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Age-Related Changes in Associative Memory for Emotional and Non-emotional Integrative Representations

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Abstract

Events often include novel combinations of items. Sometimes, through the process of integration, we experience and remember these items as parts of a whole rather than as separate entities. Recent research with younger adults has demonstrated that successfully integrating two non-emotional items at encoding, instead of imagining them separately, produces a disproportionately larger associative memory benefit than integrating an emotional and a non-emotional item (Murray & Kensinger, 2012). In the first study to examine whether age and emotion interact to influence integration, we use two measures of integrative success – the ability to successfully retrieve integrations, measured through associative cued recall, and the ability to successfully generate integrated representations at encoding, measured through self report. The cued recall results (Expt. 1 and 2) reveal that the emotional content of the word pairs interacts to influence the effect of integration on older adults' associative memory, but in the opposite direction of younger adults: Older adults show no associative retrieval benefit of integration over non-integration for non-emotional pairs, but they show a significant integrative benefit for emotional pairs. We also demonstrate (Expt. 2) that encoding time interacts with emotion and integration in different ways for older and younger adults: Putting younger adults under time pressure reduces their success in generating integrated representations at encoding for non-emotional pairs, whereas for older adults it disrupts their ability to generate integrated representations for emotional pairs. We discuss possible age-related differences in the processes used to create emotional and non-emotional integrations.

Keywords

emotion; aging; associative memory; integration

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[1]An anonymous reviewer of Murray and Kensinger (2012) raised the concern that including new "lure" words on the cued recall test might instantiate a testing effect that could bias the results: Participants may perform a less-than-thorough memory search for recall targets because they know that some words are lure words, for example. Expt. 2B of that paper demonstrated that for younger adults, exclusion of the recognition judgment on the cued recall test does not meaningfully alter the results. We opted to include the recognition judgment in Expt. 1 and 2 here to ensure that older adults' recognition performance was not tested differently than the younger adults in the main experiments of Murray and Kensinger (2012). We also collected pilot data from 18 additional older adults – ten under Expt. 1's methods and eight under Expt. 2's methods – that omitted the recognition judgment, to rule out the possibility that older adults are more susceptible to potential testing effects than younger adults. These data are shown in Appendix B.

Aging is associated with declines in the ability to form associations between novel pieces of information (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000). Some of the most notable age-related deficits in memory are in older adults' abilities to remember the context in which items were studied (e.g., Park & Puglisi, 1985; Chalfonte & Johnson, 1996) or the particular pairs of stimuli that were presented concurrently (e.g., Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003). Although many studies have revealed these age-related associative memory deficits, only one study has compared how the emotionality of the associations affects younger and older adults' abilities to learn stimulus pairs (Nashiro & Mather, 2011). The present study examines the effect of age on the ability to learn word-pair associations when one of the words is emotional: How does that emotional content affects older adults' ability to form an integrated representation (one that integrates the words into a single mental image at encoding) and to later retrieve that associated representation from memory (Expt. 1), and how is the ability to form and retrieve those integrated associations affected by speeded encoding conditions (Expt. 2)?

Integration is one process of encoding two discrete pieces of information as a single unit (Diana, Yonelinas, & Ranganath, 2008; Graf & Schacter, 1985; 1989). The benefit of such integration is that it allows retrieval access to multiple related items or features simultaneously without having to separately retrieve the individual referents (Graf & Schacter, 1989). For example, until recently, the words "bomb" and "marathon" would be unlikely to have a strong association with one another. However, after the events of the 2013 Boston Marathon bombing, these two concepts have been integrated as a single representation in the minds of many. Often, the term "integration" has been used to refer to the *encoding* process of concatenating items into a single representation, but integrative success typically is measured at *retrieval* through an assessment of associative memory performance. Here, however, we provide two measures of integrative success: one at encoding, through self-reported measures of success at generating vivid images that bring together two items into a single representation, and a second at retrieval, through associative cued recall performance. Throughout this paper, we are careful to delineate which phase of memory we are referring to when we talk about "integrative success": the generation of those representations during encoding or the later retrieval of those representations.

As is evident from the "bomb + marathon" example, it is likely that many of the integrations we form in everyday life require us to bring together two concepts that differ in emotional valence. While little investigation has examined the effects of emotional integration specifically, there has been substantial investigation into emotion's effect on more traditional types of associative learning where individuals learn that two items or features go together without integrating them into a single representation (reviewed by Mather, 2007). We have therefore utilized that literature to inform our predictions regarding younger and older adults' successful encoding and retrieval of emotional integrations.

Emotion's effect on the binding of associated neutral details is currently an issue under debate, with some evidence indicating that emotion impedes the associative binding of neutral details (Jacobs & Nadel, 1998; Payne et al., 2004) and other evidence suggesting that emotion may trigger prioritized binding mechanisms that facilitate the binding of details (Hadley & MacKay, 2006; MacKay et al., 2004; MacKay & Ahmetzanov, 2005; see also

Guillet & Arndt, 2009, for data on facilitated associative binding between neutral and highly arousing taboo words). In one recent demonstration of emotion facilitating associative binding, Nashiro and Mather (2011) demonstrated that when college-age participants were asked to recall the location on-screen for emotional and neutral images, they showed enhanced location memory for emotional but not for neutral images.

Relevant to the current investigation of integration, as more data have been acquired, it has become increasingly apparent that the way in which the emotional and neutral information are processed during encoding– whether as two separate representations that occur together, or as parts of a single mnemonic representation – is critical to how they are remembered together (Mather, 2007; Mather & Sutherland, 2011). Mather and Sutherland (2011) have proposed that the presence of physiological arousal magnifies the effects of competition by stimuli for mnemonic representation, making it even more likely that the information that gains priority – whether a single item or an integrated set of items – will maintain that prioritized representation. In the present study, we manipulate two factors – whether a word within a pair has emotional content and whether participants are asked to integrate the two words into a single representation at encoding – and investigate how the stimulus properties and the goal set by the task instructions will interact to influence what gains priority. In other words, using Mather and Sutherland (2011) as a theoretical framework, we ask: What happens when task motivations (integrative encoding instructions) encourage younger and older adults to prioritize all information present on-screen, rather than just the emotional information? Will younger and older adults demonstrate differences in the effects of emotion on the ability to form integrations when instructed to do so at encoding, and/or on the ability to retrieve those integrations from memory?

When asked to form an integrated representation of a pair of neutral items, such as “degree + surf,” one could imagine a person using their degree as a surfboard or imagine that a “surf degree” is a special degree conferred upon completion of a surfing class. Here, integration is prioritized, because that is the task goal. But what if one of the items is emotional – for example, “fire + chair”? Although the stimulus properties of the word “fire” may cause it to gain priority over the word “chair,” the instructions to integrate the words together may instead encourage a prioritization of the pairing of the words.

When we previously examined the effect of instructed integration on younger adults’ ability to form integrated images and to remember the pairs, we (Murray & Kensinger, 2012) demonstrated that college-age participants were able to integrate an emotional and a neutral item at encoding when instructed to do so. Even when under time pressure, they reported high success in creating a mental image that integrated the two concepts, suggesting that the attentional pull of the emotional item was insufficient to disrupt the process of integration when such integration was task-relevant. Interestingly, although the *creation* of the integrated representation under time pressure was facilitated by emotion, the *associative memory retrieval* benefit of integration for neutral items was significantly less pronounced if they were integrated with emotional items rather than other neutral items. Using the above examples, participants would demonstrate significantly better memory for the association between “degree” and “surf” than for the association between “fire” and “chair.” One explanation for these results is that, although task motivation may enable younger adults to integrate the emotional item with its neutral counterpart rather than only focusing on the emotional item, that tug-of-war between task motivations (encouraging processing of the pair) and attention-capturing stimulus properties (encouraging processing of the emotional word) might prevent individuals from forming particularly salient memory traces. A related interpretation of these findings, similar to an explanation put forth by Zimmerman and Kelley (2010), is that the fluent processing or rapid semantic access enabled by the emotional word may lead participants to believe that they have created a durable representation for the pair, perhaps curtailing deeper encoding. Regardless of the exact mechanism, these results reveal a disconnect between the effects of emotion on younger adults' formation of an integrative representation and on their mnemonic retrieval of that representation. Emotional stimuli may lead to short-term facilitative effects, causing younger adults to have high confidence in their encoding success (measured either through subjective ratings of integrative imagery success [Murray & Kensinger, 2012] or through judgments of learning [Zimmerman & Kelley, 2010]), but that initial facilitation may not translate to longer-term retention benefits.

Younger and older adults often are differently motivated to engage with emotional information, possibly due to age-related differences in affect regulatory goals (Carstensen, Isaacowitz, & Charles, 1999; Leclerc & Kensinger, 2008; see review by Nashiro, Sakaki, & Mather, 2012). When resources are available, older adults tend to process emotional information in a more controlled fashion than younger adults (see review by Mather & Carstensen, 2005), and they often are motivated to elaborate on emotional information so as to process its self-relevance (Gutchess et al., 2007; Kensinger & Leclerc, 2009). Instructed integration and emotion may, therefore, interact differently in younger and older adults to influence their ability to form and retrieve representations of stimulus pairs. In particular, we hypothesized that older adults would be more likely than younger adults to use controlled processes when encountering the emotional pairs, and to elaborate on the emotional integrations. For neutral pairs, however, they may be less likely than young adults to elaborate, consistent with age-related declines in the use of deliberative encoding strategies (e.g., Logan et al., 2003). Similar to a levels-of-processing effect, we hypothesized that this would lead older adults to show a larger integrative benefit for the associative retrieval of emotional pairs than non-emotional pairs. Thus, we expected to see a three-way interaction between age, emotion, and strategy use: The integrative encoding instructions would disproportionately benefit younger adults' associative retrieval of non-emotional pairs (replicating our previous finding [Murray & Kensinger, 2012]), but would disproportionately benefit older adults' associative retrieval success for emotional pairs.

Two alternate hypotheses deserve consideration, however. On the one hand, instructed integration and emotion may only interact to influence younger adults' performance; emotion may not influence older adults' performance. Thus, a three-way interaction could emerge, but it could reflect a lack of effect of emotion on older adults' associative retrieval. To our knowledge, the only previous study to compare younger and older adults' ability to associate emotional information (Nashiro & Mather, 2011) revealed an associative memory benefit for emotional picture-location judgments only for younger adults. Although Nashiro and Mather did not implement an integrative encoding task, their data could nonetheless suggest that emotion would not benefit older adults' associative integration on a word-pair

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learning task. On the other hand, however, our previous younger adult data (Murray & Kensinger, 2012) are not entirely consistent with those of Nashiro and Mather. Whereas Nashiro and Mather revealed an emotional benefit in younger adults' *retrieval* of picture-location associations, in our prior study the integrative benefit conveyed by emotion was in younger adults' *creation* of an integrated representation under speeded encoding conditions, while the *associative retrieval* benefit conveyed by integration was smaller for emotional pairs than for neutral ones. It is, therefore, possible that older adults could demonstrate an effect of emotion on the creation of an integrated representation during encoding, even if other deficits in older adults' associative binding (Chalfonte & Johnston, 1996; Naveh-Benjamin, 2000) prevent them from maintaining that bound representation in memory.

EXPERIMENT 1

Experiment 1 tested the alternate hypotheses outlined above, by asking younger and older adults to form separate mental images of two items or to form one mental image that combined the two items into a single representation. The critical question was how age, and the emotional content of the stimuli, would influence the ability to create integrated mental images at encoding or to retrieve these integrations on an associative cued recall test.

Method

Participants—Participants were 24 older adults aged 65–85 (17 female; M = 72.4) and 24 younger adults aged 18–30 (14 female; M_{age} = 19.7) recruited from the greater Boston area through print and web-based advertisement. Younger adults had not participated in any of the studies reported in Murray and Kensinger (2012). Participants were pre-screened to exclude those with a history of psychiatric or neurological disorders and for current depression or high anxiety (see Table 1 for participant characteristics). Informed consent was obtained in a manner approved by the Boston College Institutional Review Board.

Stimuli—Stimuli were common English words selected from the Affective Norms for English Words (ANEW) series (Bradley & Lang, 1999), the Kučera and Francis (1967) word list, and word lists used by Kensinger and Corkin (2003). Ratings of stimulus valence and arousal were extracted – for both older and younger adults – from Warriner, Kuperman, and Brysbaert (2013). A total of 80 positive words ($M_{valenceYA}$ = 7.07, $M_{arousalYA}$ = 5.34, $M_{valenceOA}$ = 7.15, $M_{arousalYA}$ = 5.03), 80 negative words ($M_{valenceYA}$ = 3.03, $M_{arousalYA}$ = 5.35, $M_{valenceOA}$ = 2.72, $M_{arousalYA}$ = 5.46), and 200 neutral words ($M_{valenceYA}$ = 5.72, $M_{arousalYA}$ = 4.19, $M_{valenceOA}$ = 5.67, $M_{arousalYA}$ = 3.83) were selected from those lists. Older adults rated the neutral words as significantly less arousing than younger adults, $t(360) = 4.47$, $p < 0.01$, although arousal ratings for both groups would be considered low to moderate arousal. Across the three valence categories, words were matched on frequency and imageability. Words were pseudorandomly combined to form 40 word pairs that included a positive word and a neutral word, 40 word pairs that contained a negative word and a neutral word, and 40 word pairs that contained two neutral words. For all pairs that contained an emotional word, the emotional word was always the left-hand word in the pair. The remaining 120 words (40 positive, 40 negative, 40 neutral) were used as "new" lures on the retrieval test. Pairings of words were randomly varied across participants, as were the words that appeared in each encoding condition.

All stimuli were presented on a Macintosh Intel Core 2 Duo computer running MacStim 3 software (WhiteAnt Occasional Publishing). Stimuli were presented at the center of the screen, as white text on a black background. All stimuli were presented in lowercase, with size 48 Lucida Grande font.

Procedure—The procedure was divided into an imagery practice phase, a study (encoding) phase, and an associative cued recall (retrieval) test. As described in Murray and Kensinger (2012) and in Appendix A of this manuscript, the order of imagery tasks during the study phase was not counterbalanced: Participants always performed the non-integrative trials first and integrative trials second. This is because pilot testing revealed that it was difficult for participants to generate non-integrative images after acclimating to integrative imagery. Additional testing (also reported in Appendix A) indicated that older adults were not adversely affected by fatigue when performing the integrative encoding block second; when given two blocks of integrative study (instead of a non-integrative block followed by an integrative block), older adults' memory performance did not differ between pairs studied earlier versus later.

Imagery practice phase: Participants viewed ten pairs of words (e.g., "card + mouse"), and were asked to maintain separate mental representations of each item individually ("non-integrative" encoding instructions). After each pair, they were then asked to rate the vividness of their mental image on a 1–4 scale. They were given the following heuristics: A "1" would indicate no success for that pair; they did not know what one of the words meant, they could not generate an image for one or both referents, or they could only generate a combined mental image. A "2" would indicate that they could imagine both items, but not vividly; their images were "fuzzy" or "blurry." A "3" would indicate that they could generate moderately detailed images for both items. A "4" would indicate that both items were imagined separately, clearly, and with vivid detail. For the first five pairs, participants reported to the experimenter the details of the images they generated, so that the experimenter could validate that they were performing the imagery task and using the rating scale appropriately.

Participants then viewed ten different pairs and were instructed to imagine the two words concatenated together in some way that merged them into a single image (e.g., "owl + office" could be imagined as an office full of owls in business suits; "integrative" study). Again, a 1–4 rating was made for each pair, and verbally reported for the first five pairs, to ensure that participants were performing the imagery task, and using the rating scale, as intended. Practice portions were completed for both phases (integrative and non-integrative) prior to completing any actual study trials so that participants would understand that they should report low success on a "non-integrative" trial if they imagined the two items interacting in some way.

Study phase: Participants first viewed 60 pairs and were instructed to use the non-integrative encoding strategy as practiced. Older adults were shown the pairs for six seconds and younger adults were shown the pairs for four seconds; older adults received longer encoding times because of extensive evidence for age-related slowing of processing (e.g., Salthouse, 1996). Following each pair, participants were prompted to make their 1–4 rating of non-integrative imagery success. Following non-integrative study, participants viewed 60 different pairs for six seconds and were instructed to imagine them using the integrative encoding strategy. Again, a 1–4 rating was collected after each pair was presented, but this time it reflected their ability to imagine the two items together, as one integrated representation.

Of the 60 pairs within each study block, 20 pairs contained a negative word and a neutral word, 20 pairs contained a positive word and a neutral word, and 20 pairs contained two neutral words. These pairs were presented in random order. Following the study blocks, participants performed 30 minutes of pencil-and-paper tasks to create a retention delay.

Associative cued recall test: Participants were presented with a single word on the screen along with a number from 1 – 360 (corresponding to the trial number) and were given a pad of paper with lines numbered 1 – 360. They were told that for each word, they should first decide if the word was seen during the study phase. If they believed the item to be previously studied, they were to write down the word it had been presented with during the study phase on the corresponding line. If they could not recall the paired referent, they were instructed to either make a guess or leave the line blank. If they believed the item to be a new item that had not been previously studied, they were to write "NEW" on the corresponding line. In this way, both recognition and recall data were collected simultaneously (if the participant wrote "NEW," that was counted as a "new" recognition judgment; otherwise, the item was counted as "old") to avoid contamination from re-testing the same stimuli repeatedly. The test was self-paced, and participants were instructed to press any key on the keyboard to move to the next test item after recording their response. Although, as described below, memory performance was only computed for those pairs that participants rated as successfully encoded (i.e., a rating of "3" or "4"), all 240 words from the encoding phase were tested, regardless of participants' ratings.

Results

Data Included in Analysis—Although we included in the design emotional pairs that contained positive words as well as emotional pairs that contained negative words, for neither age group did the valence of the word (positive, negative) affect integrative success at either encoding or retrieval. The valence of the pair (positive or negative) also did not interact with encoding strategy or age (all F's < 2.25). Therefore, pairs containing either a negative or positive word were collapsed into a single "emotional" category for all analyses. Additionally, only pairs that participants indicated as having encoded successfully (i.e., providing a "3" or "4" rating at encoding) were included in the memory analyses[2].

[2]The data were also analyzed with all trials included in the analyses – that is, including trials that participants rated a "1" or "2" (as well as a "3" or "4") at encoding. Doing so preserved the three-way interaction reported in Expt. 1 (between age, encoding, and emotion) and the four-way interaction reported in Expt. 2 (between age, encoding, emotion, and encoding time). Although analyzing all trials did not qualitatively change the patterns in the data, we focus on the 3–4 ratings to ensure that erroneous trials (e.g., forming an integration on a non-integration trial) were not included in analyses.

Integrative Success at Encoding: Percentage of Successfully-Integrated Pairs—We were most interested in success during the encoding of *integrative* pairs specifically, but for the sake of rigor we submitted the percentage of pairs rated as successfully imagined (i.e., rated a 3 or 4) to a mixed-factors ANOVA with encoding strategy (integrative, non-integrative) and emotional content (emotional, neutral) as within-subjects factors and age group (younger, older) as a between-subjects factor. Although older adults reported imagery success at encoding for more pairs (83.9%, *SE* = 1.3%) than did younger adults (75.5%, *SE* = 1.3%; $F(1,46) = 19.46$, $p < 0.001$, partial $\eta^2 = 0.30$), there was no main effect of encoding strategy ($F(1,46) = 0.54$, $p > 0.45$) or emotion ($F(1,46) = 1.05$, $p > 0.30$) and no significant interactions between age, emotion, or encoding (all *F*'s < 2.1, all $p > 0.15$). Encoding success rates are reported at the top of Table 2; means for positive and negative pairs are displayed separately although, as noted in the prior section, these means are collapsed into one "emotion" category for the analyses we just reported.

Retrieval Performance: Item Recognition—As described in the Methods, item recognition judgments were drawn from participants' written responses: "Hits" were counted as all old words for which participants did not write "NEW," "misses" were counted as old words for which participants incorrectly wrote "NEW," and false alarms were counted as new words for which participants provided a response or left the response line blank. Corrected recognition scores were computed for each participant by subtracting false alarm rates from hit rates (Table 3). Although the results reported below are based on corrected recognition scores, the results do not differ if only hits are analyzed.

Older vs. younger adults: Corrected recognition scores were submitted to a 2 (age: younger adults, older adults) × 2 (encoding strategy: integrative, non-integrative) × 2 (emotion: emotional, neutral) mixed-factors ANOVA. A significant main effect of age was observed ($F(1,46) = 40.99$, $p < 0.001$, partial $\eta^2 = 0.47$), with younger adults demonstrating better corrected recognition (*M* = 63.7%, *SD* = 9.6%) than older adults (*M* = 45.9%, *SD* = 9.6%). There also was a main effect of encoding strategy, with non-integrative items recognized better than integrative items ($F(1,46) = 21.52$, $p < 0.001$, partial $\eta^2 = 0.32$). Age did not interact with any factors, nor did encoding strategy and emotion interact (all *F*'s < 1).

Integrative Success at Retrieval: Associative Cued Recall—Cued recall performance was assessed for the right-hand target words from each pair. These were all neutral words, differing in whether they were paired with an emotional word (positive or negative) or a second neutral word. As reported below, cued recall data were first submitted to a 2 (age group) × 2 (encoding strategy) × 2 (cue emotionality) mixed-factors ANOVA. Because age significantly interacted with both emotion and encoding strategy, the data were then analyzed separately for both older and younger adults in a 2 (encoding strategy: integrative, non-integrative) × 2 (emotion: emotional, neutral) repeated-measures ANOVA.

Older adults vs. younger adults: The 2×2×2 ANOVA revealed a significant main effect of encoding ($F(1,46) = 15.53$, $p < 0.001$, partial $\eta^2 = 0.22$), with better recall performance for items studied integratively than non-integratively. Though no main effect of age was observed (F(1,46) = 0.64, $p > 0.43$), age group and emotion interacted significantly (F(1,46) = 15.61, $p < 0.001$, partial η^2= 0.25), and there was a significant three-way interaction among age, encoding strategy, and emotion (F(1,46) = 7.95, $p < 0.01$, partial η^2= 0.15). The interaction is displayed in Fig. 1, and the individual means for positive and negative pairs are available at the bottom of of Table 2 (note that for completeness, mean cued recall is also displayed in Table 2 for neutral pairs; these data are redundant with those displayed for neutral pairs in Fig. 1).

Older adults: A main effect of encoding was observed (integrative > non-integrative, F(1,23) = 6.22, $p = 0.02$, partial η^2= 0.21), as well as a main effect of emotion (emotion > neutral, F(1,23) = 4.46, $p = 0.05$, partial η^2= 0.16). Though the interaction between encoding and emotion did not reach significance, a trend was observed (F(1,23) = 3.94, $p = 0.06$, partial η^2= 0.15), with older adults demonstrating better memory for integrative emotional pairs than non-integrative emotional pairs and no difference between memory for integrative neutral and non-integrative neutral pairs (see Fig. 1, right bars).

Younger adults: Younger adults, like older adults, demonstrated an effect of encoding strategy (integrative > non-integrative, F(1,23) = 9.35, $p < 0.01$, partial η^2= 0.29). A main effect of emotion was also observed, F(1,23) = 11.50, $p < 0.01$, partial η^2= 0.33, but unlike older adults, this effect reflected better cued recall of target words from neutral pairs than emotional pairs. The interaction between emotion and encoding did not reach significance, but a trend was observed (F(1,23) = 4.02, $p = 0.06$, partial η^2= 0.15). The nature of this trend was in the same direction as that reported in Murray and Kensinger (2012) and was in the opposite direction as the older adults' pattern: Although younger adults received a numerical memory benefit from integration (over non-integration) for emotional pairs, that benefit was disproportionately larger for neutral pairs (Fig. 1, left bars).

Discussion—The critical finding from this experiment was that emotion and encoding strategy had an effect on associative cued recall that differed as a function of age. Before we return to the importance of this finding, it is worth noting that emotion did *not* affect either item recognition (consistent with prior findings; e.g., Kensinger, Garoff-Eaton, & Schacter, 2007) or the ability to initially form mental images. Thus, emotion and encoding strategy interacted specifically to influence the likelihood of remembering item associations. Encoding strategy alone, however, did affect both item recognition and associative cued recall. As in prior research, integration benefitted associative memory retrieval whereas non-integration benefitted item memory retrieval (Graf & Schacter, 1985; 1989).

The fact that emotion did not lead younger or older adults to report *less* success at creating an integrated image suggests that the emotional item did not capture younger or older adults' processing resources to such an extent that they could not carry out the instructed integration. An effect of emotion did emerge, however, when examining performance on the cued recall test. To return to the critical finding from this experiment: On the cued recall test, younger adults demonstrated a numerical retrieval benefit from integration (over non-integration) for emotional pairs, but a disproportionately larger advantage was observed for the integration of two neutral items. Older adults showed the opposite pattern, demonstrating a significant associative retrieval benefit from integration (over non-integration) only for emotional pairs and not neutral pairs. The three-way interaction between age, encoding strategy, and emotion was significant, confirming that older adults do indeed demonstrate qualitatively different integrative benefits at retrieval than do younger adults.

We have argued that when creating an integrated representation at encoding, younger adults may engage in more time-consuming, and possibly more elaborative, processes to successfully integrate neutral pairs than emotional pairs (Murray & Kensinger, 2012). This processing difference may lead to a subsequent memory benefit for the neutral pairs, similar to a levels-of-processing effect. Although Expt. 1 did not manipulate time pressure during encoding, the fact that the younger adults showed a larger associative retrieval benefit for integration of neutral pairs than for integration of emotional pairs remains consistent with that interpretation. Critically, however, the older adult data suggest that this processing difference may not extend to the later portion of the lifespan. Based on our prior younger adult findings, one possible reason for the opposite findings in younger and older adults is that, while younger adults may engage more time-demanding processing for neutral integrations than for emotional integrations, older adults may show the opposite pattern. In both age groups, the integration that receives more time-consuming processing at encoding may be the integration that is better remembered. One way to test for this age difference is to manipulate the amount of time individuals have to integrate pairs at encoding: If a group of individuals fails to demonstrate integrative imagery success when encoding emotional or non-emotional pairs under time pressure, those pairs may require more time for that group to integrate.

EXPERIMENT 2

Experiment 2 tests the hypothesis that older adults engage in more time-consuming processes when integrating emotional pairs at encoding compared to neutral pairs, while younger adults show the opposite pattern. We expected to replicate the key finding from Expt. 1, that older adults would demonstrate more integrative retrieval success for emotional pairs than for neutral pairs, while younger adults would show the opposite pattern. Importantly, however, we hypothesized that this pattern would only emerge when each age group was given sufficient time to integrate the pairs at encoding. Under time pressure, we further expected that younger adults would show reduced integrative success at encoding for neutral pairs, relative to longer encoding trials, whereas older adults would show reduced integrative success at encoding for emotional pairs, relative to longer encoding trials.

We tested these hypotheses by manipulating how long participants had to form the integrations during the encoding phase. If older adults utilize time-consuming processes for the creation of emotional integrations, and younger adults use time-consuming processes for the creation of neutral integrations, then older adults should report lower integrative imagery success when forming emotional integrations under time pressure than when given extended time, while younger adults should report lower integrative imagery success when forming neutral integrations under time pressure. Encoding emotional integrations (for older adults) or neutral integrations (for younger adults) under time pressure should also attenuate any benefits of integration on cued recall of those pairs, because the participants will not have sufficient time to engage in the processing that benefits retention of those pairs. As encoding time increases, the benefits of integration on cued recall of emotional pairs (for older adults) or neutral pairs (for younger adults) should show a corresponding increase.

Method

Participants—Participants were 24 older adults aged 65–85 (19 female; $M = 75.2$) who did not participate in Expt. 1, as well as 24 younger adults aged 18–30 (15 female; $M_{age} = 19.8$) who did not participate in Expt. 1 or in any experiments from Murray and Kensinger (2012). Participant characteristics are available in Table 1.

Stimuli—Stimuli were those used in Expt. 1. At encoding, pairs were presented for four, six, or eight seconds (for older adults), or for two, four, or six seconds (for younger adults). As in Expt. 1, older adults received slower encoding presentation times to compensate for age-related slowing of processing (Salthouse, 1996). Under each encoding strategy (non-integrative and integrative), 20 pairs were presented at the "speeded" encoding time, 20 pairs were presented at the "moderate" encoding time, and 20 pairs were presented at the "extended" encoding time. As described in Expt. 2A of Murray and Kensinger (2012), stimulus emotionality (whether the pair contained an emotional word or not) varied across encoding presentation time: Each presentation time contained between six to eight pairs of each emotion (positive + neutral, negative + neutral, neutral + neutral). Encoding presentation time was blocked in groups of ten pairs of the same encoding speed, in order to reduce set-shifting demands, though participants were given no cue ahead of time for how long each pair would be displayed on-screen. Assignment of pairs to each presentation time block was counterbalanced across participants.

Procedure—Aside from the encoding time manipulation, the procedure was identical to Expt. 1.

Results

Data Included in Analysis—As in Expt. 1, no difference was observed between integrative success at encoding or retrieval for positive and negative pairs for either younger or older adults, and no factors (age, emotion, encoding strategy, or encoding time) interacted with valence (all F's < 2.25). Therefore, positive and negative pairs were collapsed into a single "emotion" category, as was done in Expt. 1. Also as in Expt. 1, only pairs for which participants indicated successfully creating a vivid mental image – that is, those pairs rated either a "3" or "4" – were included in the analysis[2].

Integrative Success at Encoding: Percentage of Successfully-Integrated Pairs —Because we were most interested in success rates during the encoding of *integrative* pairs, we first report analyses examining the percentage of integrative pairs that older and younger adults rated as a "3" or "4," as a function of encoding time and emotion. We then compare the effects of age, encoding time, and emotion in the success rates for integrative pairs to the success rates for non-integrative pairs.

Integrative Pairs: Older adults vs. younger adults: The percentages of integrative pairs rated as a "3" or "4" were submitted to a 3 (encoding time: speeded, moderate, extended) ×

2 (age) × 2 (emotion) mixed-factors ANOVA. The analysis revealed a main effect of encoding time (extended = moderate > speeded; $F(2,92) = 16.80$, $p < 0.001$, partial $\eta^2 = 0.27$). Critically, a three-way interaction was observed between emotion, encoding time, and age ($F(2,92) = 4.42$, $p = 0.02$, partial $\eta^2 = 0.08$). As seen in Fig. 2A, extended encoding times lead to an increase in the proportion of *neutral* pairs given high-success imagery ratings by younger adults but lead to an increase in the proportion of *emotional* pairs given high-success imagery ratings by older adults.

Integrative Pairs: Older adults: Older adults demonstrated a significant main effect of encoding time on the percentage of pairs successfully integrated (extended > moderate = speeded; $F(2,46) = 7.99$, $p < 0.01$, partial $\eta^2 = 0.26$). Though no effect of emotion was observed ($F(1,23) < 1$), emotion and encoding time interacted significantly ($F(2,46) = 3.13$, $p = 0.05$, partial $\eta^2 = 0.12$). At extended encoding times, older adults rated more emotional pairs as successfully integrated than at moderate or speeded times; however, this was not the case for neutral pairs (see right panel of Fig. 2A).

Integrative Pairs: Younger adults: Younger adults showed a significant main effect of encoding time (extended = moderate > speeded; $F(2,44) = 11.49$, $p < 0.001$, partial $\eta^2 = 0.33$). No effect of emotion was observed ($F(1,23) = 2.85$, $p = 0.11$) and emotion and encoding time showed a marginal interaction ($F(2, 46) = 2.83$, $p = 0.07$, partial $\eta^2 = 0.11$), with more neutral pairs rated as successfully integrated at moderate or extended times than at the speeded time (see left panel of Fig. 2A).

Comparing Integrative to Non-integrative pairs: To ensure that the effects described above were specific to the integrative condition and did not persist in the non-integrative condition, we also ran an additional mixed-factors ANOVA on the percentage of all successfully-imagined pairs, including encoding strategy (non-integrative, integrative) as a within-subjects factor, along with the within-subjects factors of encoding time and emotion, and the between-subjects factor of age. That analysis revealed a significant four-way interaction between encoding strategy, encoding time, emotion, and age group ($F(2,92) = 3.86$, $p = 0.02$, partial $\eta^2 = 0.08$): In contrast to the effects described above for integrative pairs, the percentage of non-integrative pairs rated as successfully imagined did not differ across encoding time, emotion, or encoding strategy. Submitting only the non-integrative pairs to a mixed-factors ANOVA with emotion, encoding time, and age as factors confirmed that no main effects or interactions reached significance (all F's < 2.1, all $p > 0.1$). These data are displayed in Fig. 2B.

Retrieval Performance: Item Recognition

Older adults vs. younger adults: Corrected recognition data were submitted to a 3 (encoding time: speeded, moderate, extended) × 2 (age group) × 2 (encoding strategy) × 2 (emotion) mixed-factors ANOVA. This ANOVA revealed main effects of encoding strategy (non-integrative > integrative; $F(1,46) = 69.26$, $p < 0.001$, partial $\eta^2 = 0.60$), encoding time (extended > moderate > speeded; $F(2,92) = 82.04$, $p < 0.001$, partial $\eta^2 = 0.64$), and age (younger adults > older adults, $F(1,46) = 32.02$, $p < 0.001$, partial $\eta^2 = 0.41$), but no effect of emotion ($F(1,46) < 1$, $p > 0.6$). Age did not interact with any factors, nor were any other interactions observed (all *F*'s < 1.7, all *p*'s > 0.20). The item recognition data for older and younger adults are displayed in Table 4.

Integrative Success at Retrieval: Associative Cued Recall—Cued recall performance for neutral words that were paired with either emotional or other neutral words were submitted to a 3 (encoding time) × 2 (encoding strategy) × 2 (cue emotion) × 2 (age group) mixed-factors ANOVA. As reported below, because the four-way interaction was revealed to be significant, data were then analyzed separately for older and younger adults.

Older adults vs. younger adults: Main effects were observed for encoding strategy (integrative > non-integrative; $F(1,46) = 21.87$, $p < 0.001$, partial $\eta^2 = 0.32$), encoding time (extended > moderate > speeded; $F(2,92) = 16.99$, $p < 0.001$, partial $\eta^2 = 0.27$), and age group (younger > older; $F(1,46) = 7.66$, $p < 0.01$, partial $\eta^2 = 0.14$). Significant two-way interactions were observed between encoding time and encoding strategy ($F(2,92) = 4.71$, $p = 0.01$, partial $\eta^2 = 0.09$) and cue emotion and age group ($F(1,46) = 7.69$, $p < 0.01$, partial $\eta^2 = 0.14$). Replicating the pattern from Expt. 1, a significant three-way interaction was observed between encoding strategy, cue emotion, and age group ($F(1,46) = 5.40$, $p = 0.03$, partial $\eta^2 = 0.11$).

These interactions were all qualified by a significant four-way interaction between age group, encoding time, encoding strategy, and cue emotion ($F(2,92) = 6.11$, $p < 0.01$, partial $\eta^2 = 0.12$). The nature of this four-way interaction, seen in Figs. 3A and 3B, is that: (1) Younger adults demonstrate a consistent mnemonic benefit from integration over non-integration when given a neutral word with an emotional word, but show a disproportionately larger memory benefit from integrating a neutral word with another neutral word as encoding time increases; (2) Older adults never demonstrate a mnemonic benefit from integration over non-integration when given two neutral words at any encoding trial length, but do show a mnemonic benefit – that increases as encoding time increases – from integrating a neutral word with an emotional word.

Older adults: Significant main effects of encoding strategy (integrative > non-integrative; $F(1,23) = 20.89$, $p < 0.001$, partial $\eta^2 = 0.48$), encoding time (extended > moderate = speeded, $F(2,46) = 7.27$, $p < 0.01$, partial $\eta^2 = 0.24$), and cue emotion (emotional > neutral; $F(1,23) = 4.29$, $p = 0.05$, partial $\eta^2 = 0.16$) were observed. Encoding strategy and cue emotion interacted significantly ($F(1,23) = 5.61$, $p = 0.03$, partial $\eta^2 = 0.20$) such that recall performance was equivalent for neutral words that were paired with either emotional or neutral words under non-integrative study ($M_{emo} = 11.2\%$, $SE_{emo} = 1.0\%$; $M_{neu} = 11.0\%$, $SE_{neu} = 1.3\%$), but a mnemonic benefit was observed for neutral words integrated with emotional words over neutral words integrated with other neutral words ($M_{emo} = 20.2\%$, $SE_{emo} = 1.9\%$; $M_{neu} = 13.5\%$, $SE_{neu} = 1.3\%$). These data are displayed in Fig. 3A. No other interactions reached significance (all *F*'s < 2.10, all *p*'s > 0.13).

Younger adults: Younger adults demonstrated significant main effects of encoding strategy (integrative > non-integrative; $F(1,23) = 10.70$, $p < 0.01$, partial $\eta^2 = 0.32$) and encoding time (extended = moderate > speeded; $F(2,46) = 10.19$, $p < 0.001$, partial $\eta^2 = 0.31$). A significant interaction was observed between encoding time and encoding strategy ($F(2,46)$

= 3.53, $p = 0.04$, partial $\eta^2 = 0.13$), and this was qualified by a significant three-way interaction between encoding time, encoding strategy, and cue emotion ($F(2,46) = 4.06$, $p = 0.02$, partial $\eta^2 = 0.15$). Consistent with Murray and Kensinger (2012, Expt. 2), pairs containing an emotional word showed an integrative retrieval benefit over non-integration at each of the three encoding speeds. For pairs containing two neutral words, no such integrative benefit was observed when encoding trials were speeded, but one emerged during four-second encoding trials and increased in magnitude during six-second trials. These data are displayed in Fig. 3B.

Discussion

The aim of Expt. 2 was to directly test the hypothesis that the age-divergent pattern of cued recall results revealed in Expt. 1 was connected to age differences in the time-consuming nature of processes engaged for the integration of neutral and emotional pairs. The results of Expt. 2 were consistent with this interpretation. In both Expt. 1 and 2, the cued recall results revealed a three-way interaction between encoding strategy, emotion, and age group. Critically, however, the results of Expt. 2 reveal that this interaction was further qualified by a four-way interaction with encoding time: Lengthening the encoding time exaggerated the beneficial effect of integration (vs. non-integration) on younger adults' cued recall of *neutral* pairs but led to a large integrative benefit on older adult's cued recall of *emotional* pairs. The encoding data further link these divergent age patterns to the time required to initially form the integrated representation, with the encoding data also demonstrating a four-way interaction among the factors. Here, we briefly outline the patterns revealed for the young and older adults, and then, in the General Discussion, turn our attention to possible reasons for these effects of age.

Although the interaction between emotion and encoding time was only marginal for younger adults, the pattern of results are consistent with those reported by Murray and Kensinger (2012) and suggest that younger adults were able to create emotional integrations under time pressure. Even on speeded trials with the emotional pairs, younger adults reported high rates of integrative imagery success and showed some mnemonic benefit from integration (vs. non-integration) on retrieval success. Younger adults' integration of neutral pairs, however, was not successful under time pressure: They reported markedly less integrative imagery success for neutral pairs when encoding time was limited to two seconds than when encoding time was lengthened, and under time pressure, younger adults also showed no associative retrieval benefit from integration (over non-integration) of neutral pairs. Yet when the encoding time interval was lengthened (presumably giving them time to engage time-consuming processes), they not only rated themselves as more successful at generating integrative images for neutral pairs than when at faster encoding times, but they also showed a mnemonic benefit of integration (over non-integration) that was larger for the neutral pairs than for the emotional pairs.

Older adults showed a strikingly different pattern. For older adults to have integrative success at encoding (i.e., high-success ratings for the integrative images) or retrieval (i.e., an integrative > non-integrative mnemonic benefit), they needed sufficient encoding time (more than four seconds). But even when given that amount of time, integration produced an associative memory retrieval benefit only for emotional pairs. In contrast to younger adults, older adults showed no integrative associative memory retrieval benefit for neutral pairs at *any* encoding length, perhaps because of general deficits with associative binding (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000).

Older adults did demonstrate an integrative associative memory retrieval benefit for pairs containing an emotional word, but the magnitude of that benefit was tied to the length of the encoding trial. Older adults showed a larger integrative retrieval benefit when given more encoding time for emotional pairs, and they reported greater integrative imagery success for the emotional pairs when given longer encoding time. Much the same way that younger adults require sufficient time to implement the processes necessary to integrate neutral pairs, older adults require sufficient time to implement the processes needed to successfully integrate emotional pairs.

General Discussion

Across two experiments, we show that older adults demonstrate a significant associative memory retrieval benefit for neutral words that were imagined as a single, integrated unit with emotional words. No such associative memory benefit is conveyed by integration when older adults imagine two neutral words as a single unit, creating a representation, such as “surf-degree,” with no pre-existing semantic meaning (see Bastin et al., 2013 for evidence that older adults may benefit from integration when they create a representation, such as “blue-shirt” that has pre-existing meaning). Young adults show the opposite pattern, with a greater benefit of integration occurring for the retrieval of neutral word pairs than pairs with an emotional word. The encoding time required for a maximal benefit of integration also differs between younger and older adults, and – in both age groups – the type of pairs (emotional or neutral) that benefit most from extended encoding time in terms of reported integrative imagery success are also the type of pairs that show the largest benefit from integration on the cued recall test.

With regard to the initial creation of the images, it is interesting that there is never an instance when younger or older adults report *less* success at creating an integrated image of emotional pairs compared to neutral pairs, as would be hypothesized if the properties of the emotional item captured participants’ processing resources, preventing integration. Thus, in both age groups, the task demands of being asked to integrate the emotional item with the neutral item seem sufficient to enable integrative imagery to succeed. Age does, however, affect the time needed to see an emotional *advantage* for integrative imagery success (i.e., greater reported success for emotional than for neutral integrative images). For younger adults, this happens at the shortest encoding time, and for older adults this happens at the longest encoding time.

Although the present study reveals for the first time that age affects the way that emotion influences integration success at both encoding and retrieval, we can only speculate on the reason for these age differences. One possibility is that older adults may be more likely than younger adults to gain emotional meaning from events (Carstensen, Fung, & Charles, 2003) and to process emotional information in a controlled fashion to serve emotion regulatory goals (Carstensen, Isaacowitz, & Charles, 1999; see review by Mather & Carstensen, 2005). They may not be able to implement these controlled processes for neutral pairs, or when put under time pressure. A related, and not mutually exclusive, possibility is that younger adults may be able to integrate emotional-neutral pairs under time pressure because the emotional content facilitates more rapid access to the semantic meaning of the items (e.g., Bate et al., 2010), or facilitates a prioritized binding of the disparate items into a single representation (Hadley & MacKay, 2006; MacKay et al., 2004; MacKay & Ahmetzanov, 2005; Mather, 2007). Given prior evidence that older adults do not show enhanced picture-location binding for emotional images under conditions in which emotion benefits younger adults' binding (Nashiro and Mather, 2011), one possibility is that older adults do not benefit from the same prioritized binding of information during the presence of an emotional response as younger adults. In fact, situations that demand reliance on these facilitated processes (e.g., speeded encoding trials) may be those that are most likely to reveal the benefit of emotion on young adults' formation of integrative images, consistent with the finding that this benefit vanished when younger adults were given more time to create the integrative images at encoding. However, future research is needed to clarify whether there are specific types of facilitation that occur for younger but not older adults: Fast access to semantic details, fluent processing within mental imagery regions, or prioritized binding of activated concepts all could contribute to young adults' ability to create integrated images for emotional pairs even when under time pressure.

Although it would be straightforward to think that the processes that facilitate the creation of an integrative image under time pressure would also facilitate the retention of that association in memory, the present study reveals exactly the opposite conclusion. For both younger and older adults, the type of integrative images (emotional or neutral) that benefits most from extended encoding time also is the type to show the largest integrative benefit on an associative memory test. This pattern emphasizes that processes that aid in the creation of a representation do not necessarily aid in its maintenance over time.

There are three main limitations of this study, which suggest avenues for future research. First, we did not directly measure the time it took participants to form each mental image, and therefore we do not know the effect of age or emotion on the minimum amount of time required to form successful integrative images. Second, we do not know whether it is generally the amount of encoding time that matters for integrative imagery success, or whether there is a specific process (e.g., elaboration of mental images) that was affected by the encoding time manipulation. Future research could ask participants to provide more detailed descriptions of their mental images as a way to elucidate the differences between images created under time pressure and those created with extended time. Future research designs could also use divided attention manipulations, provide emotion regulation instructions, or guide participants toward specific integration strategies to hone in on the reasons for the age differences revealed here. Third, because we used an extreme age group design, we could not identify when across the adult lifespan these age differences emerge.

Despite these limitations, the present study provides the first evidence that emotion has different effects on integrative success in young and older adults. The results further reveal that the effects of emotion on integrative success differ depending on whether integrative success is defined as the ability to generate an integrative representation at encoding or as the ability to retrieve the associated representation from memory. These results emphasize that factors, such as emotion, that facilitate the initial creation of a representation do not necessarily facilitate the retention of that representation in memory.

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Appendix A. Testing Order and Fatigue Effects in Older Adults

Pilot testing (reported in Murray & Kensinger, 2012) indicated that when the order of encoding conditions is reversed – with integrative imagery preceding non-integrative imagery – younger adults were significantly impaired at being able to successfully generate non-integrative images. Self-reports from those participants revealed that once individuals had become practiced at integrating items together into a single image, it was very difficult to then begin imagining pairs separately. For this reason, we elected to always present the non-integrative encoding condition first and the integrative encoding condition second.

To determine if this was also the case for older adults, we piloted a small sample (N = 7) of older participants who performed the encoding task with the conditions reversed (integrative

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first). As with younger adults, we found that although the rates of integrative imagery success were not different from those shown in Fig. 2A, every older adult tested had difficulty successfully generating non-integrative images, at all encoding speeds, regardless of emotionality, when they had become extensively practiced at performing integrative imagery prior to the non-integrative task. Note that the mean percentage of non-integrative pairs rated a 3 or 4 never rose above 50% in this pilot study, whereas it never dropped below 50% (Fig. 2B) when the non-integrative block preceded the integrative block:

Pair Type	Speed	Rating ≥ 3
Emotional	Speeded	27.1%
	Moderate	40.0%
	Extended	45.7%
Neutral	Speeded	25.7%
	Moderate	34.3%
	Extended	47.1%

It could also have been the case, in the studies reported here, that older adults are more susceptible to the effects of fatigue than younger adults, and therefore may have had their resources depleted by the time they began the integrative encoding condition. As suggested by an anonymous reviewer, fatigue effects may affect the processing of emotional and non-emotional information differently. To test this, we recruited a new group of 20 older adults to perform the same task described in Expt. 2, but with two consecutive blocks of integrative study instead of one block of non-integrative followed by one block of integrative. If older adults experience fatigue effects after one block of study, we would expect study block (first or second) to affect memory performance.

However, no effect of study block was observed on memory performance ($F(1,19) = 0.36$, $p > 0.55$). Shown in the table below, cued recall performance was nearly identical – and, if anything, numerically better for the second block. Study block did not interact with emotion (emotional, neutral) or encoding speed (four seconds, six seconds, eight seconds; *F*s < 1). Main effects of speed ($F(2,38) = 10.98$, $p < 0.001$) and emotion ($F(1,19) = 7.60$, $p = 0.01$) were observed, and no interactions reached significance (all *F*s < 1). The performance in Block 2 was also very similar to the performance seen in Expt. 2 (Fig. 3A), suggesting that older adults did not have serious problems switching from the non-integrative task to the integrative task.

		Block 1	Block 2
Speeded	Emo	0.107	0.102
	Neu	0.087	0.139
Moderate	Emo	0.211	0.237
	Neu	0.125	0.154
Extended	Emo	0.283	0.272

	Block 1	Block 2
Neu	0.196	0.158

Appendix B. Older Adults' Cued Recall Pilot Data, With No Recognition Judgment, Following the Methods of Expt. 1 & 2

Experiment	Encoding Strategy	Pair Type	Time	Mean
1 (*N* = 10)	Integrative	Emotional	---	22.9
		Neutral	---	16.4
	Non-integrative	Emotional	---	14.7
		Neutral	---	15.0
2 (*N* = 8)	Integrative	Emotional	Speeded	12.2
			Moderate	18.2
			Extended	21.4
		Neutral	Speeded	13.6
			Moderate	15.2
			Extended	14.3
	Non-integrative	Emotional	Speeded	10.5
			Moderate	12.3
			Extended	13.2
		Neutral	Speeded	8.8
			Moderate	8.4
			Extended	13.0

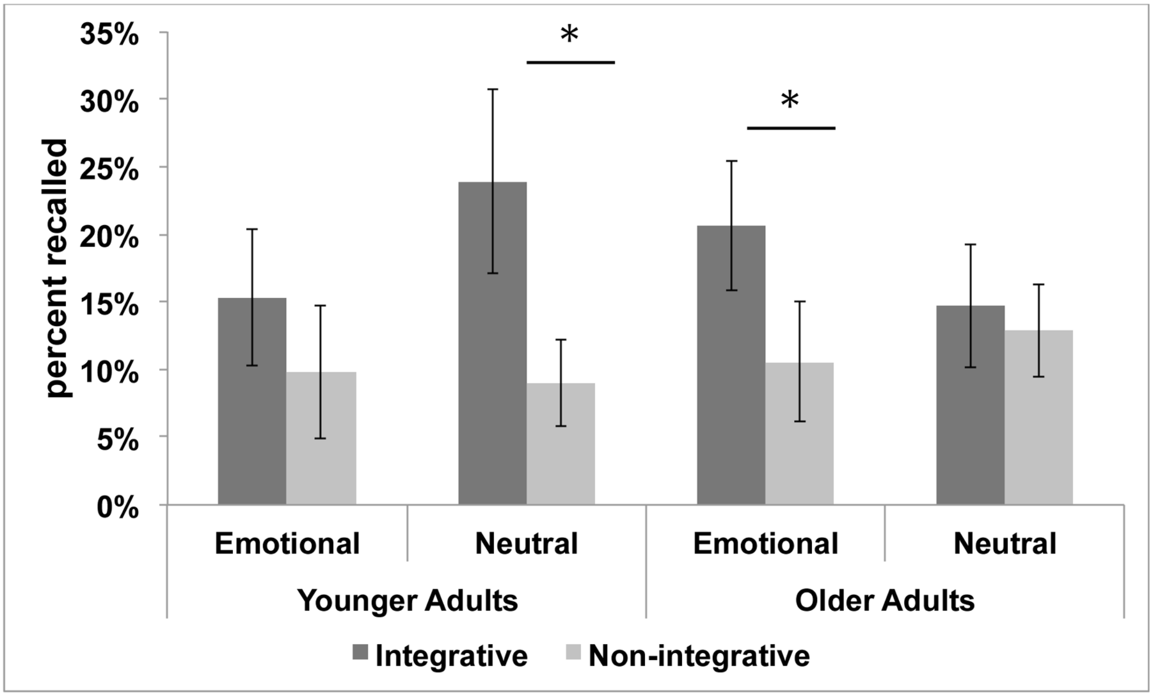

Figure 1.

Associative cued recall performance, Expt. 1. Younger adults show a significant benefit from integration (dark bars > light bars) for neutral pairs, whereas older adults show a significant benefit from integration for emotional pairs. Error bars represent 95% confidence interval around the mean (corrected for within-subject comparisons; Morey, 2008). Asterisks indicate significance within condition at a Bonferroni-corrected alpha level of $p < 0.0125$.

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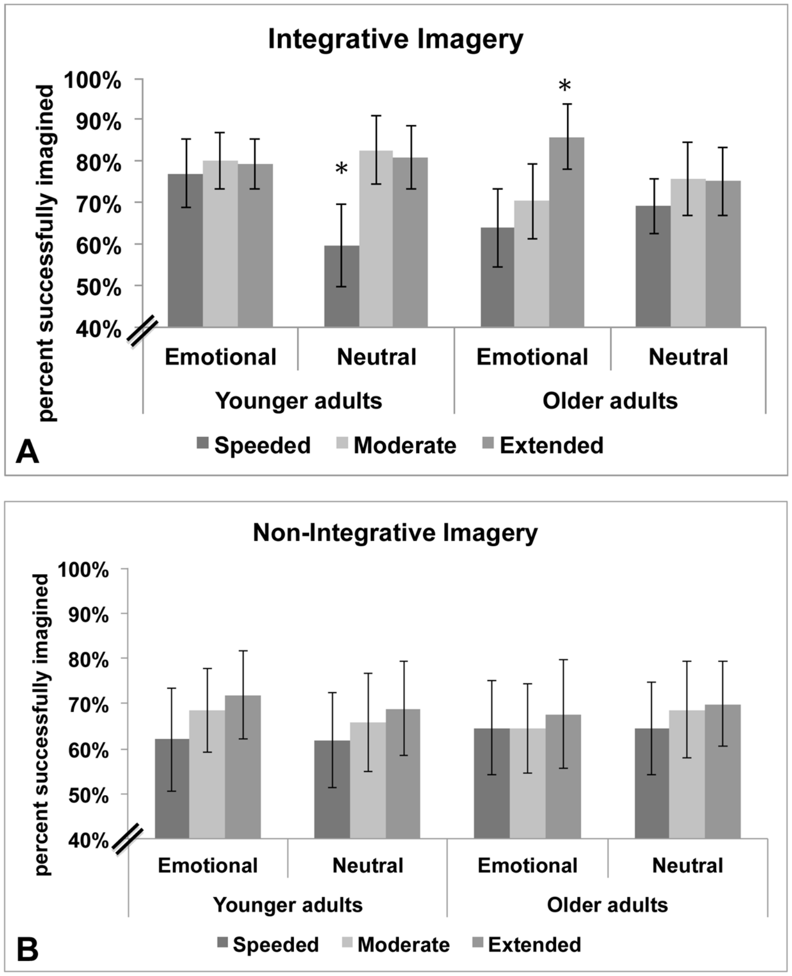

Figure 2.

Percentage of integrative pairs rated as a “3” or “4” at encoding for the integrative (A) and non-integrative (B) conditions, Expt. 2. In the integrative condition, younger adults (left bars) report no difference in successful integration of emotional pairs regardless of encoding speed, but report integrating significantly fewer neutral pairs when encoding is speeded. Older adults (right bars) report no difference in successful integration of neutral pairs regardless of encoding speed, but report integrating significantly more emotional pairs when encoding time is extended. In the non-integrative condition, no difference is observed in the number of pairs rated as successfully imagined across any of the factors of interest (emotion, encoding time, or age). For both graphs, error bars represent 95% confidence interval around the mean (corrected for within-subjects comparisons; Morey, 2008). Asterisks indicate significance within condition at a Bonferroni-corrected alpha level of $p < 0.004$.

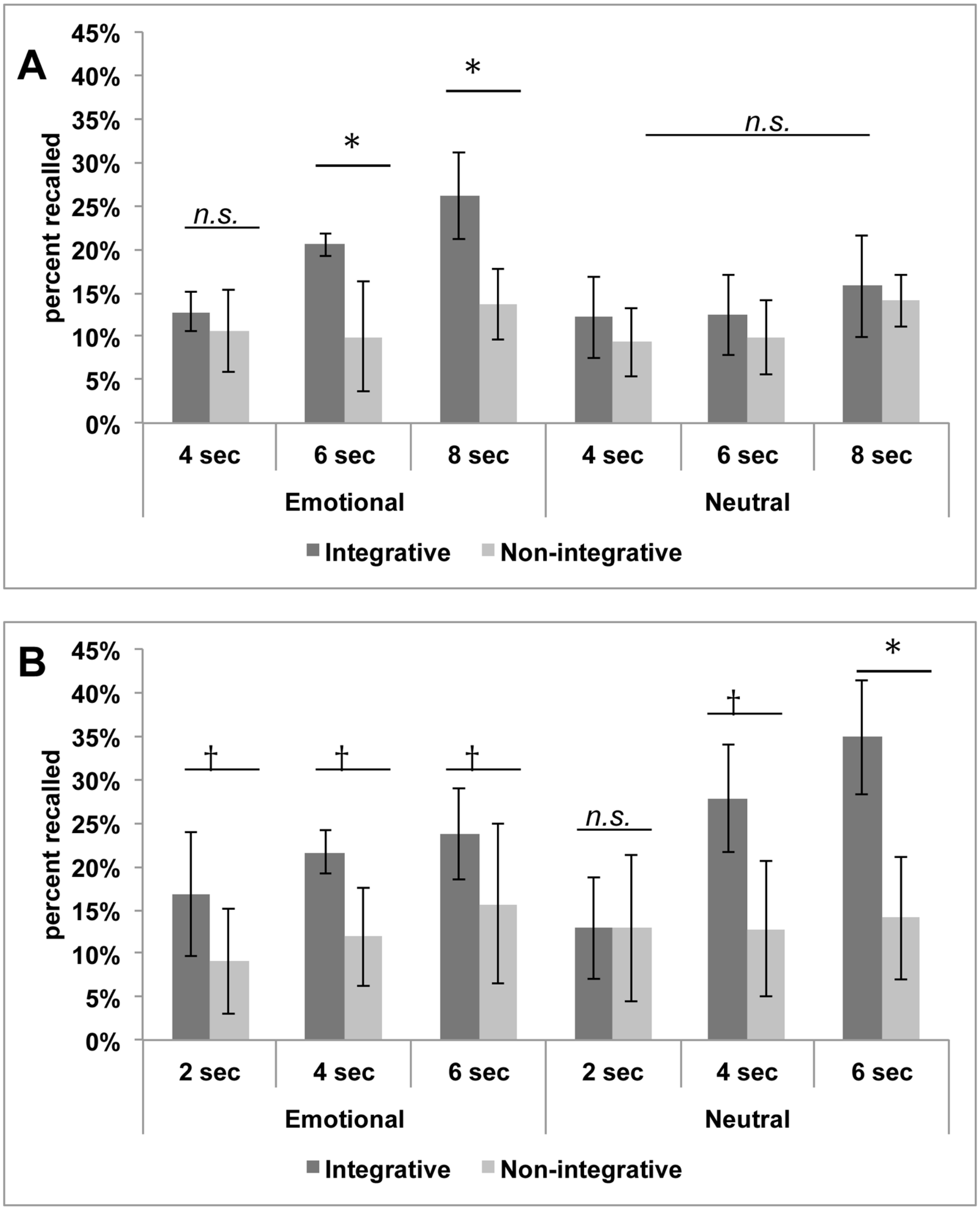

Figure 3.

Associative cued recall performance, Expt. 2. (A) Older adults do not show a mnemonic benefit from integration of neutral pairs regardless of encoding speed, nor do they show an integrative benefit for emotional pairs when encoding is speeded. However, a significant benefit from integration of emotional pairs (dark bars > light bars) is seen when given six or eight seconds to encode. (B) Younger adults show a benefit from integration for all pairs, except for neutral pairs when encoding is speeded. The benefit from integration is disproportionately larger for neutral pairs than for emotional pairs when younger adults are given four or six seconds to encode. Error bars represent 95% confidence interval around the mean (corrected for within-subjects comparisons; Morey, 2008). Asterisks indicate significance within condition at a Bonferroni-corrected alpha level of $p < 0.008$; crosses (†) indicate significance at an uncorrected alpha level of $p < 0.05$.

Table 1

Participant Characteristics

Exp.	Measure	Age Group	Mean	SD	*t*	*p*
1	Beck Depression Inventory	Younger	2.74	0.49	n/a	
	Geriatric Mood Scale	Older	0.88	0.12	n/a	
	Shipley Vocabulary	Younger	32.91	1.90	5.74	<0.001
		Older	35.50	1.13		
	Digit Symbol Copy	Younger	60.22	5.11	7.30	<0.001
		Older	51.08	3.40		
	VVIQ[a]	Younger	63.56	7.55	4.27	<0.001
		Older	71.90	5.88		
2	Beck Depression Inventory	Younger	2.10	0.44	n/a	
	Geriatric Mood Scale	Older	0.66	0.14	n/a	
	Shipley Vocabulary	Younger	36.45	2.50	2.06	0.04
		Older	37.60	1.10		
	Digit Symbol Copy	Younger	58.49	5.67	10.04	<0.001
		Older	45.28	3.07		
	VVIQ	Younger	62.00	7.07	5.73	<0.001

The Beck Depression Inventory is from Beck, Epstein, Brown, and Steer (1988); the Geriatric Mood Scale is from Sheikh and Yesavage (1986); the Shipley Vocabulary Test is from Shipley (1986); the Digit Symbol Copy is from Wechsler (1997); the Vividness of Visual Imagery Questionnaire (VVIQ) is from Marks (1973).

[a]We reversed the scoring scale so that a “1” would indicate low imagery and a “5” would indicate high imagery, to be consistent with the experimental task instructions; maximum possible imagery score = 80.

Table 2

Integrative Success at Encoding and Retrieval for Positive + Neutral, Negative + Neutral, and Neutral + Neutral Word Pairs in Expt. 1

Integrative Imagery Success at Encoding

Group	Encoding	Pos + Neu	Neg + Neu	*t* (pos vs. neg)	Neu + Neu
Younger Adults	Non-Int	84.7	81.8	1.27, $p > 0.2$	84.2
	Int	84.1	85.0	0.65, $p > 0.5$	84.3
Older Adults	Non-Int	77.0	78.2	1.43, $p > 0.1$	80.1
	Int	74.2	72.7	0.80, $p > 0.4$	74.2

Integrative Success at Retrieval (for Neutral Words, Paired with a Positive or Negative Item)

Group	Encoding	Pos + Neu	Neg + Neu	*t* (pos vs. neg)	Neu + Neu
Younger Adults	Non-Int	9.0	11.2	0.61, $p > 0.5$	9.0
	Int	15.0	15.7	0.17, $p > 0.8$	23.9
Older Adults	Non-Int	10.0	11.1	0.56, $p > 0.5$	12.9
	Int	19.5	21.5	0.46, $p > 0.6$	14.7

Note: For encoding success, values reflect the percentage of items assigned an imagery success rating of 3 or 4. For retrieval success, values reflect corrected recognition scores. *t*(pos vs. neg) reports the t-test and p-value for the comparison of success for neutral words paired with positive vs. negative words.

Table 3

Item Recognition Percentage (Standard Deviation) for Hits and False Alarms, Expt. 1

Group	Encoding strategy	Pair type	Hits	False Alarms
Younger Adults	Integrative	Emotional	68.2 (10.9)	6.4 (1.9)
		Neutral	66.2 (13.2)	6.8 (2.5)
	Non-integrative	Emotional	74.7 (12.0)	6.4 (1.9)
		Neutral	72.3 (11.4)	6.8 (2.5)
Older Adults	Integrative	Emotional	52.4 (13.0)	9.7 (1.8)
		Neutral	53.5 (14.7)	12.0 (2.2)
	Non-integrative	Emotional	60.9 (11.2)	9.7 (1.8)
		Neutral	60.0 (12.6)	12.0 (2.2)

Table 4

Item Recognition Percentage (Standard Deviation) for Hits and False Alarms, Expt. 2

Group	Strategy	Pair type	Time	Hits	False Alarms
Younger Adults	Integrative	Emotional	Speeded	65.6 (13.0)	9.2 (1.2)
			Moderate	73.4 (10.4)	9.2 (1.2)
			Extended	79.4 (15.6)	9.2 (1.2)
		Neutral	Speeded	62.5 (13.7)	9.0 (1.3)
			Moderate	67.4 (13.1)	9.0 (1.3)
			Extended	77.3 (18.3)	9.0 (1.3)
	Non-Int	Emotional	Speeded	72.1 (11.0)	9.2 (1.2)
			Moderate	77.9 (12.7)	9.2 (1.2)
			Extended	86.9 (10.7)	9.2 (1.2)
		Neutral	Speeded	70.7 (11.4)	9.0 (1.3)
			Moderate	78.6 (10.2)	9.0 (1.3)
			Extended	83.7 (12.4)	9.0 (1.3)
Older Adults	Integrative	Emotional	Speeded	48.7 (6.2)	9.9 (3.7)
			Moderate	54.7 (6.2)	9.9 (3.7)
			Extended	60.6 (6.0)	9.9 (3.7)
		Neutral	Speeded	50.3 (8.8)	9.8 (3.9)
			Moderate	56.5 (10.6)	9.8 (3.9)
			Extended	61.5 (7.4)	9.8 (3.9)
	Non-Int	Emotional	Speeded	57.1 (7.6)	9.9 (3.7)
			Moderate	60.6 (9.0)	9.9 (3.7)
			Extended	73.4 (7.2)	9.9 (3.7)
		Neutral	Speeded	55.8 (7.7)	9.8 (3.9)
			Moderate	60.9 (7.5)	9.8 (3.9)
			Extended	71.5 (6.6)	9.8 (3.9)

Note: Non-Int = words from non-integrative imagery condition