newly learned meaningful relative to arbitrary associations. Using a paradigm adapted from Castel (2005), older and younger adults learned realistic (consistent with prior knowledge) and unrealistic prices of grocery store items. In one condition, participants retrieved the prices in a speeded two-alternative forced-choice recognition task, and in another condition, participants retrieved the prices in a slowed version of the same recognition task, which allowed for the engagement of cognitive control. Participants made confidence judgments while selecting the correct price in both conditions. In contrast to other paradigms that use semantically related words with preexisting associations (e.g., chair-table) as the basis for prior knowledge (e.g., Patterson et al., 2009), the current paradigm requires participants to form new associations for all stimuli, regardless of whether they are consistent or inconsistent with prior knowledge. That is, even for item pairs that are consistent with prior knowledge, participants cannot rely on preexisting associations as the price for a realistic item can fall within a range of expected prices (i.e., the only difference between the item types is whether they are meaningful or congruous with prior knowledge representations). We hypothesized that if controlled retrieval, at least partially, accounts for older adults' reduced memory for arbitrary associations, then age differences in memory and confidence ratings for unrealistic prices should be seen in the controlled, but not speeded, retrieval condition. We predicted that controlled retrieval demands should be indexed by an increase in response time for unrealistic compared with realistic prices, at least in younger adults. We did not predict the same response time patterns (and had no predictions) for older adults, given the evidence of reduced controlled retrieval, even with long or no imposed time limits (Light et al., 2004). Finally, no age differences in memory or confidence ratings for realistic prices were expected in either condition.

Method

Participants

A total of 146 older and younger adults were recruited for the study. Seventy participants (36 younger adults, $M = 20.17$ years, $SD = 3.34$, 7 male and 34 older adults, $M = 68.56$ years, $SD = 4.77$, 11 male) were randomly assigned to the speeded retrieval condition, and 76 participants (40 younger adults, $M = 18.95$ years, $SD = 1.32$, 7 male and 36 older adults, $M = 69.89$ years, $SD = 4.15$, 15 male) were assigned to the controlled condition. The younger adults were students at the University of Toronto and received course credit for their participation. The older adults were recruited from the community and received monetary compensation. All participants were familiar with local grocery pricing and went grocery shopping a minimum of twice a month based on self-report.

All older adults were cognitively intact, as demonstrated by their scores on the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975; $M = 28.91$, $SD = 1.43$), Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005; $M = 26.63$, $SD = 2.90$), and Short Blessed Test (SBT; Katzman et al., 1983; $M = 1.17$, $SD = 1.70$). The older adults ($M = 17.82$, $SD = 4.94$) had more years of education than the younger adults ($M = 13.31$, $SD = 1.95$), $t(142) = 7.36$, $p < .0001$, and had higher vocabulary scores on the Shipley-2 (Shipley, Gruber, Martin, & Klein, 2009) test (older adults: $M = 34.54$, $SD = 4.84$; younger adults: $M = 27.76$, $SD = 5.39$), $t(142) = 7.93$, $p < .0001$, as would be expected given the growth of vocabulary with age (e.g., Park et al., 2002). Younger adults in the two retrieval conditions showed no differences in years of education or vocabulary scores, p values $> .6$. Older adults in the two conditions showed no differences in years of education, vocabulary, MoCA, or SBT scores (after using Bonferroni correction for multiple comparisons), p values $> .1$; however, older adults in the speeded condition ($Mdn = 30$) showed slightly higher MMSE scores than older adults in the controlled condition ($Mdn = 29$), $U = 385$, $z = 2.86$, $p < .005$ (Mann–Whitney tests were used as scores were not normally

distributed).[1] Education data were missing from 2 older adults, and vocabulary scores were missing from 2 younger adults. Two older adults (one from each retrieval condition) who scored below 50% accuracy on both realistic and unrealistic trials were replaced. Four older adults who failed to respond on more than 30% of the trials on the speeded condition (M = 45% of trials missed) were also replaced. All experimental protocols were reviewed and approved by the ethics committee of the University of Toronto.

Stimuli

Eighty pictures of common grocery store items were used in the study. Forty of the items were presented with realistic prices, and the other 40 were presented with unrealistic prices. The items were counterbalanced, such that each item was equally likely to be presented with a realistic or unrealistic price (i.e., half the participants saw a set of items with realistic prices and the other half saw the same set of items with unrealistic prices and vice versa). Realistic prices were selected on the basis of several local grocery stores (an average price was chosen), and unrealistic prices were selected by increasing each item's price by a random value between $8 and $14 using a random number generator. Realistic prices ranged from $1.19 to $11.99, and unrealistic prices ranged from $9.49 to $23.99. As in Castel (2005), all prices ended in the digit 9. Each item was presented individually at the center of the screen, and the name of the item was displayed above the item in 18-point Courier New font. During encoding, each item's corresponding price was shown above the item, adjacent to its name. During retrieval, two prices were displayed below each item (one on the right and one on the left); the price previously paired with the item (i.e., the correct answer) was equally likely to occur on the right or left.

Procedure

The task was performed in two study-test phases, such that the 80 items were divided into two encoding and retrieval phases presented alternately (i.e., 40 items – 20 realistic and 20 unrealistic—were presented in encoding-retrieval phase 1, and the remaining 40 items were presented in phase 2). The items at encoding and retrieval were divided into realistic and unrealistic 5-item blocks presented in alternating order (realistic always presented first). The order of the blocks was fixed across participants. The items within each block were also fixed but presented in a random order for each participant. The interstimulus interval (ISI) varied randomly between 500 and 3,500 ms within each block, and there was a 14-s fixation period between blocks. Each item was presented for 4 s at encoding. During retrieval, each item was presented for 6 s in the slower condition and for 4 s in the faster condition—a time that we believed would limit controlled retrieval, given the somewhat complex test task (described below). We refer to the slower condition as a "controlled" or "control-based" condition based on earlier work indicating that strategic retrieval is sensitive to response speeding (Yonelinas, 2002), and not due to manipulations, such as strategy instruction, that attempt to directly control the type of retrieval process that participants employ. Participants in the 4-s condition were informed that items at retrieval would be presented rapidly, and that they should respond as accurately as possible. Participants in the 6-s condition were also told to respond as accurately as possible. The two choices at retrieval were always close in value, such that both choices were either realistic or unrealistic (i.e., encoding the items categorically would not aid performance).

Prior to encoding, participants were instructed to remember the exact price for each item, regardless of whether it was realistic or unrealistic and were informed of the nature of the recognition task. During retrieval, participants selected the price on the left or right below each item and additionally rated whether each choice was made with high or low confidence. Specifically, participants used "Q" and "W" keys on the left side of the keyboard to select the price on the left and the "O" and "P" keys on the right side to select the price on the right. The "Q" and "O" keys were labeled "1" for high confidence, and the "W" and "P" keys were labeled "2" for low confidence. Hence, on each retrieval trial, participants pressed one of four keys. At the end of the testing session, participants completed a background questionnaire and the Shipley-2 (2009) vocabulary test, and older adults were additionally administered the MMSE, SBT, and MoCA.

Results

Trials with no responses and trials with a reaction time (RT) faster than 250 ms (unintentional responses) were first eliminated from all analyses (younger adults: 2% of all trials due to misses and 0.03% due to unintentional responses; older adults: 7.4% due to misses and 0.2% due to unintentional responses).[2] Accuracy, RT for correct trials, and the proportion of correct responses made with high confidence were each analyzed by conducting a 2 × 2 × 2 mixed analysis of variance (ANOVA) with Age (young and old) and Retrieval condition (4 s and 6 s) as between-subjects variables and Item Type (realistic and unrealistic) as a within-subjects variable. RT for correct trials was winsorized at the 90% level per subject and trial type by replacing the top and bottom 5% of trials with the 95th and 5th percentile, respectively.

Accuracy

Accuracy data are shown in Figure 1. Accuracy for the different item types in both conditions was significantly greater than 50% for younger and older adults, p values $< .0001$. The three-way ANOVA showed main effects of age, $F(1, 142) = 11.18$, $p < .005$, $\eta_p^2 = .07$, with better performance by younger adults, and item type, $F(1, 142) = 85.95$, $p < .0001$, $\eta_p^2 = .38$, with better performance on realistic trials, and significant interactions between age and item type, $F(1, 142) = 4.88$, $p < .05$, $\eta_p^2 = .03$, and retrieval condition and item type, $F(1, 142) = 7.75$, $p < .01$, $\eta_p^2 = .05$. Critically, the three-way interaction between age, retrieval condition, and item type was significant, $F(1, 142) = 5.25$, $p < .05$, $\eta_p^2 = .04$, suggesting that age differences in performance on

[1] Controlling for MMSE scores between the two older adult groups did not affect any of the reported results. Specifically, ANCOVAs (with MMSE scores as a covariate) on the older adult data with retrieval condition as a between-subjects variables and item type as a within-subjects variable, as expected, showed no significant interactions between the two variables for accuracy, RT, or confidence ratings, p values $> .3$ (see Results for more details).

[2] There were no differences in the proportion of missed responses between item types for both younger and older adults, p values $> .9$.

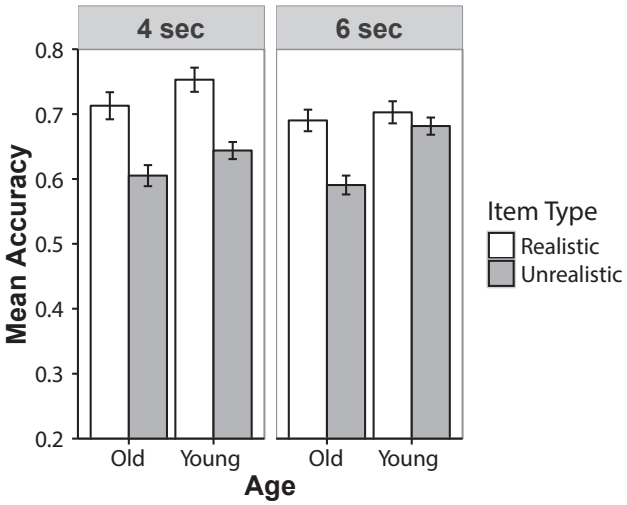

Figure 1. Memory for realistic and unrealistic prices in the two retrieval conditions in older and younger adults. Error bars represent standard errors of the mean.

the different item types depended on the retrieval condition. The main effect of retrieval condition and the interaction between age and retrieval condition were not significant, F values < 1. Separate two-way ANOVAs on age and item type were subsequently conducted for each retrieval condition. The analysis on the slower retrieval condition showed main effects of age, $F(1, 74) = 8.26$, $p < .01$, $\eta_p^2 = .10$, and item type, $F(1, 74) = 21.89$, $p < .0001$, $\eta_p^2 = .23$, which were qualified by a significant interaction, $F(1, 74) = 9.85$, $p < .005$, $\eta_p^2 = .12$. Consistent with the findings from Castel (2005), younger adults outperformed older adults on the unrealistic, $t(74) = 4.61$, $p < .0001$, $d = 1.07$, but not on realistic, $t < 1$, trials. Additionally, older, $t(35) = 5.22$, $p < .0001$, $d = 0.87$, but not younger, $t(39) = 1.30$, $p > .2$, adults showed a difference in performance between the two item types, with better performance on the realistic trials.

In contrast to performance on the 6-s test trials, the analysis on the speeded retrieval condition showed only a main effect of item type, $F(1, 68) = 73.55$, $p < .0001$, $\eta_p^2 = .52$. Neither age as a main effect, $F(1, 68) = 3.61$, $p = .062$, $\eta_p^2 = .05$, nor in interaction with item type, $F < 1$, showed reliable differences. Both older, $t(33) = 4.99$, $p < .0001$, $d = 0.86$, and younger, $t(35) = 7.86$, $p < .0001$, $d = 1.31$, adults performed better on the realistic relative to the unrealistic trials, and there was no significant age difference on the realistic, $t(68) = 1.50$, $p > .1$, or unrealistic, $t(68) = 1.85$, $p = .068$, trials.

Thus, both younger and older adults showed greater memory for realistic than unrealistic prices on the fast-paced speeded retrieval condition. However, only younger adults showed equivalent performance for realistic and unrealistic prices on the slower, more controlled retrieval condition. This equivalent performance was partly due to improved performance on unrealistic trials by younger adults in the controlled retrieval condition relative to those tested in the speeded condition, $t(74) = 2.00$, $p < .05$, $d = 0.46$, which suggests that strategic retrieval improves memory for arbitrary associations in younger adults. Interestingly, younger adults in the controlled retrieval condition also showed worse performance on the realistic trials compared with those in the speeded condition, $t(74) = 2.02$, $p < .05$, $d = 0.47$, suggesting a possible associative memory advantage for information consistent with prior knowledge when less control is engaged. Finally, unlike younger adults, older adults showed no significant difference in performance on the realistic or unrealistic trials across the two retrieval conditions, t values < 1.

Reaction Time

RT data are shown in Figure 2. The three-way ANOVA on RT for correct trials showed main effects of age, $F(1, 142) = 89.44$, $p < .0001$, $\eta_p^2 = .39$, with faster performance by younger adults, item type, $F(1, 142) = 11.02$, $p < .005$, $\eta_p^2 = .07$, with faster performance on the realistic trials, and retrieval condition, $F(1, 142) = 132.11$, $p < .0001$, $\eta_p^2 = .48$, with faster performance by participants in the speeded condition, demonstrating the efficacy of the speed manipulation. That is, although the requirement to provide a confidence judgment may have arguably initiated a more controlled retrieval process even in the 4-s condition, the main effect of retrieval condition suggests that the speed manipulation was successful, and more controlled retrieval was engaged in the 6 s than the 4-s condition, which was also supported by the accuracy data (e.g., Yonelinas, 2002). The analysis also showed a significant interaction between age and retrieval condition, $F(1, 142) = 4.14$, $p < .05$, $\eta_p^2 = .03$, with older adults showing overall more slowing than younger adults on the slowed relative to the speeded condition. The interactions between age and item type and retrieval condition and item type, F values < 1, and the three-way interaction, $F(1, 142) = 2.48$, $p > .1$, did not reach significance. Additional analyses revealed that younger adults showed no significant difference between realistic and unrealistic trials in the speeded condition, $t(35) = 1.54$, $p > .1$, but were slower on the unrealistic than realistic trials in the controlled condition, although the difference just failed to reach conventional levels of statistical

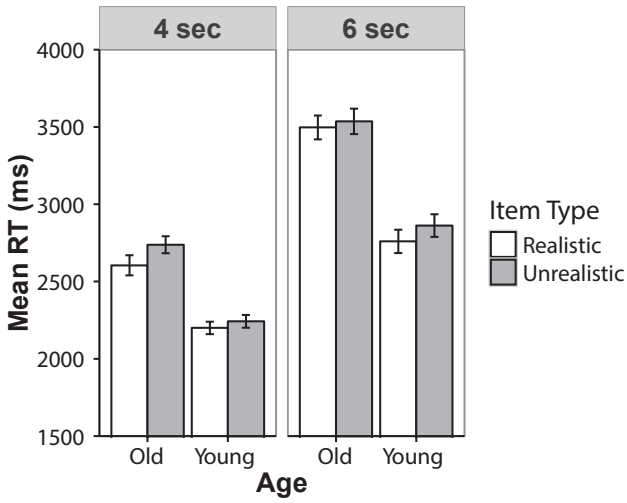

Figure 2. Response time for realistic and unrealistic prices in the two retrieval conditions in older and younger adults. Error bars represent standard errors of the mean.

significance,[3] $t(39) = 1.96$, $p = .057$, $d = 0.31$. Combined with the memory accuracy data (although not as robust), this provides additional support to the notion that slow, strategic retrieval was used to aid performance on unrealistic trials in the controlled condition in young adults. Older adults, on the other hand, showed the opposite pattern, with no RT difference between the trial types in the controlled condition, $t < 1$, and slower responding on the unrealistic than realistic trials in the speeded condition, $t(33) = 3.05$, $p < .005$, $d = 0.52$. These results should be interpreted with caution; however, given that the three-way interaction between age, retrieval condition, and item type did not reach statistical significance.

Confidence

We analyzed confidence by comparing the proportion of correct responses made with high confidence (i.e., responses that were both correct and high in confidence) for the different retrieval conditions and item types—data are shown in Figure 3. The three-way ANOVA showed a main effect of item type, $F(1, 142) = 91.65$, $p < .0001$, $\eta_p^2 = .39$, with a greater proportion of correct high confidence responses for realistic relative to unrealistic trials. The ANOVA also showed a significant interaction between age and item type, $F(1, 142) = 4.08$, $p < .05$, $\eta_p^2 = .03$, with older adults showing an overall larger difference between the proportion of high confidence responses for realistic over unrealistic trials compared with younger adults. The main effects of age, $F(1, 142) = 1.96$, $p > .1$, and retrieval condition, $F < 1$, and the interactions between age and retrieval condition, $F(1, 142) = 3.38$, $p = .068$, $\eta_p^2 = .02$, condition and item type, and the three-way interaction, F values < 1, were not significant. Additional analyses showed that older and younger adults showed a significant difference in the proportion of correct high confidence responses only for the unrealistic trials in the controlled condition, $t(74) = 2.70$, $p < .01$, $d = 0.63$, demonstrating that the largest age difference in confidence was for trials that involved strategic retrieval of arbitrary associations.

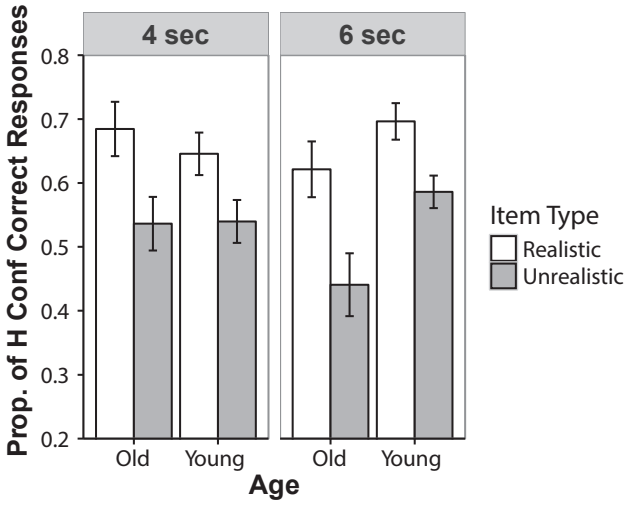

Figure 3. Proportion of correct responses made with high confidence for realistic and unrealistic prices in the two retrieval conditions in older and younger adults. Error bars represent standard errors of the mean.

Discussion

Age differences in associative memory are influenced by the meaningfulness of the stimuli used and their consistency with prior knowledge. In the current study, we investigated the role of memory retrieval on this effect by testing older and younger adults' memory for realistic and unrealistic grocery prices in two retrieval conditions (slow vs. speeded) intended to vary the extent of reliance on cognitive control, while keeping the rate of item presentation at encoding constant across both conditions. In the slow, more control-based condition, older and younger adults showed similar memory performance for meaningful, realistic prices, but younger adults showed an age-related advantage for unrealistic prices, consistent with previous work (Castel, 2005). In the speeded condition, however, older and younger adults showed equivalent performance for both realistic and unrealistic prices, and both age groups showed a similar memory benefit for the realistic prices. These results suggest that age differences in memory for arbitrary associations are, at least partially, mediated by age differences in strategic, controlled retrieval.

Controlled retrieval is commonly defined as an effortful memory process that involves the strategic search for a target memory when it is not directly elicited or recovered from available cues. This strategic search may include initiating and constraining retrieval to relevant cues, as well as monitoring recovered memories and determining whether they are consistent with task goals. Older adults show reduced controlled retrieval relative to younger adults (e.g., Dywan & Jacoby, 1990; Jennings & Jacoby, 1993; Yang & Hasher, 2007; see also Touron, 2015 for age differences in "memory retrieval avoidance"), and those reductions have been associated with poor performance on associative memory tasks (Cohn et al., 2008; Dew & Giovanello, 2010; Light et al., 2004). In the current study, we found evidence suggesting that age reductions in controlled retrieval particularly impair memory for random associations that are not supported by existing knowledge representations.

Specifically, our findings suggest that unlike older adults, younger adults were able to use strategic retrieval when remembering unrealistic prices in the slower, controlled condition, which improved memory for those prices to the same level as realistic prices. This interpretation is supported by the marginally slower response time (fell just short of statistical significance) for unrealistic relative to realistic trials in the controlled, but not speeded, retrieval condition. Older adults, on the other hand, showed no improvement in memory for unrealistic prices in the controlled condition, and unexpectedly, showed slower responding for unrealistic compared with realistic trials in the speeded, but not controlled, condition. Finally, age differences in the proportion of high confidence correct responses were only seen for unrealistic trials in the controlled condition, further supporting the notion that younger, but not older, adults were able to utilize strategic retrieval in that condition. It is important to note, however, that this significant difference was due to both a slight increase in the proportion

[3] Note that winsorizing more of the RT data (e.g., 15%—top and bottom 7.5%—rather than 10%) results in a difference between unrealistic and realistic trials that reaches the conventional alpha level, $t(39) = 2.01$, $p = .05$, $d = 0.32$, suggesting that some extreme RT scores may have played a role in decreasing the magnitude of the difference.

of high confidence correct responses for unrealistic prices from the speeded to the controlled condition in younger adults, and a decrease in the proportion of such responses in older adults (both differences not significant). Future work will be needed to determine why older adults show a decrease in the proportion of high confidence correct responses, as well as a lack of slowing for the unrealistic trials on the controlled relative to the speeded condition (i.e., patterns opposite to those seen in younger adults).

Previous studies have typically focused on the contributions of existing semantic knowledge to new episodic learning when demonstrating the distinction between age differences in memory for random, but not meaningful, associations (e.g., Castel, 2005, 2007; McGillivray & Castel, 2010 ; Mohanty et al., 2016; see also Kan, Alexander, & Verfaellie, 2009). That is, learning of new information is enhanced when it is anchored to existing knowledge representations or incorporated into an existing mental framework. While our study illustrates the importance of strategic retrieval for arbitrary information, our findings support these previous interpretations by demonstrating a general memory advantage for meaningful information in older adults, as well as in younger adults in the speeded condition. Thus, controlled retrieval does not seem to be necessary for the retrieval of newly acquired information that is consistent with previous knowledge, resulting in a learning advantage for that type of information. Interestingly, our findings suggest that reduced controlled retrieval might actually improve memory for meaningful information, at least in younger adults, as demonstrated by their enhanced memory for realistic prices in the speeded relative to the controlled condition. This finding additionally highlights an important difference between newly formed and preexisting (e.g., chair-table) meaningful associations, given that previous studies have shown a memory advantage, rather than deficit, for preexisting associations with increased retrieval duration (e.g., Patterson et al., 2009), possibly illustrating a controlled retrieval advantage for relearned preexisting knowledge.

Although we did not predict better memory for realistic prices in the speeded condition, the finding is similar to previous reports demonstrating that forced-choice recognition is enhanced by manipulations that decrease explicit or effortful memory processes (e.g., Lee, Blumenfeld, & D'Esposito, 2013 ; Voss, Baym, & Paller, 2008; Voss & Paller, 2010). For example, Voss et al. (2008) demonstrated that forced-choice recognition performance for visual stimuli improved when effortful processing was reduced through a divided attention manipulation and speeded responding (i.e., when time pressure was imposed). It is possible, then, that speeded retrieval provides similar memory advantages to newly learned meaningful associations. However, it is important to note that the memory boost described in the studies noted above occurred when awareness of retrieval was absent (i.e., participants showed an increase in memory even though they were "guessing"). Younger adults in the current study showed no significant difference in confidence ratings for realistic prices between the speeded and controlled conditions—although it was trending in the expected direction (proportion of correct high confidence responses: .64 vs. .70 for the speeded and controlled conditions, respectively). Nonetheless, the results suggest a possible speeded retrieval advantage for meaningful associations in young adults.

A few limitations in the current study should be noted. First, although the response time and confidence findings were consistent with our predictions, they were not as robust as the memory accuracy data, as evidenced by the lack of significant three-way interactions. Nonetheless, those findings augment the memory accuracy data, and taken together, our results provide support to the argument that controlled retrieval contributes to age differences in memory for arbitrary, but not meaningful, associations. In addition, while the data suggest that younger adults engage in controlled, strategic retrieval in the slow retrieval condition, additional data on strategy use would have strengthened the argument. However, considering the evidence from the current study, and the fact that the accuracy data in the slow condition replicate those reported in Castel (2005; a study that used a self-paced cued recall task, widely considered to engage controlled retrieval processes), it seems reasonable to suggest that younger adults recruited controlled, strategic retrieval processes in the slow condition (see also Craik and Rabinowitz (1985); Naveh-Benjamin, Brav, and Levy (2007) for evidence of spontaneous strategy use in young adults).

In sum, our findings indicate that reduced controlled or strategic retrieval in older adults contributes to their age-related decrease in memory for arbitrary associations. Strategic retrieval does not seem to aid memory for meaningful associations (which does not decrease with old age), and is possibly supported by existing knowledge representations (see van Kesteren et al., 2013; van Kesteren, Ruiter, Fernández, & Henson, 2012 for a neural framework). Whereas previous work has argued that older adults' binding deficits (e.g., Naveh-Benjamin, 2000) or "hyper-binding" (i.e., binding too much; e.g., Campbell, Hasher, & Thomas, 2010) result in general associative memory impairments, the present results suggest that the relationship between associative memory and old age is more complex, with retrieval processes partly contributing to a pattern of preserved and reduced memory for associations.

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