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Associative memory in aging: The effect of unitization on source memory

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Abstract

In normal aging, memory for associations declines more than memory for individual items. Unitization is an encoding process defined by creation of a new single entity to represent a new arbitrary association. The current study tested the hypothesis that age-related differences in associative memory can be reduced following encoding instructions that promote unitization. In two experiments, groups of 20 young and 20 older participants learned new associations between a word and a background color under two conditions. In the item detail condition, they had to imagine that the item is the same color as the background; an instruction promoting unitization of the associations. In the context detail condition, that did not promote unitization, they had to imagine that the item interacted with another colored object. At test, they had to retrieve the color that was associated to each word (source memory). In both experiments, the results showed an age-related decrement in source memory performance in the context detail but not in the item detail condition. Moreover, Experiment 2 examined receiver operating characteristics in older participants and indicated that familiarity contributed more to source memory performance in the item detail than in the context detail condition. These findings suggest that unitization of new associations can overcome the associative memory deficit observed in aging, at least for item-color associations.

Keywords: aging, associative memory, source memory, unitization

Introduction

Age-related differences in episodic memory are characterized by difficulties in creating and retrieving associations between single units of information, whereas memory for individual items is less affected (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000). This associative memory decline has been reported for a wide range of materials, including word pairs, pairs of pictures, item-spatial location associations, object-color associations, and face-name associations (Old & Naveh-Benjamin, 2008 for a meta-analysis).

A failure to spontaneously implement efficient associative strategies is one determinant of the older adults' decline in associative memory. Several lines of evidence support this idea. First, the effect of age on associative memory is typically reduced or even eliminated when participants study pairs of semantically related materials (Badham, Estes, & Maylor, 2012; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Patterson, Light, Van Ocker, & Olfman, 2009). In this case, preexisting relations between items provide a schematic framework for learning the pairs and minimize the need for initiating effortful encoding strategies. Second, for unrelated new associations, age differences were found to be greater following intentional than incidental encoding (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2009). This was interpreted as resulting from the greater self-initiation of associative strategies in young compared to older participants when they were informed about the upcoming memory test. Finally, the instruction to encode word pairs by means of a deep relational encoding strategy (e.g., to create a sentence that binds the two words) can reduce the associative impairment of older participants (Giovanello & Schacter, 2012; Naveh-Benjamin, Brav, & Levy, 2007). Actually, this sentence generation strategy, used at both encoding and retrieval, can effectively eliminate the age-related associative decline (Naveh-Benjamin et al., 2007).

Strategies based on elaborative meaning such as sentence generation have long been known to be crucial for associative priming and are thought to facilitate the establishment of a unitized representation of the association (Graf & Schacter, 1989). Unitization occurs when the different components of an association are processed in such a way that they become integrated into a coherent whole. Several recent studies have shown that explicit associative memory can also benefit from unitization (Bader, Mecklinger, Hoppstädter, & Meyer, 2010; Diana, Yonelinas, & Ranganath, 2008; Pilgrim, Murray, & Donaldson, 2012; Quamme, Yonelinas, & Norman, 2007; Rhodes & Donaldson, 2008; Yonelinas, Kroll, Dobbins, & Soltani, 1999). It can therefore be hypothesized that the previously reported advantage of an elaborative and integrative strategy in older adults' memory for word pairs (Giovanello & Schacter, 2012; Naveh-Benjamin et al., 2007) could be at least partly due to the creation of unitized representations that can be recognized as single entities compared to non-unitized associations. Some evidence in favor of age invariance in memory for intra-item unitized associations comes from a study of face recognition showing that older adults were as able as young adults to reject unstudied faces made of a recombination of facial features from two studied faces (Edmonds, Glisky, Bartlett, & Rapcsak, 2012). Thus, aging did not affect memory for the holistic representation of faces. Kilb and Naveh-Benjamin (2011) also suggested that older participants benefit from repeating pairs before study because this increases unitization of the pairs, although the creation of a holistic representation was not directly manipulated in that study.

The current study thus tested the hypothesis that age-related differences in associative memory can be significantly reduced when participants are instructed to use an encoding strategy that promotes unitization. In two experiments, we used a procedure that was successful at alleviating the memory impairment of amnesic patients whose item recognition memory was less affected in comparison to their severe deficit of contextual recollection

(Diana, Yonelinas, & Ranganath, 2010; Yonelinas et al., 2002). Here, young and older adults performed a source memory task where items were associated with one of two background colors (red or green) under two conditions. In the condition that encouraged unitization, participants had to imagine the items in the associated color. This instruction led the color to be encoded as a feature of the item (item detail condition). In the condition that did not encourage unitization, the instruction was to imagine the item in a situation with a green 100-euro bill if the background was green or with a red stop sign if the background was red. Color was thus associated with the item as separate contextual information (context detail condition). If the unitization of associations is an effective way of attenuating the age-related associative decline, we expected that older adults should perform better in the item detail condition (unitized item-color associations) than in the context detail condition (non-unitized item-color associations), and that age differences should be significantly reduced in the item detail condition.

Experiment 1

Methods

Participants

Twenty young adults (age range: 18-35 years old, mean age: $M = 24 \pm 3.9$, 12 women) and 20 older adults (age range: 60-91 years old, $M = 76 \pm 8$, 11 women) participated to the study. All participants were recruited from the local community. None of them reported a neurological or a psychiatric condition that could interfere with cognitive functioning. In addition, all the older participants reported being in good health and having good hearing and vision or appropriate correction for visual or auditory disorders when necessary. On average, young participants completed more years of education than older participants (young: $M = 14 \pm 2.2$; older: $M = 12.5 \pm 1.9$), $t(38) = -2.6$, $p < .05$. None of the older participants evidenced any sign of cognitive decline (Mattis Dementia Rating Scale (Mattis, 1973), score range: 133-144 out of 144) or depressed mood (Geriatric Depression Scale (Yesavage et al., 1983), score range: 1-5, cut-off for significant depressive symptoms = 6). Participants gave their informed consent to take part to the study, which was approved by the Ethics Committee of the Faculty of Medicine of the University of Liège.

Materials

A list of 40 concrete nouns, as well as the associated descriptive sentences were selected from the materials used by Diana et al. (2008, 2010) and translated into French. Each sentences provided an explanation as to why the item might be associated with a stop sign or a 100-euro bill (context detail condition) or why the item might be green or red (item detail condition). The words were randomly divided in two sets of 20 items. Each word had a sentence for both the item detail and context detail conditions such that assignment of the words to the two conditions could be counterbalanced across participants. The descriptive sentences were selected based on a pilot study in young adults that matched performance between conditions (Diana et al., 2010). Examples of sentences in the item detail condition are “The turtle is red because kids at the beach painted the shell so it would stand out amongst the other turtles” for the association “turtle-red”, and “The cloth is green because the waiter used it to clean up spilled pea soup” for the association “cloth-green”. Examples of sentences in the context detail condition are “The monkey is on the stop sign to show people that they should turn right to get to the zoo” for the association “monkey-red”, and “The sock has a 100-euro bill in it because the traveler put the bill in his sock to keep it safe” for the association “sock-green”. The words were randomly divided in two sets of 20 items. The attribution of the sets to the context detail and item detail conditions was counterbalanced across participants.

Procedure

Participants were tested individually in two sessions about one week apart. Each participant performed both conditions, which were administered in distinct sessions in order to minimize the contamination of one encoding condition on the other. Half of the participants started with the item detail condition, while the other half were first given the context detail condition. Stimuli were presented on a laptop computer. Each trial consisted of the presentation of a word against a background color (either green or red), with a sentence at the bottom of the screen. Before each task, participants were informed that their memory for the association between each word and the background color would be subsequently tested. In the item detail condition, they were asked to imagine the item as if it were the same color as the background, to read the sentence explaining why the item is that color, and to report whether this explanation was easy or difficult to imagine. In the context detail condition, participants were asked to imagine the item interacting with a stop sign (red background) or with a 100-euro bill (green background), to read the sentence explaining why the item is associated with the stop sign or the 100-euro bill, and to report whether imagining that explanation was easy or difficult. Pictures of a stop sign and a 100-euro bill were shown before the task. The stimulus remained on the screen until a response was made. After a 20s interval filled with conversation, the test phase began in which the participants were presented with a randomized list of the studied words one at a time. For each word, they were asked to indicate whether the associated background was red or green. The test phase was also self-paced. In addition to comparison of the proportions of total correct source judgments between groups and conditions, the analyses will also consider separately source recall performance for trials where the associations were judged easy versus difficult to imagine at encoding. We assumed that unitization should have the greatest effects for associations that participants easily imagined as integrated (when therefore the encoding manipulation was more effectively applied).

Results

Figure 1A presents the proportions of correct source judgments (correctly recalled background color) for each condition and each group. The proportions were submitted to a 2 (group) by 2 (condition) repeated measure ANCOVA. Number of years of education was entered as a covariate, as it differed between groups. There was a significant main effect of group, $F(1, 37) = 8.7$, $p < .01$, $MSE = 0.02$, indicating globally poorer memory performance in the older group. There was no main effect of condition, $F(1, 37) = 0.03$, $p > .85$, $MSE = 0.01$. The group by condition interaction was significant, $F(1, 37) = 4.8$, $p < .05$. Post-hoc Tukey's HSD tests showed that there was an age-related decrease in the context detail condition ($p < .01$), but not in the item detail condition ($p > .55$).

The potential effect of testing order (item detail first versus context detail first) was assessed by including order in the above-mentioned ANCOVA. None of the effects involving order was significant, all $Fs < 1$.

The proportions of correct source responses were further analyzed by considering whether the participants reported that the association with the color was easy versus difficult to imagine on the basis of the provided explanation. For each participant, items were classified as easy-to-image or difficult-to-imagine on the basis of the rating that the participant provided during the encoding phase. Proportions of correct source judgments were then computed separately for associations judged as easy to imagine and for associations judged as difficult to imagine. Table 1 presents the proportions (and ranges) of items classified as easy to imagine in each group and each condition (proportions of difficult-to-imagine items are given by 1 - the proportions of easy-to-imagine items). A group × condition ANOVA on the proportions of easy-to-imagine items indicated that older participants said that the associations were easy to imagine less frequently than young adults did, $F(1, 38) = 7.66$, $p < .05$. However, there was no difference in the proportion of easy-to-imagine judgments at encoding between the two conditions and no interaction with age, ps > .20.

Figure 1B shows the proportions of correct source responses for easy-to-imagine and difficult-to-imagine items in each group. For items that were easy to imagine, a group × condition ANCOVA, including education as a covariate, indicated a marginal effect of group, $F(1, 37) = 3.57$, $p > .06$, MSE = 0.01, no main effect of condition, $F(1, 37) = 0.02$, $p > .88$, and a significant group by condition interaction, $F(1, 37) = 8.3$, $p < .01$, MSE = 0.01. The latter interaction revealed between-group differences in the context detail condition (Tukey's HSD test, $p < .01$), but not in the item detail condition ($p > .95$). For items that were difficult to imagine, however, the ANCOVA showed that older participants performed more poorly than young participants in both conditions, $F(1, 35) = 7.5$, $p < .01$, MSE = 0.05, but there was no main effect of condition, $F(1, 35) = 0.70$, $p > .40$, and no interaction, $F(1, 35) = 0.13$, $p > .71$.

Finally, as encoding was self-paced, study time was compared across age group as a function of conditions and of whether associations were judged easy or difficult to imagine with a 2 by 2 by 2 ANOVA. As expected from the general slowing in processing time in aging (Salthouse, 2000), older adults took more time to create a mental image of the novel associations and indicate whether it was easy or difficult to imagine (young: M = 8.8 s ± 2.6; older: M = 14.4 s ± 5.1), $F(1, 33) = 32.2$, $p < .001$, MSE = 3.1. However, study time did not significantly differ between conditions, between easy- and difficult-to-imagine associations, nor were any interactions significant (all ps > .09). The results suggest that the age-related differences in memory that were observed were not related to tradeoffs between speed and accuracy.

In sum, the results of Experiment 1 indicated that age deficits in associative recognition were significantly reduced when participants encoded item-color associations by imagining each item in the associated color compared to a condition where they associated the item with another colored object. However, one potential limitation of the current Experiment is that performance was quite high in the sense that the young subjects performed above 90% correct in both conditions. Although performance was significantly lower than perfect, it is possible that ceiling effects may have partially masked the effects of unitization on young subjects. Experiment 2 was conducted in order to determine whether the same pattern of results would be obtained when performance was lowered.

Experiment 2

Participants

Twenty young adults (age range: 18-33 years old, mean age: M = 24.4 ± 4.1, 10 women) and 20 healthy older adults (age range: 60-82 years old, M = 73.0 ± 7.5, 10 women) participated in the study (and none did participate in Experiment 1). Both groups were matched in terms of the number of years of education they completed (young: M = 14 ± 2.7; older: M = 14 ± 2.3), $t(38) = 0.95$, $p = .95$. None of the older participants evidenced any sign of cognitive decline (Mattis Dementia Rating Scale (Mattis, 1973), score range: 133-144 out of 144). Participants gave their informed consent to take part to the study following the guidelines of the Ethics Committee of the Faculty of Psychology of the University of Liège.

Materials and procedure

The experimental task was similar to that in Experiment 1, with two exceptions. First, the study lists contained 100 items in each condition (item detail and context detail). The items and the explanations for why the item was associated with a stop sign or a 100-euro bill (context detail) and for why the item is green or red (item detail) were French translations of the materials used in the patient study by Diana et al. (2008, 2010). Second, during the test phase, participants were asked to indicate the color that was associated with each item by means of a 1 to 6 confidence scale, with “1” and “6” corresponding to high confidence red and green responses respectively, “2” and “5” representing moderate confidence red and green responses, and “3” and “4” referring to low confidence red and green responses.

Results

As testing order (starting with the item detail condition versus the context detail condition) did not influence performance, the analyses were performed on scores collapsed across order. Figure 2A presents the proportions of correct source judgments (correctly recalled background color) for each condition and each group. Proportions of correct source judgments were measured by collapsing responses across confidence (i.e., for green items, confidence responses 4 through 6 referred to correct “green” responses, and 1 through 3 referred to incorrect “red” responses). A 2 (group) by 2 (condition) repeated measure ANOVA showed a significant main effect of group, $F(1, 38) = 11.76$, $p < .01$, $MSE = 0.01$, indicating globally poorer memory performance in the older group. There was no main effect of condition, $F(1, 38) = 0.21$, $p > .64$, $MSE = 0.004$. The group by condition interaction was significant, $F(1, 38) = 7.63$, $p < .01$. Post-hoc Tukey’s HSD tests showed that there was an age-related deficit in the context detail condition ($p < .001$), but not in the item detail condition ($p > .37$).

As in Experiment 1, for each individual, items were separated as a function of whether the associations were judged as easy or difficult to imagine. Table 1 shows the proportions of items rated as easy to imagine by individuals at encoding. A group × condition ANOVA on these proportions revealed that older adults judged the associations as easy to imagine less frequently than young adults, $F(1, 38) = 6.37$, $p < .05$, $MSE = 0.03$. There was no effect of condition and no interaction, $Fs < 1$.

Proportions of correct source judgments were calculated for easy-to-imagine and difficult-to-image associations (Figure 2B). A group by condition ANOVA on the proportions of correct source responses for easy-to-imagine associations revealed a main effect of group, $F(1, 38) = 7.1$, $p < .05$, $MSE = 0.01$, no main effect of condition, $F(1, 38) = 0.8$, $p > .37$, $MSE = 0.005$, and a significant interaction, $F(1, 38) = 8.7$, $p < .01$, $MSE = 0.005$. Tukey's HSD post-hoc tests showed that older adults performed as well as young participants in the item detail condition ($p > .88$), but poorer in the context detail condition ($p < .01$). For difficult-to-imagine associations, a group by condition ANOVA on the proportions of correct source responses indicated that older participants performed less well than young adults, $F(1, 35) = 11.23$, $p < .01$, $MSE = 0.01$, but there was no main effect of condition and no interaction, $Fs < 1$.

An analysis of study time was also performed comparing groups and conditions as a function of ease-to-imagine the novel associations. Study time did not differ between groups, $F(1, 36) = 2.9$, $p > .09$. Participants took longer to encode associations in the context detail condition ($M = 10$ s $\pm$ 4) than in the item detail condition ($M = 7$ s $\pm$ 2), $F(1, 36) = 31.9$, $p < .01$. Study time was also longer for associations judged as more difficult to imagine ($M = 9$ s $\pm$ 3) than for associations judged as easy to imagine ($M = 8$ s $\pm$ 3), $F(1, 36) = 20.6$, $p < .01$. However, none of the interactions was significant (all $Fs < 1$), suggesting that the group by condition interaction on proportions of correct source judgments was not due to differences in encoding time.

Finally, in an exploratory analysis, we examined confidence ratings from the source memory test and calculated Receiver Operating Characteristics (ROCs) for each of the older participants to estimate the contribution of recollection and familiarity to overall performance (Yonelinas, 1994; Yonelinas & Parks, 2007). The results of the analysis must be interpreted cautiously because the current data set included only 50 items per subject/condition which is somewhat low for a standard ROC analysis, and many of the younger subjects had ROCs with false alarm rates of zero thus we could not conduct a similar analysis on the younger group. Figure 3 shows the average ROCs of older adults, as well as familiarity and recollection estimates in each condition. A paired t-test showed that familiarity estimates were higher in the item detail condition than in the context detail condition, $t(19) = 2.41$, $p < .05$, whereas recollection estimates did not differ between the two conditions, $t(20) = -0.6$, $p > .54$. The results are in agreement with prior studies of young subjects in showing that familiarity-based recognition is higher in the item detail condition than in the context detail condition (Diana et al., 2008, 2010). To the extent that older subjects are assumed to have a more pronounced deficit in recollection than familiarity, the results suggest that their preserved performance on the item detail condition reflects greater dependence on familiarity in this condition.

Discussion

In the current study, we compared young and older adults' performance on source (color) memory following encoding instructions that did or did not encourage unitization of new item-color associations (Diana et al., 2010). A high degree of unitization was induced by mental imagery instructions that integrated the color as an item feature (item detail). The encoding instructions that did not promote unitization required mental imagery of the interaction of the item with another object of the designated color. By processing color as a contextual detail, item and color thus remained two separate components within the association (context detail). The notion of unitization suggests that processing a new association by integrating the components into a "gestalt" will result in the formation of a new item representation. Consequently, subsequent source judgments can be based on the reactivation of this new entity which encompasses the color information, as can occur with item-only judgments. In contrast, source judgments in the context detail condition will be based on the retrieval of the arbitrary association between two separate representations, as is required in typical associative memory tasks.

Considering the extensive literature showing that aging leaves item memory relatively unaffected in comparison to associative memory (Old & Naveh-Benjamin, 2008), we expected that unitization should lead to a significant attenuation of age-related differences in associative memory compared to the condition that did not promote unitization. Consistent with our hypothesis, the results showed that older adults significantly benefited from unitization, so that they performed as well as young adults in the item detail condition. This contrasted with the significant age effect on associative memory in the context detail condition. The proposal that this suppression of age-related differences in source memory is attributable to the benefit of unitization is further supported by the finding that the interaction between age and encoding condition was only visible for item-color pairs that participants could easily imagine as integrated, in other words when unitization was more successful. This study thus adds to previous reports showing that specific associative strategies can modulate the effects of aging on associative memory (Giovanello & Schacter, 2012; Naveh-Benjamin et al., 2007) and indicates that unitization can facilitate encoding of new associations in older adults, at least for learning new item-color associations.

It should be noted that another study reported larger age-related deficits in associative recognition for materials that were expected to be more easily unitized (i.e., two highly similar faces) than for materials that were more difficult to unitize (i.e., two very different faces) (Jäger, Mecklinger, & Kliegel, 2010). These results were interpreted as reduced efficiency in processing the unitized faces in older subjects because of the high level of feature overlap in that condition. Those results may indicate that the effectiveness of unitization as an encoding strategy in the elderly may be dependent in part on the type of materials that are to be encoded.

In the current study, it is unlikely that the observed group by condition interaction was driven by between-condition differences in task implementation or in task difficulty for several reasons. First, the setting of the task was identical in both conditions: the word and the color remained present in front of the participants during each encoding trial, together with a sentence. The only difference between the conditions was the nature of the relationship between the item and the color invoked by the sentence. Even if the pictures of the stop sign or green euro bill were not in front of the participant during encoding, the explanatory sentences made explicit reference to this object. The creation of the relationship between the item and the color was supported by sentences conveying an elaborated meaning to the relationship and that were piloted in young adults to ensure equal performance in both conditions (Diana et al., 2010). Second, if age differences were due to the difficulty of the encoding task, then we would have expected age effects for associations that participants reported as difficult to imagine, but not for associations that were easy to imagine. Yet, even easy-to-imagine associations in the context detail condition were less well remembered by older adults, suggesting that the differential effect of aging on the two conditions is not related to encoding difficulty. Third, in the two experiments, young adults' performance was matched in both conditions. In Experiment 2, performance was even numerically better in the context detail condition (although not significantly). So age effects occurred in a condition which was, if anything, slightly easier for young adults.

More plausibly, the differential effect of aging on memory performance in the item detail and context detail conditions stemmed from differences in the underlying memory processes. The classical finding that there is a disproportionate effect of aging on recollection (conscious recall of the encoding episode) as compared to familiarity (feeling that some information is old in the absence of mental reinstatement of the learning episode) is relevant to the current results (see Yonelinas, 2002 for a review). Indeed, it has been suggested that poor recollection is a key mediator of age-related differences in associative memory while preserved familiarity supports memory for individual items (Cohn, Emrich, & Moscovitch, 2008; Dew & Giovanello, 2010; Kilb & Naveh-Benjamin, 2011; Naveh-Benjamin et al., 2009). This implies that conditions that reduce the need for recollection processes to retrieve associations would attenuate older adults' impairment. From this viewpoint, the age-related associative decline in the context detail condition would stem from a decrease in recollection processes, whereas performance in the item detail condition would be unaffected by aging because participants relied on intact familiarity processes. Previous evidence showed that the current manipulation differentially recruits recollection and familiarity processes. Indeed, process estimation methods in young participants showed that when source information is encoded as an item feature, subsequent source judgments are based on familiarity more often than when the item and the color have not been unitized. In contrast, young participants tended to use more recollection when color was encoded as a context detail, leading to overall comparable source memory performance (Diana et al., 2008). Moreover, when young healthy participants are prevented from using recollection by imposing a speeded response deadline (Diana et al., 2008) or when amnesic patients with selective recollection deficits are tested (Diana et al., 2010), performance was greater in the item detail than in the context detail condition.

Consistent with these findings, ROC-derived estimates of familiarity in the current study indicated that, in older adults, familiarity contributed more to the retrieval of item-color associations when color has been integrated as an item feature than when color was encoded as a context feature. Age invariance in associative memory would thus depend on how much memory performance can rely on familiarity, as also suggested by the preserved ability of older adults to discriminate between studied and unstudied intra-facial combinations in a task demonstrated as being familiarity-dependent (Bartlett, Shastri, Abdi, & Neville-Smith, 2009;

Edmonds et al., 2012). In contrast, when item and color were encoded as separate components, source retrieval depends more heavily on recollection. Poorer performance in this condition would therefore be related to the decrease of recollection with aging (Yonelinas, 2002). This interpretation should be confirmed in future studies with a number of stimuli sufficiently large to allow stable ROCs in both young and older adults.

Finally, the current findings of age-related differences in memory for non-unitized associations but age invariance for unitized associations lead to hypotheses about the brain regions involved. More specifically, particular interest is directed towards the structures within the medial temporal lobe (including the hippocampus, parahippocampal, entorhinal and perirhinal cortices), which are an important site of changes during aging (Raz et al., 2005). In an fMRI study examining the neural correlates of the current item-color associative memory paradigm in young participants, successful source retrieval in the item detail condition was more associated with activity of the perirhinal cortex than correct source memory in the context detail condition (Diana et al., 2010). In contrast, the retrieval of the background color in the context detail condition elicited specific hippocampal and parahippocampal activation. It was also found that an encoding condition that involved unitization was associated with increased activation of the perirhinal cortex that predicted subsequent familiarity-based associative recognition (Haskins, Yonelinas, Quamme, & Ranganath, 2008). Interestingly, Staresina and Davachi (2010) showed that perceptual unitization occurs in posterior ventral occipito-temporal regions whereas more anterior temporal regions including the perirhinal cortex was selectively sensitive to subsequent memory for these representations. Considering that, in normal aging, recollection has been associated with the functional activation and volume of the hippocampus and familiarity with the activation and volume of perirhinal/entorhinal cortices (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Yonelinas et al., 2007), a prediction to be tested in older participants is that preserved familiarity-based memory for item-color associations in the item detail condition is associated with the perirhinal cortex whereas decreased recollection of the associations encoded in the context detail condition is associated with hippocampal involvement.

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Table 1

Mean proportions (and ranges) of items classified as easy to imagine based on individual ratings during the encoding phase

	Young		Older	
	Item detail	Context detail	Item detail	Context detail
Experiment 1	.72 (.16)	.71 (.16)	.56 (.16)	.61 (.19)
	.50 - 1	.50 - 1	.25 - 1	.15 - 1
Experiment 2	.73 (.15)	.73 (.22)	.61 (.12)	.63 (.14)
	.52 - .99	.15 - 1	.35 - .90	.30 - .95

Standard deviations in parentheses.

Figure caption

Figure 1. Experiment 1. Proportions of correct source judgments as a function of group and condition. A. Global performance. B. Performance assessed separately for easy-to-imagine and difficult-to-imagine associations.

Figure 2. Experiment 2. Proportions of correct source judgments as a function of group and condition. A. Global performance. B. Performance assessed separately for easy-to-imagine and difficult-to-imagine associations.

Figure 3. A. Older adults' average ROC curves for the item detail and context detail conditions, fit using the Dual-Process Signal Detection Model (DPSD model). B. Recollection (proportion) and familiarity (d') estimates based on DPSD model fits as a function of condition.

Figure 1

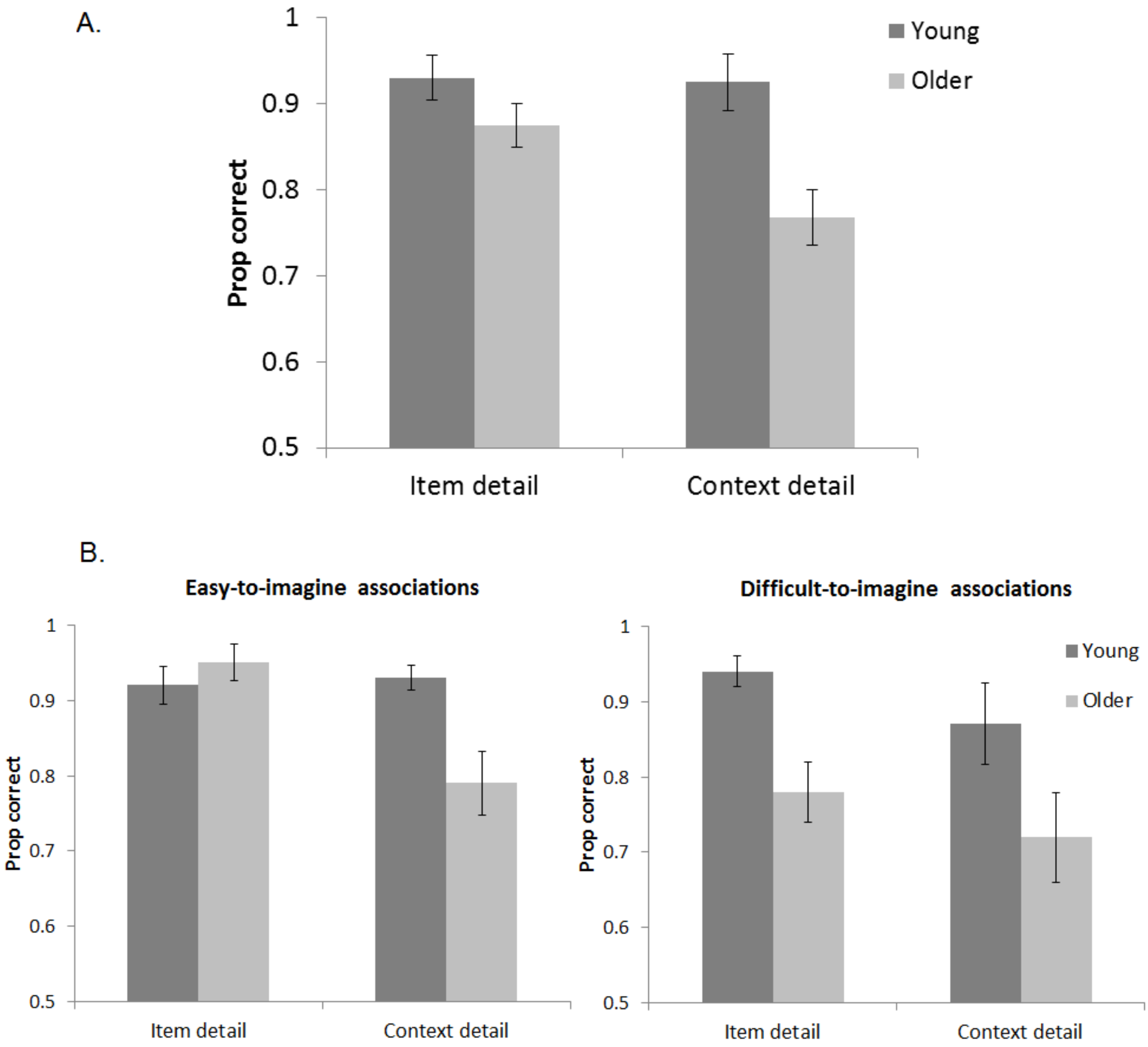

A.
1
0.9
0.8
0.7
0.6
0.5
Prop correct
Young
Older
Item detail
Context detail
B.
Easy-to-imagine associations
Difficult-to-imagine associations
1
0.9
0.8
0.7
0.6
0.5
Prop correct
Young
Older
Item detail
Context detail

Figure 2

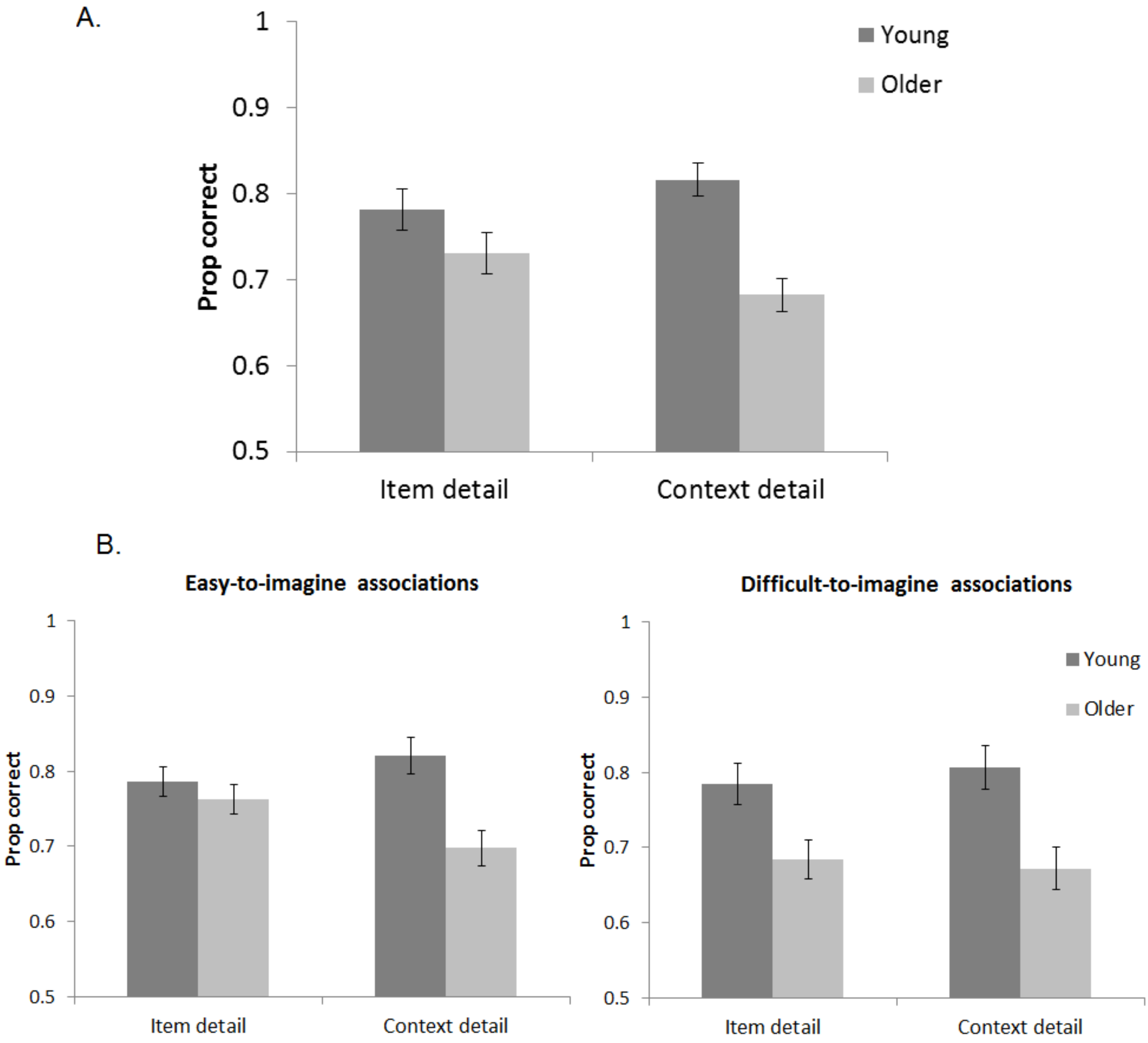
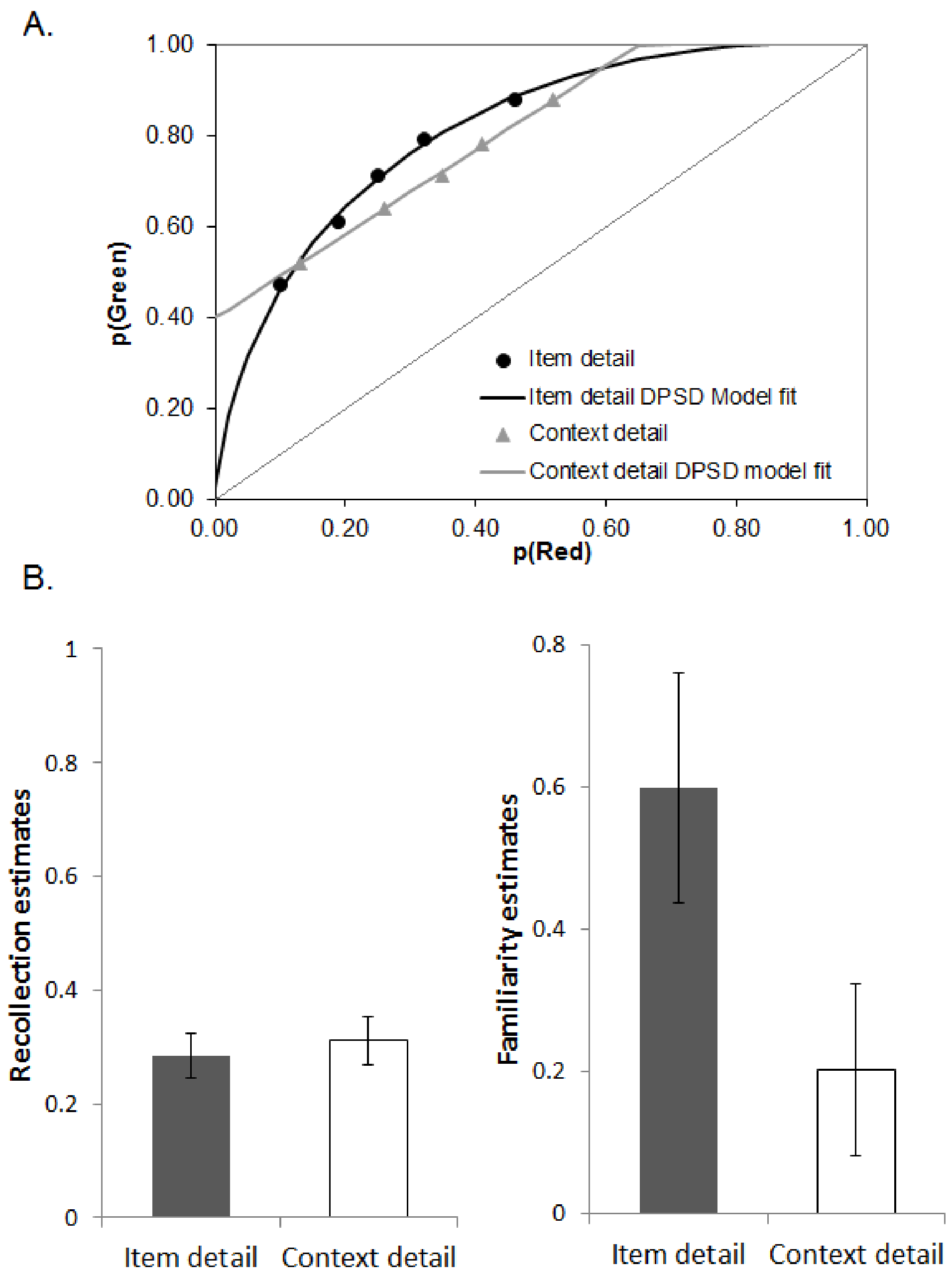

A.
1
0.9
0.8
0.7
0.6
0.5
Prop correct
Young
Older
Item detail
Context detail
B.
Easy-to-imagine associations
Difficult-to-imagine associations
1
0.9
0.8
0.7
0.6
0.5
Prop correct
Young
Older
Item detail
Context detail

Figure 3


A.
1.00
0.80
0.60
0.40
0.20
0.00
p(Green)
0.00
0.20
0.40
0.60
0.80
1.00
p(Red)
Item detail
Item detail DPSD Model fit
Context detail
Context detail DPSD model fit
B.
Recollection estimates
1
0.8
0.6
0.4
0.2
0
Item detail
Context detail
Familiarity estimates
0.8
0.6
0.4
0.2
0
Item detail
Context detail