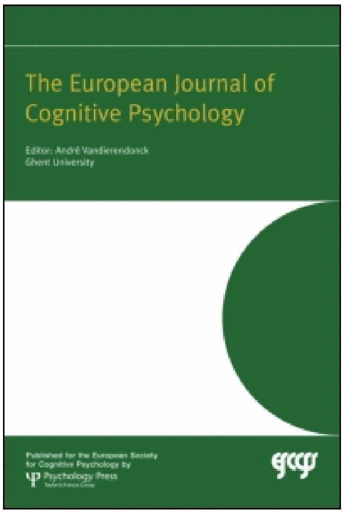

European Journal of Cognitive Psychology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713734596

Effects of ageing on associative memory for related and unrelated pictures

Angela H. Gutchess [a]; Denise C. Park [b]
[a] Brandeis University, Waltham, MA, USA [b] University of Texas at Dallas, Dallas, TX, USA

First Published:March2009

To cite this Article Gutchess, Angela H. and Park, Denise C.(2009)'Effects of ageing on associative memory for related and unrelated pictures',European Journal of Cognitive Psychology,21:2,235 — 254

To link to this Article: DOI: 10.1080/09541440802257274

URL: http://dx.doi.org/10.1080/09541440802257274

EUROPEAN JOURNAL OF COGNITIVE PSYCHOLOGY
2009, 21 (2/3), 235–254

Psychology Press
Taylor & Francis Group

Effects of ageing on associative memory for related and unrelated pictures

Angela H. Gutchess
Brandeis University, Waltham, MA, USA

Denise C. Park
University of Texas at Dallas, Dallas, TX, USA

Associative memory deficits are pervasive with age. Memory for complex pictures, however, also seems to require the association of several scene elements into one representation, but picture memory is often age-invariant. We speculated that the natural relationships contained in pictures may explain this distinction and that memory for scenes with unusual novel relationships would be affected with ageing. In three experiments, we found that, counter to our predictions, the relatedness of scene elements exerted little influence on picture memory and did not differentially affect older compared to younger adults. These data suggest that the semantically rich associations contained in pictures need not rely on prior knowledge and experiences in order to support age-invariant picture memory. Our results indicate that associative memory for complex pictures may differ from memory for interitem associations, which may be more affected by ageing.

Keywords: Ageing; Associative memory; Picture memory; Recognition; Relatedness.

Associative memory undergoes pronounced impairment with age. Older adults exhibit difficulty associating, or "binding", pieces of information together into a single memory trace (Chalfonte & Johnson, 1996; Naveh-

Correspondence should be addressed to Angela Gutchess, Department of Psychology, Brandeis University, 415 South Street, MS 062, Waltham, MA 02454-9110, USA. E-mail: gutchess@brandeis.edu

Grant support from the National Institute on Aging (R01 AG006265 and P50 AG011715; awarded to DCP) and a seed grant from the Center on Aging and Cognition: Health, Education, and Training (awarded to AHG) supported this research, and funds from Brandeis University supported the preparation of this manuscript. We thank Julie Hautamaki, Siva Sethuraman, Laura Rallo, and Nora Goudsmit for experimental assistance. We also thank John Henderson's laboratory at Michigan State University for making some of their stimuli available on their website.

http://www.psypress.com/ecp DOI: 10.1080/09541440802257274

Benjamin, 2000). Naveh-Benjamin (2000) has proposed an associative deficit hypothesis of ageing, suggesting that older adults' intact ability to encode items is dissociated from their impaired ability to encode interitem relationships. Deficits in associative memory occur for items and contexts (Chalfonte & Johnson, 1996; Park & Puglisi, 1985; Park, Puglisi, & Lutz, 1982) as well as for pairs of distinct items, including word pairs, object picture pairs, and name–face pairs (Naveh-Benjamin, 2000; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003), even when item memory is intact. Memory for complex pictures also seemingly requires the ability to associate various components of scenes into a single representation in memory, but picture memory is largely invariant with age (e.g., Park, Puglisi, & Smith, 1986; Park, Smith, Morrell, Puglisi, & Dudley, 1990; Smith, Park, Cherry, & Berkovsky, 1990; Smith, Park, Earles, Shaw, & Whiting, 1998). In the present studies, we investigate the extent to which complex pictures place demands on associative memory under a variety of conditions.

One possible explanation for the age-invariance in picture memory is that complex pictures demand less associative processing than other types of items. There is some evidence that particular task conditions can reduce associative memory demands. For example, unitisation, that is, merging two distinct items into one single item such as the words "jail" and "bird" into "jailbird" or connecting two words in a sentence, reduces the extent of amnesic patients' associative memory impairments for word pairs (Giovanello, Keane, & Verfaellie, 2006; Quamme, Yonelinas, & Norman, 2007). With ageing, the effects of unitisation have been assessed by asking research participants to enact object-action phrases (e.g., "put the money in the wallet"), and this manipulation equivalently enhances young and older adults' memory for the object-action associations (Mangels & Heinberg, 2006). Age differences in associative memory also can be reduced with incidental encoding strategies that support associative memory (Naveh-Benjamin, Brav, & Levy, 2007).

Another important factor could be the inherent interrelatedness of picture elements. For complex pictures, the elements to be bound typically share a natural, meaningful relationship with each other. Information that is highly meaningful and interrelated, as is the case for the information contained in complex pictures, may reduce the binding demands and determine which medial temporal regions are implicated in associative processes. Memory for complex meaningful pictures can be astonishingly good (Standing, 1973), and memory for these types of pictures can be largely equivalent across young and older adults (Park et al., 1986, 1990; Smith et al., 1990, 1998). Age differences emerge in picture memory, however, when pictures are not meaningfully related or lack rich semantic or perceptual details (Park et al., 1990; Smith et al., 1990, 1998). One aspect of picture memory that has not been investigated is the importance of the relatedness of elements in complex scenes. Previous studies using related and unrelated picture pairs used simple drawings of related (e.g., ant-spider) and unrelated (e.g., spider-cherry) objects and noted that older adults exhibited poorer memory for the pairings than young (Naveh-Benjamin et al., 2003; Park et al., 1990). However, the associative demands and support provided by the interrelated picture information could differ for complex scenes.

We conducted three picture memory experiments in which we systematically manipulated intrapicture information, comparing the effects of ageing on recognition for scenes that contained related, predictable elements versus scenes that were composed of elements that would be unexpected and might not be automatically bound together. We expected that unrelated, low plausibility scenes would place large demands on binding processes and thus older adults' memory would be impaired relative to young adults' memory for unrelated scenes. We expected that scenes with related and predictable context would have reduced binding demands so that the previously mentioned pattern of age-equivalent picture memory (Park et al., 1986, 1990; Smith et al., 1990, 1998) would be replicated.

The inclusion of two additional factors, environmental support and encoding intentionality, allowed us to investigate the contribution of relatedness to binding under a variety of conditions. Environmental support, such as rich contextual information, can improve older adults' performance on memory tasks by reducing the demands on cognitive resources (Craik & Byrd, 1982; Craik & Jennings, 1992). Past research suggests that the encoding of rich, meaningful stimuli, particularly when tested in a recognition paradigm, can provide appropriate environmental support. As shown in Park, Puglisi, and Sovacool (1984), one way to manipulate environmental support is by removing seemingly extraneous picture backgrounds at recognition, and this impairs performance of both young and elderly adults. We incorporated this manipulation in the present study and predicted that an increase in environmental support would reduce binding demands and thus reduce age differences in memory (as in Park et al., 1984). Varying the amount of environmental support provides a measure of binding in that memory for tightly bound information may be disrupted when environmental support is reduced. This predicts that "unbinding" of information, through the removal of environmental support, will affect young more than elderly because young should have more successfully bound information together during the initial encoding phase. Likewise, the loss of environmental support should impact memory for related more than unrelated scenes because this type of scene should undergo greater binding when environmental support is present. Although we predict that older adults will be less affected by the removal of background information than young, it is possible that they will be more prone to misrecognition, on the basis that poorly bound representations are subject to distortion (Lyle & Johnson, 2006). We manipulated encoding intentionality by directing participants to associate the object and background together, as opposed to encoding the object alone. We expected that encoding intentionality would support greater association of object with background for the young, so that age differences would become larger under conditions of intentionality (as in Naveh-Benjamin et al., 2007).

The specifics of the three experiments are as follows. In the first two experiments, we assessed the effects of "unbinding" a scene. Subjects studied a complex picture with a central object presented against a background that was highly related or relatively unrelated. At recognition, we removed the backgrounds leaving only the central target object to be recognised. We expected that the loss of picture background context would impair performance of both young and elderly adults, due to a loss of environmental support at recognition (Park et al., 1984). Although this procedure relies upon correct recognition of picture elements rather than associations per se, we have used similar procedures successfully and found them to be sensitive to the effects of age on memory for backgrounds versus objects (Gutchess et al., 2007). Moreover, we also hypothesised that older adults would be relatively less affected than young by the removal of the backgrounds in the unrelated condition, because they were less effective at binding target to context than young. In contrast, removal of the related background would strongly impact target recognition, because the target should be more tightly bound to the background compared to the unrelated condition. In the third experiment, we examined the impact of intact and recombined target-background relationships on recognition for related and unrelated items.

EXPERIMENT 1

In the first experiment, participants intentionally encoded an object in relation to a background that was either related or unrelated. At recognition, the backgrounds were removed for half of the pictures, representing a loss of environmental support (Park et al., 1984). In this study, we hypothesised that young would be more effective than old at binding a target to a context in the unrelated condition, but that both age groups would be effective in the related condition. Thus, when subjects had to recognise items without backgrounds, the old would be less impaired than the young in the unrelated condition, due to the fragile binding for the target/background pair in the old.

Methods

Participants. Thirty-four young (ages 17–23; M age = 20.15, SD = 1.26; 17 females) and 34 elderly (ages 62–86; M age = 72.03, SD = 6.20; 17 females) participants took part in the study in exchange for payment or credit towards course requirements. Based on self-report, older adults were screened to have at least a 10th grade education, to be free from visual, auditory or cognitive impairments that would affect their participation, and to not have been hospitalised or had surgery in the previous 6 months. Older adults had more years of education (M = 14.94, SD = 2.06) than the young (M = 13.50, SD = 1.20), $t(66) = 3.53$, $p < .002$. The samples exhibited the expected pattern of age-related differences in measures of speed of processing (Hedden et al., 2002) and vocabulary (Shipley, 1986). Older adults had higher vocabulary scores (M = 34.65, SD = 3.28) than young adults (M = 31.47, SD = 3.18), $t(66) = 4.05$, $p < .001$, but completed fewer items on the digit comparison task (older adult M = 53.66, SD = 11.39 vs. young adult M = 74.61, SD = 11.58) on a speed of processing measure, $t(63) = 7.35$, $p < .001$. All participants provided written informed consent for a protocol approved by the Institutional Review Board.

Materials and procedure. In the study, we used 105 line-drawing pictures consisting of a target object and a supporting, related background (e.g., a squirrel eating a nut in a tree). The backgrounds were then swapped among pictures such that each target object was re-paired with an unrelated background to create an additional 105 pictures (e.g., a squirrel eating a nut on a kitchen counter). Finally, the background of each picture was removed to create a set of 105 pictures of the target-item only. See Figure 1 for examples of the three types of stimuli. This set of 315 pictures was counterbalanced such that, across subjects, each object was seen at recognition with a related background, an unrelated background, and without a background, as well as appearing as a studied target item and an unstudied lure item.

Participants viewed 60 line-drawings of a target item on a background. Many of the previous studies report age-equivalent memory for line-drawings of scenes (e.g., Park et al., 1986; Smith et al., 1990), which suggests that even these stimuli can impart sufficiently complex contextual information. Half of the encoded pictures consisted of a pairing of a background and target item that together constituted a familiar scene while the other half of the pictures consisted of pairings of a background with a target item that comprised an unusual or unrelated scene at encoding (see Figure 1). Participants were instructed to "study and try to remember the entire picture. Attempt to associate the target item with the background so that you can remember them together when you are tested later." Pictures

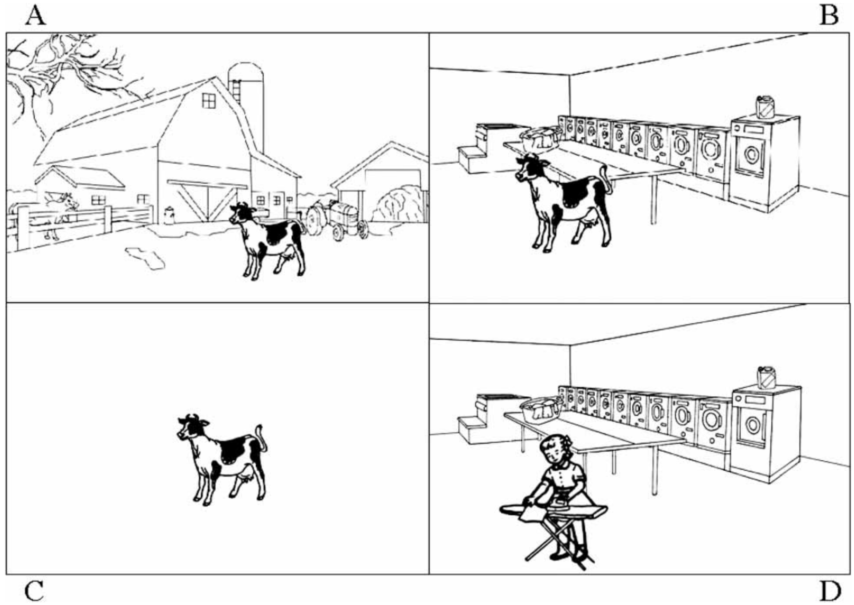

Figure 1. Examples of picture stimuli, consisting of a related picture (A), an unrelated picture (B), and a no-background picture (C). In Experiment 3, lure pictures consisted of recombinations of objects and backgrounds originally encoded in different picture pairings. Using these examples, a participant could have originally encoded the pictures displayed in Panels A and D (both in the related condition) and then encounter the same elements at recognition in the unrelated combination depicted in Panel B; this would constitute an RR-U trial (i.e., object and background were studied in separate Related pairings at encoding, but tested in a new Unrelated pairing at recognition).

were presented on a computer for 4 s each with a 1 s interstimulus interval. These pictures consisted of a central target item and a related or unrelated background (30 of each type). To reinforce the encoding instruction, we provided the participants with four practice encoding and recognition trials before studying the pictures on the computer. Participants were instructed, "remember that you are basing your decision on the entire picture you just studied. If you saw the target item before but it was not paired with the same background, you would respond NO because you did not study the entire identical picture previously." After the practice recognition test, the correct responses were explained to the participants.

After encoding, there was a 12 min retention interval, during which time participants completed the vocabulary subscale of the Shipley Institute of Living Scale (Shipley, 1986). Then, participants' picture memory was assessed. The recognition test consisted of 105 pictures: the 60 that were previously studied and 45 new lures. Half of the previously studied pictures (15 related and 15 unrelated) and one-third of the lures (i.e., 15) had the background removed while the other pictures had backgrounds intact (15 related and 15 unrelated targets; 15 related and 15 unrelated new lures). Participants were instructed to respond on the basis of the item only, ignoring the background information. Participants pressed a key labelled "yes" for pictures with target items they had studied previously and one labelled "no" for pictures they had not studied earlier. The backgrounds were removed from half of the previously studied pictures and a third of the lure items so that we could assess the contribution to memory of the environmental support provided by the presence of the background. Stimuli were presented in a random ordering for each subject with PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants also completed the digit comparison task (Hedden et al., 2002; modelled after Salthouse & Babcock's, 1991, Letter Comparison Task) as a measure of speed of processing.

Results and discussion

To assess recognition performance, we calculated A' scores (Snodgrass & Corwin, 1988) as a measure of corrected recognition, using the hit rates to either the related or unrelated target pictures and the false alarm rates to related and unrelated lure pictures, with and without backgrounds. Results were tested using a mixed design ANOVA, with age (young/older) as a between-subjects variable and relatedness (related/unrelated) and background (present/absent at recognition) as within-subject variables. The only effect to reach significance was that of background, $F(1, 66) = 71.27$, $p < .001$, $\eta^2_p = .52$), with pictures containing a background at recognition ($M = 0.92$) supporting more accurate recognition than pictures without a background ($M = 0.85$), consistent with the findings of Park et al. (1984). No other effects approached significance (Fs < 1). Results are shown in Figure 2. Contrary to our predictions, unrelated backgrounds did not disproportionately affect older adults compared to younger adults and, in fact, memory for objects presented on unrelated backgrounds was no worse than memory for objects presented on a related background. Even when the backgrounds were removed, pictures encoded in related and unrelated contexts were remembered equivalently, suggesting that the presence of an unrelated background did not inhibit recognition of object pictures. Consistent with prior studies, the age groups did not differ in picture recognition ability.

The results suggest that the different types of background contexts do not differ in their binding demands for younger or older adults. Both unrelated and related backgrounds enhance memory performance compared to pictures that lack background context.

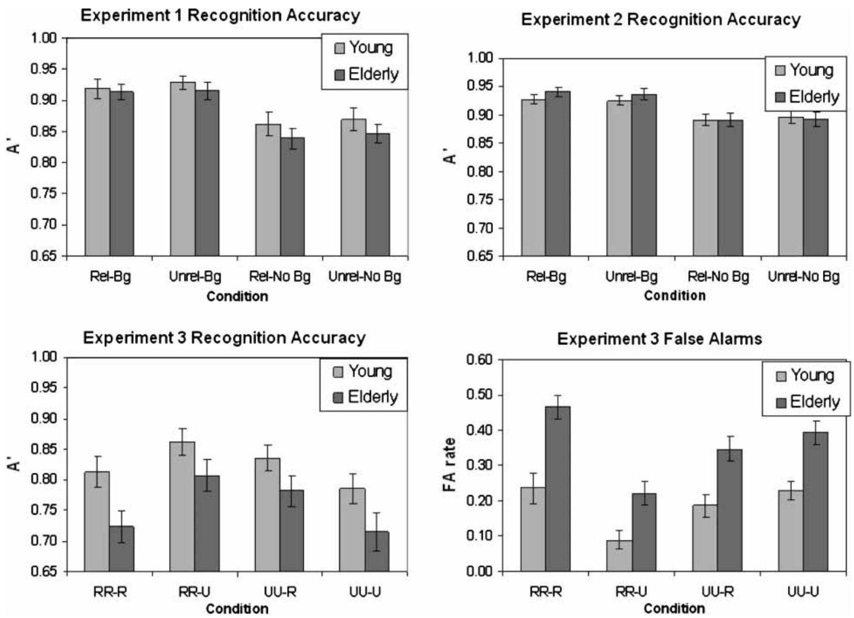

Figure 2. Memory performance for young and elderly adults in each of the three experiments.

EXPERIMENT 2

Although the complex scene context may engender semantic meaning that supports memory for both related and unrelated information, it is possible that our instructions contributed to the pattern of performance on this task. Our instructions emphasised encoding objects with their backgrounds, and this may have encouraged participants to place undue emphasis on the backgrounds. Even though prior studies have identified larger associative deficits with age under associative encoding instructions rather than item encoding instructions (Naveh-Benjamin, 2000), picture contexts could operate differently. In the case of unrelated backgrounds, participants may have focused on the bizarre nature of the unrelated pairings, which enhanced memory performance on these pictures (e.g., McDaniel & Einstein, 1986). Experiment 2 deemphasised the encoding of backgrounds; encoding instructions emphasised encoding of the items only and background information was incidental to the task.

Methods

Participants. Thirty-two young (ages 19–28; *M* age = 22.25, *SD* = 2.16; 16 females) and 33 elderly (ages 60–81; *M* age = 72.06, *SD* = 6.05; 16 females) participated in the study. Although participants were drawn from the same population as those in Experiment 1, the samples were non-overlapping (as also was the case for Experiment 3). Older adults had completed more years of education ($M = 15.73$, $SD = 2.27$) than young ($M = 14.73$, $SD = 1.03$), $t(63) = 2.26$, $p < .03$, and had higher Shipley vocabulary scores (older adult $M = 35.18$, $SD = 3.92$; young adult $M = 31.66$, $SD = 3.59$), $t(63) = 3.78$, $p < .001$. Young adults completed more items on the speed of processing task ($M = 72.53$, $SD = 10.12$) than older adults ($M = 56.71$, $SD = 13.89$), $t(61) = 5.18$, $p < .001$.

Materials and procedure. With the sole exception of the instructions and practice, the task was identical to that of Experiment 1. Whereas in Experiment 1 participants were instructed to associate the target item to the background during the encoding task, participants in Experiment 2 were instructed, "study and try to remember the target item only. ... Try to remember the item regardless of the background so that you can recognise it when you are tested later." This instruction allowed us to assess the contribution of the background to recognition memory, even when the binding of related or unrelated information was incidental to the encoding task. The practice encoding and recognition trials were consistent with this instruction. Participants were instructed, "remember that you are basing your decision on only the target items you just studied. If you saw the target item before but now it is on a different (or blank) background, you would respond YES because you did study that target item previously."

Results and discussion

A' corrected recognition scores were calculated and subjected to a mixed design ANOVA. As was the case for Experiment 1, the effect of background was the only effect to reach significance, $F(1, 63) = 34.97$, $p < .001$, $\eta_p^2 = .36$. Pictures containing a background at recognition ($M = 0.93$) were more accurately recognised than pictures lacking a background ($M = 0.89$). No effects or interactions involving age emerged (Fs < 1.2), again illustrating the age-invariant nature of picture recognition ability. Results are displayed in Figure 2.

Experiment 2 replicates the pattern of results seen for Experiment 1, and suggests that the relatedness of background information has no effect on picture memory for both young and older adults even when the background information is not emphasised at encoding. Even when background information is incidentally encoded, young and elderly show equivalent support from backgrounds at recognition through superior memory when backgrounds are re-presented. This pattern suggests that backgrounds, whether relevant or irrelevant, are automatically bound to the target objects at the time of encoding. In contrast to the findings of age impairments in binding ability in a number of tasks (Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003, 2004), associative memory ability seems to be intact when the elements to be bound together are related in a semantically meaningful and perceptually rich environment, as is the case for complex pictures. Unrelated pictures do not differ from related pictures, regardless of whether the background is presented with the object at recognition. Our results replicate Smith et al.'s (1990) findings that young and elderly adults can exhibit equivalent picture memory when pictures are complex and semantically meaningful. Whereas the earlier study reports age differences in memory for abstract pictures that lack semantically meaningful content, we find that memory can be age-invariant for unrelated pictures. These data suggest that elements need not be schematically related based on familiar experiences, but need only lend themselves to rich interpretation.

EXPERIMENT 3

Although the previous two experiments are consistent in their findings that the relatedness of scene elements does not differentially affect picture recognition in young or older adults, the results do not present a pure test of binding ability. That is, accurate recognition could be achieved on the basis of recognising a previously studied object, regardless of the background. Even though we argue that "unbinding", or removing background information at the time of recognition, provides a test for how well item and background elements are bound together at the time of encoding, Experiment 3 adopts a more conventional associative memory task in which accurate recognition relies on the ability to correctly identify intact object–background associations from recombined object–background pairs. Based on the results of Experiments 1 and 2, we predict that both age groups will respond similarly to manipulations of the relatedness of object and background pairs.

Methods

Participants. Drawn from the same populations as the previous experiments, 28 young (M age = 20.96, $SD = 1.82$; 19 females) and 32 older adults (M age = 69.66, $SD = 4.22$; 18 females) participated in the study. Older adults tended to have more years of education ($M = 15.72$; $SD = 2.36$) than young adults ($M = 14.95$; $SD = 1.29$), but this difference was not significant, $t(58) = 1.54$, $p = .13$. As in the previous experiments, older adults ($M = 56.63$; $SD = 9.11$) completed fewer items on the digit comparison speed of processing task than young adults ($M = 78.71$; $SD = 12.60$), $t(58) = 7.85$, $p < .001$.

Materials and procedure. Participants intentionally encoded 96 line-drawing pictures, 48 consisting of objects placed in related backgrounds and 48 consisting of objects placed in unrelated backgrounds. Participants were instructed to "study and try to remember the entire picture. Attempt to associate the target object with the background so that you can remember them together when you are tested later." This instruction was reinforced with four practice study and test trials that contained intact pictures as well as some in which the background had been changed. Pictures were encoded for 4 s each. Following a 12 min retention interval, participants completed the recognition task, during which time participants judged whether the *exact* picture had been encoded previously and made a "yes" or "no" response with a keypress. Participants were reminded that "some pictures may have both a background and a target item that you studied previously but they were not paired together before. For those items you should respond NO. Only respond YES if you studied all of the parts in the SAME picture previously." Each participant was tested on 48 old target pictures (half related, half unrelated), and 48 lure pictures consisting entirely of previously studied elements. Lure pictures were recombinations of previously encoded object–background pairs, and object and the background always had the same encoding history (i.e., both studied in related pairs or both studied in unrelated pairs) but were drawn from two different encoded pictures. For the 48 lure pictures, 12 consisted of elements that were encoded in related pairings and were tested in a new related combination (RR-R), 12 consisted of elements that were encoded in related pairings and were tested in a new unrelated combination (RR-U), 12 consisted of elements that were encoded in unrelated pairings and were tested in a new related combination (UU-R), and 12 consisted of elements that were encoded in unrelated pairings and were tested in a new unrelated combination (UU-U). Using this naming convention, the first two letters indicate the relatedness of the encoding condition for the object and background elements (which always have the same encoding condition), and the last letter indicates the relatedness of the recognition condition, in which encoded elements from two separate studied pictures are combined into a single picture. See Figure 1 for an example of a recombination. Four counterbalanced orders were used to vary whether pictures were tested as targets or lures and for lures, to alternate which versions of the pictures were presented at encoding versus recognition. The encoding and recognition tasks were presented using E-Prime software (Psychology Software Tools, Pittsburgh, PA).

Results and discussion

In this study, there were two types of hit rate for previously studied pictures: one for related pictures and one for unrelated pictures. In contrast, there were four false alarm rates for the recombinations of old pictures: RR-R, RR-U, UU-R, UU-U. Corrected recognition A' scores were calculated for related and unrelated encoding items using the two hit rates and four different false alarm rates. We calculated the A' for RR-R by using hit rates for related items that had been presented at encoding along with the false alarm rates to RR-R pictures (i.e., both the object and background were originally presented in different related scenes but participants mistakenly claimed to recognise the lure picture that was a recombination of these elements into a new related scene) and the A' for UU-U by using hit rates for unrelated items that had been presented at encoding along with the false alarm rates to UU-U pictures (i.e., both the object and background were originally presented in different unrelated scenes but participants mistakenly claimed to recognise the lure picture that was a recombination of these elements into a new unrelated scene). For the pairings that changed their relatedness status, we chose to use the hit rate that matched the *recognition* condition.[1] Therefore, the A' score for RR-U was calculated by using the hit rates for unrelated items and the false alarm rates to RR-U pictures (i.e., both the object and background were originally presented in different related scenes but participants mistakenly claimed to recognise the lure picture that was a recombination of these elements into a new unrelated scene). The A' score for the UU-R condition was calculated by using the hit rates for related items and the false alarm rates to UU-R pictures (i.e., both the object and background were originally presented in different unrelated scenes but participants mistakenly claimed to recognise the lure picture that was a recombination of these elements into a new related scene).

In analyses of the corrected recognition scores (A'), the main effect of relatedness at encoding reached significance, with higher scores for related pictures ($M = 0.80$) than unrelated pictures ($M = 0.78$), $F(1, 58) = 4.76$, $p < .05$, $\eta_p^2 = .08$. The relatedness of the backgrounds and objects at encoding interacted with the relatedness of the scenes at recognition, $F(1, 58) = 36.87$, $p < .001$, $\eta_p^2 = .39$. As seen in Figure 2, corrected recognition scores tend to be higher when there is a mismatch between the relatedness of the pairing at encoding and recognition. We collapsed across the different conditions in order to compare average A' scores for pictures in which the relatedness at encoding and recognition matched versus mismatched. The results of a 2

[1] The other alternative would have been to calculate A' scores with the hit rate that matched the *encoding* condition (e.g., using the related hit rate for the RR-U condition). When A' scores are calculated with these hit rates, the pattern of significant main effects and interactions is unaffected.

(match/mismatch) × 2 (young/elderly) ANOVA supports the observation that recognition was more accurate for the mismatched ($M = 0.82$) compared to the matched relatedness ($M = 0.76$), $F(1, 58) = 36.87$, $p < .001$, $\eta_p^2 = .39$. It is hardest to reject novel repairings of objects and backgrounds when the elements share the same type of related or unrelated relationship as at encoding (i.e., RR-R and UU-U conditions, relative to RR-U and UU-R conditions). This difference is significant for both types of pairs, RR-R vs. RR-U, $F(1, 58) = 17.63$, $p < .001$, $\eta_p^2 = .23$, and UU-U vs. UU-R, $F(1, 58) = 10.70$, $p < .003$, $\eta_p^2 = .16$. Although the difference appears to be slightly larger for RR-U compared to RR-R pairings, in comparison to the difference between the UU-R and UU-U conditions, this was not borne out statistically ($F < 1$). There was also a main effect of age with higher corrected recognition scores for young than older adults, $F(1, 58) = 4.85$, $p < .05$, $\eta_p^2 = .08$. No other effects approached significance (Fs < 2).

Because the corrected recognition scores were affected by the relatedness of the objects and backgrounds and differed across the age groups, we conducted additional analyses on the hit and false alarm rates. Hit rates exhibited a main effect of relatedness, $F(1, 58) = 12.75$, $p < .001$, $\eta_p^2 = .18$, with higher hit rates for object presented in a related background ($M = 0.74$) compared to those presented in unrelated backgrounds ($M = 0.68$). Although older adults ($M = 0.74$) exhibited a trend for higher hit rates than young adults ($M = 0.68$), this effect did not reach significance, $F(1, 58) = 2.58$, $p = .11$, $\eta_p^2 = .04$. The Age × Relatedness interaction did not approach significance ($F < 1$).

For the false alarm rates (see Figure 2), the main effects of the relatedness at encoding, $F(1, 58) = 4.22$, $p < .05$, $\eta_p^2 = .07$, and the relatedness at recognition, $F(1, 58) = 16.54$, $p < .001$, $\eta_p^2 = .22$, reached significance. Participants committed more false alarms when encoding was unrelated ($M = 0.29$) as opposed to related ($M = 0.25$), but at recognition, committed more false alarms to related ($M = 0.31$) than unrelated ($M = 0.23$) pairs. Older adults committed significantly more false alarms than young adults, $F(1, 58) = 23.18$, $p < .001$, $\eta_p^2 = .29$, but none of the interactions involving age approached significance (Fs < 2). These main effects were qualified by an interaction of the relatedness at encoding and recognition, $F(1, 58) = 43.01$, $p < .001$, $\eta_p^2 = .43$. Note that the relative benefit for RR-U compared to RR-R trials on the corrected recognition A' measure seems to be driven by the substantially lower false alarm rate in the RR-U condition, compared to the heightened false alarm rate in the RR-R condition. This observation was supported by a follow-up 2 × 2 ANOVA comparing the false alarm rates to RR-U and RR-R lures for young and elderly, which revealed a significant main effect of relatedness, $F(1, 58) = 54.42$, $p < .001$, $\eta_p^2 = .48$. There was also a trend for difference between false alarms to RR-U and RR-R lures to be larger for young than older adults, $F(1, 58) = 3.42$, $p < .08$, $\eta_p^2 = .06$, and a significant main effect of age such that older adults committed more false alarms than young, $F(1, 58) = 19.70$, $p < .001$, $\eta_p^2 = .25$.

Unlike the previous experiments, we find that older adults perform less accurately than young adults in the binding of related and unrelated picture elements, and that this performance difference is due primarily to a heightened false alarm rate. Indeed, young and elderly exhibit rather high false recognition rates on some conditions of this task, a pattern that is in stark contrast to their highly accurate picture recognition ability demonstrated in Experiments 1 and 2. In this experiment, the relatedness of information affected recognition ability in young and elderly, in contrast to the findings from Experiments 1 and 2. As in the previous experiments, however, the relatedness of the objects and backgrounds does not *differentially* affect memory across the two age groups. Although older adults are less accurate than young, this age difference occurs across the board; the binding of both related and unrelated information is similar for young and elderly. Although binding unrelated information together at encoding seemed to be somewhat more difficult than binding related information together, changes in the relatedness condition at recognition substantially affected memory performance. Changing the type of relationship between scene elements (i.e., related to unrelated and vice versa; RR-U and UU-R conditions) from the time of encoding to the time of recognition generally benefited performance compared to memory for pictures tested with novel relationships of the same type (i.e., RR-R or UU-U). Although relatedness affects binding ability, it generally appears to be the case that relatedness facilitates encoding, although relatedness can backfire at recognition by leading to higher levels of memory errors when a lure pair shares a naturally occurring relationship (as in the RR-R pairs).

Even though older adults bind information together more poorly than young adults, the associative memory impairment is rather modest compared to previous studies (i.e., a .07 difference between the mean A' score for our young and elderly compared to a .15 age difference in A' scores in Naveh-Benjamin et al., 2003, Exp. 1). This seems to suggest that even under heavy binding demands, older adults benefit from rich pictorial information. Importantly, relatedness does not differentially impact memory binding across the age groups. Unrelated pairings are bound proportionately as well for older adults as for young adults. This finding suggests that in the case of pictures containing rich semantic information, contextual information can be used to support binding even if the contexts do not have longstanding associations with the objects through extensive prior experience. In contrast, relatedness severely impacts the ability of older adults to associate pairs of words, simple pictures of objects, or name–face pairs (Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003, 2004). Whereas age differences were modest in the ability to remember related word pairs on an associative memory test, older adults performed substantially worse on memory for unrelated word pairs. Taken together, the pattern of findings underscores the supportive nature of picture contexts for memory. Despite the preponderance of age-related impairments in associative memory for many types of information, both related and unrelated picture contexts are bound relatively well to objects with age.

GENERAL DISCUSSION

Across three experiments, we report evidence that ageing exerts little influence on associative memory for complex pictures. Counter to our predictions, our manipulation of relatedness does not affect older adults' associative memory performance any more than it affects young adults across all three experiments. In fact, the relatedness of object and background information had no effect on either group in Experiments 1 and 2; in Experiment 3, information that was related at encoding was remembered somewhat better than information that was unrelated at encoding, but there was no overall advantage for remembering information presented in a related pairing at recognition. The pattern of data reported in our studies differs from previous findings (e.g., Naveh-Benjamin et al., 2003), in which older adults' associative deficits are larger for unrelated information than related information.

Furthermore, our manipulations of environmental support and encoding intentionality did not interact with ageing or the relatedness of the scenes. Older adults recognise re-presented bound pictures just as well as young adults and the removal of previously bound background information affects older adults no differently than young (Experiments 1 and 2). We had predicted that the environmental support provided by backgrounds would be particularly important for related scenes, and that the removal of background information would disproportionately impair memory for related scenes. However, recognition of both related and unrelated scenes was similarly affected by the loss of environmental support, and this did not differ across the age groups. Unlike previous studies (e.g., Naveh-Benjamin, 2000), intentional associative encoding instructions, a factor varied across Experiments 1 and 2, do not magnify older adults' associative memory impairments. This provides further evidence that the relationships contained in complex pictures support associative memory for young and older adults, even if those relationships are of an unusual or unexpected nature.

Regarding the two candidate explanations for age-invariant picture memory that we put forth in the introduction, that complex pictures have relatively low associative processing demands and that the natural relationships contained in pictures support memory, our evidence tends to support the first, but not the second, hypothesis. Elderly remember pictures with novel and unusual relationships just as well as young adults. The divergence of our results from the previous findings suggests that complex scene associations are special and distinct from other types of associative memory. Related and unrelated components are bound together equally well by both younger and older adults, and associative and item-based encoding instructions support young and older adults' memory equally well. This finding is surprising, given the contribution of top-down contextual influences on the identification of objects in schema-consistent and schema-inconsistent scenes (Biederman, Mezzanotte, & Rabinowitz, 1982; see reviews by Bar, 2004; Henderson & Hollingworth, 1999). Our findings suggest that these top-down influences may be less important for memory and/or when there is a relatively lengthy encoding period. It is also surprising in terms of the ageing literature, which suggests that older adults have more difficulty integrating schema-inconsistent information into a script (Hess & Tate, 1992). We propose that the natural supporting relationship between a meaningful background and an object automatically engenders the formation of associations in memory. Even when the elements are combined in an unusual fashion, the rich semantic information contained in scenes supports a meaningful interpretation of the interacting components. A novel semantic association can be created easily to explain how the elements came to be combined in such a way; this interpretation is consistent with Smith et al.'s (1998) finding that semantically meaningful pictures can be remembered equivalently by young and elderly. Although we suggest that perceptual complexity is an important factor (as found by Smith et al., 1990), it is possible that the rich associations imparted by contexts, visual or not, are the critical component (see Bar, 2007) that supports older adults' memory. The high level of recognition for pictures containing unusual relationships does not seem to be explained simply as a bizarreness effect. In the present studies, we found no evidence that bizarreness enhanced item memory relative to typical scenes in Experiments 1 and 2, or that bizarreness improved binding, as assessed by Experiment 3. In addition, previous studies suggested that bizarreness enhances item, but not source, memory (Macklin & McDaniel, 2005), which would preclude an effect on memory for associations.

Another possibility, as suggested by Mayes, Montaldi, and Migo (2007), is that distinct regions of the medial temporal lobes contribute based on the properties of the information to be associated. The hippocampus plays a role in binding (Giovanello, Schnyer, & Verfaellie, 2004; Henke, Weber, Kneifel, Wieser, & Buck, 1999; Preston, Shrager, Dudukovic, & Gabrieli, 2004; Sperling, Chua, et al., 2003), and ageing is known to affect the function of the hippocampus, with several studies identifying decreased activation of the medial temporal lobes for older adults (e.g., Daselaar, Veltman, Rombouts, Raaijmakers, & Jonker, 2003; Grady et al., 1995; Grady, McIntosh, Rajeh, Beig, & Craik, 1999; Park et al., 2003; Sperling, Bates, et al., 2003). However, ageing may not equivalently affect all regions of the medial temporal lobes. Perirhinal cortex does not lose volume with age, in contrast to the hippocampus and entorhinal and posterior parahippocampal cortices, which do lose volume with age (Dickerson et al., in press; Du et al., 2006; Raz, Rodrigue, Head, Kennedy, & Acker, 2004). These differences may be particularly important given recent evidence suggesting that subregions of the medial temporal lobes differ in their contributions to associative memory depending on the type of information. Across-domain associations (e.g., sound–picture) require the hippocampus to a greater extent than within-domain associations, which may be supported in part by the perirhinal cortex (Mayes et al., 2007). This explanation predicts that associative memory for complex scene elements should be governed by different regions than associative memory for other information. In contrast to other types of association (e.g., object–object; word–word) that are bound through hippocampally mediated mechanisms, it is possible that our complex scenes engaged the perirhinal cortex in an age-invariant manner (Dickerson et al., in press), possibly because the highly interrelated picture elements promoted unitisation (Mayes et al., 2007).

Although neuroimaging data are needed to evaluate potential differences in the neural regions that contribute to complex picture memory for related and unrelated elements, at present we favour an account that emphasises the supportive nature of the task conditions in picture memory. Even if complex pictures promote unitisation via the perirhinal cortex, one might expect that the novel relationships depicted in unrelated pictures would recruit the hippocampus (Köhler, Danckert, Gati, & Menon, 2005). Because the hippocampus is more sensitive to the effects of ageing, this would seem to predict poorer memory for older adults on unrelated picture pairs, which was not the case in our data. The semantically rich and meaningful associations that can be generated amongst even novel and unrelated picture elements engage the associative memory network in young and older adults. Recent functional neuroimaging data from our laboratory identified age-equivalent engagement of the hippocampus for unrelated and related pictures in an associative memory task, even though the stimuli were simple pictures of objects (Leshikar, Gutchess, Hebrank, Sutton, & Park, 2008). We suggest that the pattern of similar neural results reflected the supportive nature of the task conditions, in which young and elderly created a sentence to integrate the two depicted items. Complex pictures, as used in the present study, may engage integrative processes automatically.

In summary, our findings build on previous literature demonstrating that picture memory is relatively intact with age (e.g., Park et al., 1986, 1990; Smith et al., 1990, 1998) by extending the findings of relative invariance with age to associative memory. Importantly, our results suggest that associative deficits do not characterise all types of memory with age.

REFERENCES

Bar, M. (2004). Visual objects in context. *Nature Reviews Neuroscience*, *5*, 617–629.

Bar, M. (2007). The proactive brain: Using analogies and associations to generate predictions. *Trends in Cognitive Sciences*, *11*, 280–289.

Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology*, *14*, 143–177.

Chalfonte, B. L., & Johnson, M. K. (1996). Feature memory and binding in young and older adults. *Memory and Cognition*, *24*, 403–416.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments and Computers*, *25*, 257–271.

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. Trehaub (Eds.), *Aging and cognitive processes* (pp. 191–211). New York: Plenum.

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 Associates, Inc.

Daselaar, S. M., Veltman, D. J., Rombouts, S. A., Raaijmakers, J. G., & Jonker, C. (2003). Deep processing activates the medal temporal lobe in young but not elderly adults. *Neurobiology of Aging*, *24*, 1005–1011.

Dickerson, B. C., Feczko, E., Augustinack, J. C., Pacheco, J., Morris, J. C., Fischl, B., & Buckner, R. L.(in press). Differential effects of aging and Alzheimer's disease on medial temporal lobe cortical thickness and surface area. *Neurobiology of Aging*.

Du, A.-T., Schuff, N., Chao, L. L., Kornak, J., Jagust, W. J., Kramer, J. H., et al. (2006). Age effects on atrophy rates of entorhinal cortex and hippocampus. *Neurobiology of Aging*, *27*, 733–740.

Giovanello, K. S., Keane, M. M., & Verfaellie, M. (2006). The contribution of familiarity to associative memory in amnesia. *Neuropsychologia*, *44*, 1859–1865.

Giovanello, K. S., Schnyer, D. M., & Verfaellie, M. (2004). A critical role for the anterior hippocampus in relational memory: Evidence from an fMRI study comparing associative and item recognition. *Hippocampus*, *14*, 5–8.

Grady, C. L., McIntosh, A. R., Horwitz, B., Maisog, J. M., Ungerleider, L. G., Mentis, M. J., et al. (1995). Age-related reductions in human recognition memory due to impaired encoding. *Science*, *269*, 218–221.

Grady, C. L., McIntosh, A. R., Rajah, M. N., Beig, S., & Craik, F. I. M. (1999). The effects of age on the neural correlates of episodic encoding. *Cerebral Cortex*, *9*, 805–814.

Gutchess, A. H., Hebrank, A., Sutton, B., Leshikar, E., Chee, M. W. L., Tan, J. C., et al. (2007). Contextual interference in recognition memory with age. *NeuroImage*, *35*, 1338–1347.

Hedden, T., Park, D. C., Nisbett, R., Ji, L.-J., Jing, Q., & Jiao, S. (2002). Cultural variation in verbal versus spatial neuropsychological function across the life span. *Neuropsychology*, *16*, 65–73.

Henderson, J. M., & Hollingworth, A. (1999). High-level scene perception. *Annual Review of Psychology*, *50*, 243–271.

Henke, K., Weber, B., Kneifel, S., Wieser, H. G., & Buck, A. (1999). Human hippocampus associates information in memory. *Proceedings of the National Academy of Sciences of the USA*, *96*, 5884–5889.

Hess, T. M., & Tate, C. S. (1992). Direct and indirect assessments of memory for script-based narratives in young and older adults. *Cognitive Development*, *7*, 467–484.

Köhler, S., Danckert, S., Gati, J. S., & Menon, R. S. (2005). Novelty responses to relational and non-relational information in the hippocampus and the parahippocampal region: A comparison based on event-related fMRI. *Hippocampus*, *15*, 763–774.

Leshikar, E. D., Gutchess, A. H., Hebrank, A. C., Sutton, B. P., & Park, D. C. (2008). *The impact of increased relational encoding demands on frontal and hippocampal function in older adults.* Unpublished manuscript, University of Illinois at Urbana-Champaign, IL.

Lyle, K. B., & Johnson, M. K. (2006). Importing perceived features into false memories. *Memory*, *14*, 197–213.

Macklin, C. B., & McDaniel, M. A. (2005). The bizarreness effect: Dissociation between item and source memory. *Memory*, *13*, 682–689.

Mangels, J. A., & Heinberg, A. (2006). Improved episodic integration through enactment: Implications for aging. *Journal of General Psychology*, *133*, 37–65.

Mayes, A., Montaldi, D., & Migo, E. (2007). Associative memory and the medial temporal lobes. *Trends in Cognitive Sciences*, *11*, 126–135.

McDaniel, M. A., & Einstein, G. O. (1986). Bizarre imagery as an effective memory aid: The importance of distinctiveness. Journal of Experimental Psychology: Learning, Memory. *and Cognition*, *12*, 54–65.

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., Brav, T. K., & Levy, O. (2007). The associative memory deficit of older adults: The role of strategy utilization. *Psychology and Aging*, *22*, 202–208.

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.

Park, D. C., & Puglisi, J. T. (1985). Older adults' memory for the color of matched pictures and words. *Journal of Gerontology*, *40*, 198–204.

Park, D. C., Puglisi, J. T., & Lutz, R. (1982). Spatial memory in older adults: Effects of intentionality. *Journal of Gerontology*, *37*, 330–335.

Park, D. C., Puglisi, J. T., & Smith, A. D. (1986). Memory for pictures: Does an age-related decline exist? *Psychology and Aging*, *1*, 11–17.

Park, D. C., Puglisi, J. T., & Sovacool, M. (1984). Picture memory in older adults: Effects of contextual detail at encoding and retrieval. *Journal of Gerontology*, *39*, 213–215.

Park, D. C., Smith, A. D., Morrell, R. W., Puglisi, J. T., & Dudley, W. N. (1990). Effects of contextual integration on recall of pictures by older adults. *Journal of Gerontology: Psychological Sciences*, *45*, 52–57.

Park, D. C., Welsh, R. C., Marshuetz, C., Gutchess, A. H., Mikels, J., Polk, T. A., et al. (2003). Age differences in frontal and medial temporal activations associated with the maintenance of complex pictures in working memory. *Journal of Cognitive Neuroscience*, *15*, 1122–1134.

Preston, A. R., Shrager, Y., Dudukovic, N. M., & Gabrieli, J. D. (2004). Hippocampal contribution to the novel use of relational information in declarative memory. *Hippocampus*, *14*, 148–152.

Quamme, J. R., Yonelinas, A. P., & Norman, K. A. (2007). Effect of unitization on associative recognition in amnesia. *Hippocampus*, *17*, 192–200.

Raz, N., Rodrigue, K. M., Head, D., Kennedy, K. M., & Acker, J. D. (2004). Differential aging of the medial temporal lobe: A study of a five-year change. *Neurology*, *62*, 433–438.

Salthouse, T. A., & Babcock, R. L. (1991). Decomposing adult age differences in working memory. *Developmental Psychology*, *27*, 763–776.

Shipley, W. C. (1986). *Shipley Institute of Living Scale*. Los Angeles, CA: Western Psychological Services.

Smith, A. D., Park, D. C., Cherry, K., & Berkovsky, K (1990). Age differences in memory for concrete and abstract pictures. *Journal of Gerontology: Psychological Sciences*, *45*, P205–P209.

Smith, A. D., Park, D. C., Earles, J. L. K., Shaw, R. J., & Whiting, W. L. (1998). Age differences in context integration in memory. *Psychology and Aging*, *13*, 21–28.

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

Sperling, R. A., Bates, J. F., Chua, E. F., Cocchiarella, A. J., Rentz, D. M., Rosen, B. R., et al. (2003). fMRI studies of associative encoding in young and elderly controls and mild Alzheimer's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, *74*, 44–50.

Sperling, R. A., Chua, E., Cocchiarella, A., Rand-Giovannetti, E., Poldrack, R., Schacter, D. L., & Albert, M. (2003). Putting names to faces: Successful encoding of associative memories activates the anterior hippocampal formation. *NeuroImage*, *20*, 1400–1410.

Standing, L. (1973). Learning 10000 pictures. *Quarterly Journal of Experimental Psychology*, *25*, 207–222.