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Effects of arousal and context on recognition memory for emotional pictures in younger and older adults

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Abstract

Background/Study context—Previous studies found that older adults tend to remember more positive than negative information (i.e., positivity bias), leading to an age-related positivity effect. However, the extent to which factors of arousal and contextual information influence the positivity bias in older adults remains to be determined.

Methods—In this study, 27 Chinese younger adults (20.00 ± 1.75 years) and 33 Chinese older adults (70.76 ± 5.49) learned pictures with negative, positive and neutral valences. Half of the pictures had a human context, and the other half did not. In addition, emotional dimensions of negative and positive pictures were divided into high-arousal and low-arousal. The experimental task was to provide old/new recognition and confidence rating judgments.

Results—Both groups of subjects showed the positivity bias for low-arousal pictures, but the positivity bias was restricted to low-arousal pictures without the human context in older adults. In addition, the positivity bias was mainly driven by the recollection process in younger adults, and it was mainly driven by both the recollection and familiarity processes in older adults. The recognition of the nonhuman positive pictures was correlated with cognitive control abilities, but the recognition of pictures with human contexts was correlated with general memory abilities in older adults.

Conclusion—This study highlights the importance of arousal and contextual information in modulating emotional memory in younger and older adults. It suggests that there are different mechanisms for memorizing pictures with and without human contexts in older adults.

Keywords

memory; emotion; aging; social context; arousal

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Note

IAPS pictures we used in the study are numbers 2730, 3500, 6210, 6230, 6250, 6260, 6300, 6312, 6370, 9250, 9410, 9810, 9921, 9000, 9280, 9340, 9560, 9561, 2750, 2751, 2900, 3300, 9041, 9220, 9331, 9520, 9530, 1080, 2702, 2692, 2682, 2681, 2600, 2590, 2575, 2372, 2312, 2110, 2100, 2020, 5450, 5480, 5621, 8180, 8300, 4598, 5470, 4002, 4003, 4300, 4659, 4664, 4680, 4683, 4800, 1610, 5030, 5779, 5870, 5891, 7286, 8600, 2000, 2092, 2360, 4700, 5831, 8032, 8050.

INTRODUCTION

As individuals age their physical health and cognitive abilities decline (Hedden & Gabrieli, 2004). At the same time, studies find that older adults tend to experience fewer negative emotions, pay more attention to positive stimuli (Knight et al., 2007; Thomas & Hasher, 2006), and remember more positive (vs. negative) information (i.e., positivity bias). In contrast, younger adults remember comparable negative and positive information, or even more negative (vs. positive) information (i.e., negativity bias). The age-related shift in the ratio of positive to negative material processed in attention and memory is referred to as the “positivity effect” (For reviews, see Charles & Carstensen, 2010; Mather & Carstensen, 2005; Scheibe & Carstensen, 2010). Thus, the positivity effect occurs due to either a reduced negativity bias or an increased positivity bias with age (Hess, Popham, Dennis, & Emery, 2013).

The positivity effect is manifested in memory of emotional pictures (e.g., Charles et al., 2003; Mather & Knight, 2005), words (e.g., Kensinger, 2008; Thomas & Hasher, 2006), faces (e.g., Leigland et al., 2004) and autobiographical events (Fernandes, Ross, Wiegand, & Schryer, 2008; Gallo, Korthauer, McDonough, Teshale, & Johnson, 2011; Kennedy, Mather, & Carstensen, 2004). Although older adults are less likely to recall and recognize pictures overall, the age difference is the greatest for negative pictures and the smallest for positive pictures (e.g., Charles, Mather, & Carstensen, 2003). These findings support the socioemotional selectivity theory (SST) (Mather & Carstensen, 2005). The SST emphasizes that the motivation shifts in the priorities of different goals with age (Charles & Carstensen, 2010; Scheibe & Carstensen, 2010). Although goals associated with emotional meaning and well-being become more salient as people approach the end of life, goals associated with acquiring knowledge for future use become less so (Mather & Carstensen, 2005). Thus, the emotional regulation in older people aims to change the self in order to adjust to a given situation (Scheibe & Carstensen, 2010), and the positivity effect relies on preserved controlled processing, especially emotional regulation, rather than a cognitive decline (Nashiro, Sakaki, & Mather, 2013; Reed & Carstensen, 2012).

Nevertheless, the positivity effect is not found in some studies (e.g., Denburg, Buchanan, Tranel, & Adolphs, 2003; Gruhn, Smith, & Baltes, 2005; Leclerc & Kensinger, 2011 for pictures). In these studies, both younger and older adults showed positivity or negativity bias, but the age by valence interaction was not significant, so the bias does not change with age. It has been suggested that positivity effect appears in particular tasks and stimulus parameters (i.e., boundary condition) (Mather & Knight, 2005; Reed & Carstensen, 2012). Several factors may serve as boundary conditions to influence the positivity bias in older adults. The first factor is the arousal level. There are different mechanisms for processing high and low arousing stimuli (Kensinger & Corkin, 2004). The retention of low-arousal stimuli is associated with more controlled processing and emotional regulation, and relies on prefrontal functions (Scheiben & Carstensen, 2010), whereas the high-arousal processing is more automatic and relies on functions of the amygdala (Dolcos, LaBar, & Cabeza, 2004; Kensinger & Corkin, 2004). Recent studies suggest that the positivity effect in older adults may be restricted to low-arousal stimuli (Kensinger, 2008; Streubel & Kunzmann, 2011; Tomaszczyk & Fernanes, 2013). For example, older and younger adults showed similar

recall performance for high-arousal positive and negative words in Kensinger (2008). In contrast, older adults recalled and recognized more low-arousal positive words than negative ones, and younger adults showed the opposite. However, when a recognition task was used, the positivity bias was not found in older adults, nor was an age-related positivity effect (Mickley & Kensinger, 2009; Waring & Kensinger, 2009). In addition, younger adults showed higher recognition for positive than negative low-arousal pictures (Mickley & Kensinger, 2009). Therefore, further studies are needed to clarify whether low-arousal stimuli are necessary for the positivity bias in recognition tasks.

One advantage of the recognition procedure is that recollection- and familiarity-based retrieval can be estimated separately because the two processes rely on distinct cognitive and neural mechanisms (for reviews, Yonelinas, 2002; Eichenbaum, Yonelinas, & Ranganath, 2007). Previous studies have suggested that the recollection process is disrupted in normal aging to a greater extent than familiarity is (Yonelinas, 2002), and emotion enhances recollection rather than familiarity (e.g., Ochsner, 2000). However, it is unclear whether the positivity bias/effect is related to recollection or/and familiarity. Some studies have reported that the positivity effect is associated with detailed information (e.g., Mickley & Kensinger, 2009), whereas others have suggested that the positivity effect is related to overall memory (Kensinger, Garoff-Eaton, & Schacter, 2007) or a familiarity-based process (Spaniol, Voss, & Grady, 2008). However, no studies have estimated the contribution of the two processes for the positivity bias/effect directly.

In addition to the arousal level, the second factor that influences the positivity bias in older adults is contextual information. This issue has been largely neglected and considered only in recent years (Scheiben & Startensen, 2010). Even for low-arousal stimuli, people respond and react to them in different ways when contextual information varies. For example, compared with the scene of a lonely sick dog on the street, the scene of a sick dog held by a crying boy leads to a higher arousal level and empathetic feelings. Social stimuli may attract more attention, induce more emotional arousal reaction and a more self-referential process (Adolphs, 2010a). Thus, social context is an important factor to influence emotional regulation by recruiting the activity of the amygdala and medial prefrontal cortex, which in turn influences the memory process (Adolphs, 2010b).

However, to what extent social processing influences the positivity effect is still unclear. Some studies have suggested that social factor initiated automatic processing, leading to a decreased positivity effect in the social context. For example, a recent study (Hess et al., 2013) observed both younger and older adults showed negativity bias for pictures at a comparable level under a social context, whereas older adults recalled more positive pictures than negative ones under a nonsocial context. Younger adults also recalled them with comparable performance when a self-referential task was used. On the other hand, other studies have shown that older adults benefit from rich contextual information because of goal-driven, top-down processing, especially for positive stimuli, showing the positivity effect under contextual condition. For example, Richter, Dietzel, & Kunzmann (2010) found the positivity bias for both younger and older adults when recognizing film with sound (vs. without sound). Happy clips were recognized more than sad or angry ones by both groups of

subjects. Younger adults recognized more happy clips than older adults did in the poor-context condition, but this pattern disappeared in the rich-context condition.

In sum, although some studies find an age-based positivity effect, to what extent the factors of arousal and contextual information influence the positivity bias in different age of groups is unclear. To address this issue, in the current study Chinese younger and older adults were recruited to perform a recognition task for pictures with negative, neutral and positive valences. Half of the pictures included human or human-related information, reflecting social interaction, and the other half included nonhuman information. To dissociate the effect of arousal, low and high arousal pictures were selected for the negative and positive valences. Because the positivity bias is obvious for high-functioning older adults (Mather & Carstensen, 2005; Reed & Carstensen, 2012), we controlled general cognitive functions by excluding low-functioning older adults. After participants learned the pictures by judging their emotional valences, they were asked to perform a recognition judgment task, and make confidence ratings for their recognition, by which recollection and familiarity processes were estimated (Yonelinas, 1997, 2002). We compared the data between groups, and analyzed the positivity bias for each group separately. We predicted that the effects of arousal and human context would interact to influence the positivity bias in younger and older adults.

METHODS

Participants

Twenty-seven right-handed younger adults (14 male) with a mean age of 20.00 ± 1.75 years and 33 older adults (14 male) with a mean age of 70.76 ± 5.49 years participated in this experiment. The younger adults were Peking University students, the older adults were recruited from the nearby community, some of whom were retired faculties from Peking University. They were native Chinese speakers with normal or corrected-to-normal vision and without any history of neurological or psychiatric disorders. All participants provided written informed consent in accordance with the procedures and protocols approved by the Ethics Review Board of Department of Psychology, Peking University.

A series of neuropsychological tests were administered (Table 1) to assess general abilities of the two groups of subjects. These tests consisted of the WAIS-II-R (Wechsler Adult Intelligence Scale), WMS-II-R (Wechsler Memory Scale), MMSE (Mini Mental State Examination), MEQ (Morningness - Eveningness Questionnaire) (Horne & Ostberg, 1976), WCST (Wisconsin Card Sorting Test) and State-trait anxiety inventory (STAI). Five older subjects were excluded from further analysis, two with low MMSE scores (less than 26), one with a poor memory performance in the WMS-II-R, and two with low cognitive control abilities (i.e., high preservative errors: the number of errors when subjects make a judgment based on the previous criterion). One younger adult was excluded because of a higher change in state anxiety before and after the test. Finally, the data from 26 younger and 28 older participants were analyzed.

Materials

Two within-subjects factors were included in the study: context (human, nonhuman) and emotion (high-arousal negative, high-arousal positive, low-arousal negative, low-arousal positive, neutral). The combination of the two factors resulted in ten experimental conditions, as shown in Figure 1 (i.e., HA-negative, HA-positive, LA-negative, LA-positive and neutral valences in human or nonhuman contexts) (Figure 1). The stimuli consisted of 200 colorful, nameable pictures (20 per condition) with a resolution of 1024×768 pixels. All pictures with human contexts included human or human interactions. Pictures without human contexts included animals, objects and scenes. Among them, 69 pictures were selected from the International Affective Picture System database (IAPS. Lang, Bradley, & Cuthbert, 2008). Others were selected from the Internet in order to balance picture features in different conditions (e.g., valence, arousal, contents, cultural significance) (for IAPS numbers, see Note). The pictures for each condition were divided into two subsets to be used as old and new ones. There were no significant differences between the two subsets in their valence and arousal ratings. The stimuli were counterbalanced so that each subset had an equal chance of being used as old or new pictures.

The picture selection was based on the rating results of valence and arousal scores that were performed by another group of 19 participants (i.e., rating group, 10 male, mean age 20.40 ± 1.47 years. See below). The subjects in the rating group and the younger adults in the experimental group were matched for age, education and gender ($ps > .30$).

Material rating results

Nineteen right-handed younger adults evaluated each picture's valence (1 = very unpleasant to 9 = very pleasant) and arousal (1 = very calming to 9 = very arousing) (Table 2). For valence rating, the full factorial analysis (valence * arousal * context) showed significant interactions between valence and arousal ($F(1.53, 27.48) = 13.41, p < .001, \eta^2 = .48$) (Mauchly's $p = .014$, epsilon used from the Huynh-Feldt = .76), arousal and context ($F(1, 18) = 5.50, p = .031, \eta^2 = .23$). There was also a significant effect of valence ($F(1.49, 26.80) = 168.38, p < .001, \eta^2 = .90$) (Mauchly's $p = .01$, epsilon used from the Huynh-Feldt = .74), arousal ($F(1, 18) = 12.56, p = .002, \eta^2 = .41$) and context ($F(1, 18) = 17.00, p < .001, \eta^2 = .49$). The negative pictures were rated as the lowest in valence (3.23 ± 0.55), followed by neutral pictures (4.69 ± 0.55), and positive pictures were rated with the highest valence levels (6.78 ± 0.61), $ps < .001$. Further analysis showed HA-pictures were rated more negative than LA-pictures in negative condition ($p < .001$), but not in positive or neutral conditions ($ps > .20$). In addition, HA-pictures were rated more negative than LA-pictures in human-context condition ($p = .01$), but not in nonhuman condition ($p = .35$).

For arousal rating, the full factorial analysis (valence * arousal * context) showed significant effects of valence ($F(1.87, 38.65) = 55.18, p < .001, \eta^2 = .76$) (Mauchly's $p = .015$, epsilon used from the Huynh-Feldt = .91), arousal ($F(1, 18) = 76.48, p < .001, \eta^2 = .81$), and context ($F(1, 18) = 21.10, p < .001, \eta^2 = .54$). Pictures with human context were more arousing than those without human context. Negative (5.67 ± 0.72) and positive (5.53 ± 1.04) pictures were rated more arousing than neutral ones (4.35 ± 0.69), $ps < .001$. Importantly, negative and positive pictures did not differ in arousal rating, $p = .70$. Although there were significant

interactions between valence and arousal ($F(1.60, 28.77) = 18.36, p < .001, \eta^2 = .51$) (Mauchly's $p = .03$, epsilon used from the Huynh-Feldt = .80, this pattern appeared whether the arousal level was low or high, and whether contexts included human information or not. This indicated that negative and positive pictures were optimally matched in their arousal levels.

Because many aging studies used IAPS pictures as material, we also analyzed the data to ensure that our material was similar to the standard database. The results indicated that there were statistically significant high correlations between the IAPS and our rating data ($r = .94$ for valence, $r = .84$ for arousal).

Procedure

The procedure included a study phase and a test phase. During the study phase, participants were presented 110 pictures one after the other at the center of the screen (3 s for each), and rated their pleasantness based on a 7-point scale (1 for very unpleasant, 7 for very pleasant, 4 for neutral) (Figure 2a). To avoid the induction of long-lasting mood states, the pictures were pseudo-randomized so that no more than three pictures of the same emotion condition were presented consecutively. The first and the last five pictures were filler items to control the serial position effect. Participants undertook a short practice session to familiarize themselves with the task.

Before the test phase, participants performed the distraction task of subtracting 7 from 1000 continuously for three minutes. During the test phase, they viewed all of the 100 old studied pictures intermixed with 100 new pictures, and judged whether each picture was an old one that they had studied or a new one (Figure 2b). Following the old/new response, they had to rate their response confidence based on a 6-point scale (1 for lowest; 6 for highest). To balance the overall memory, and to better analyze the contribution of recollection and familiarity processes (Mickley et al., 2008), the delay between the study phase and the test phase differed for the two groups (24 hours for younger adults and 30 min for older adults) (e.g., Jacques et al., 2009; Ritchey et al., 2011). The pictures were presented randomly during the test, and the response keys for the old/new judgments were counterbalanced across subjects.

At the beginning of the experiments, all subjects completed the STAI-state and STAI-trait tests. After the experiment, subjects completed the STAI test again.

Data analysis

The rating score, corrected recognition (Hit-FA), estimations of recollection and familiarity processes were calculated and analyzed separately using repeated-measures ANOVAs. The value of d' was also calculated for each subject and averaged across subjects. Because the results of d' and the corrected recognition were similar, only the corrected recognition results were reported. The recollection and familiarity processes were estimated using a receiver operating characteristic (ROC) curve (e.g., Ranganath et al., 2004, Haskin et al., 2008; Ozubko et al., 2012). The 6-point ROC curves can be plotted for the hit rates against the FA rates across various response criteria. Then, the curves are fitted using the dual-process detection model (Yonelinas, 1997; Ozubko, Gopie, & MacLeod, 2012) (<http://>

psychology.ucdaavis.edu/Labs/Yonelinas/PWT) and Excel data solver. The solver attempts to find the best fit for the curve by minimizing the sum-squared error of the points from the curve. After the ROC curve is fit, r_0 is used as an estimate of recollection, and d' is used as an estimate of familiarity for each participant (Ozubko et al., 2012).

Two main ANOVAs were performed. First, to clarify the main effects of each factor and their interactions, the full factorial ANOVA (valence * arousal * context * age) was performed. We divided neutral pictures ($N = 10$) into high-arousal and low-arousal sets according to their arousal rating scores in material preparation. The age difference was based on the full factorial ANOVA. Second, because there was a small number of neutral pictures ($N=5$ in each condition) in the full ANOVA, to further investigate the positivity bias in each group, another ANOVA with context (human, nonhuman) and emotion (HA-negative, HA-positive, LA-negative, LA-positive, neutral) as within-subjects factors were performed for each group. Partial Eta Squared (η^2) was calculated to estimate the effect size of each analysis. The degrees of freedom (dfs) were adjusted according to tests of sphericity. If the sphericity test was significant for a certain factor or interaction, its df was adjusted by Huynh-Feldt approach. Bonferroni correction was applied to the multiple comparisons. The significance level was set as $p < 0.05$ (two tailed).

In addition, to clarify whether memory performance in each condition was modulated by different mechanisms, we performed a correlational analysis for the memory performances and neuropsychological assessments for older adults. At the same time, to clarify the mechanism of the positivity bias, we correlated the difference scores between recognition of positive and negative pictures (i.e., bias score) with neuropsychological assessments. Based on the sample size, the significance level was $r = .40$ ($p < .05$, two tailed).

RESULTS

Neuropsychological assessments

The results of the series of neuropsychological tests illustrated that older adults had lower cognitive function, including general memory and executive functions (Table 1). Compared with the younger adults, the older adults had lower MMSE scores ($p < .01$). They had lower memory performance in WMS, e.g., picture recall, word-pair cued-recall, story memory and general MQ ($ps < .01$), but their picture recognition was comparable to younger adults' ($p = .79$). The MEQ score was higher for older adults than younger adults. Because morning type adults show a more positivity effect (e.g., Biss & Hasher, 2012, Rowe et al., 2007), subjects in both groups were randomly tested in the morning or afternoon. The anxiety state score did not differ before and after study for both groups ($ps > .05$), and no subjects were excluded because of large STAI state change. Older adults had lower anxiety trait and state scores than younger adults ($ps < .05$).

Subjects also performed subtests of the WAIS-II-R that were related to pictures. The older adults had lower scores in digit-symbol coding and picture completion ($p < .01$), suggesting that they are less efficient in processing picture-related information. In addition, the older adults had lower performance on the WCST. They had higher preservative responses (PR) and preservative errors (PE) ($ps < .01$), which suggests that their executive functions are

lower than those of younger adults. Because levels of general memory and executive functions influence positivity effects in older adults, we excluded older subjects who had the lowest scores in WMS or WCST ($> 2SD$ of mean).

Rating results during memory encoding

Consistent with the stimulus rating results, in both groups, negative pictures (2.71 ± 0.52 for younger, 3.06 ± 0.72 for older) were rated as having the lowest valence, then neutral ones (3.74 ± 0.51 for younger, 4.45 ± 0.69 for older), and positive ones had the highest valence levels (5.30 ± 0.55 for younger, 5.42 ± 0.74 for older).

We performed the full factorial analysis (valence * arousal * context * age) to get the main effects of each factor and their interactions. The results showed significant interactions among the four factors ($F(2,104) = 3.58$, $p = .032$, $\eta^2 = .07$). Negative pictures were rated as having the lowest valence, then neutral ones, and positive ones had the highest valence levels for both groups and for each condition, $ps < .001$. As can be seen in Figure 3, the pictures with human contexts (Figure 3, left) were rated more negative than those with nonhuman contexts (Figure 3, right) for HA-pictures and LA-negative pictures in both groups of subjects. The human/nonhuman context and arousal are moderating variables for age effects in the rating judgment. The simple effect analyses showed that under the nonhuman context, older adults rated more positive than younger adults for LA-pictures and neutral pictures ($ps < .01$). In contrast, under the human context, younger adults gave more positive ratings than older adults for the HA-positive pictures ($p = .019$) (Figure 3). These results were consistent with previous studies (e.g., Kwon et al., 2009; Streubel & Kunzmann, 2011), and suggest that older adults are prone to find more positive meanings even for neutral pictures.

The three-way interactions verified that the factors of context and arousal influenced the age difference in various conditions. There were significant three-way interactions of age * context * arousal ($F(2, 104) = 3.33$, $p = .07$, $\eta^2 = .06$), age * context * valence ($F(1.88, 97.48) = 5.10$, $p = .01$, $\eta^2 = .09$), and age * arousal * valence ($F(2, 104) = 4.73$, $p = .01$, $\eta^2 = .08$). Simple effect analyses showed that HA- and LA-pictures were rated comparable in valence under the nonhuman condition ($ps > .10$), but the HA-pictures were rated more negative than the LA-pictures under the human condition for both groups of subjects (Figure 3). This suggests that the arousal effect is significant for pictures with a human context but not for those without a human context. In addition, the age difference (older > younger) appeared for pictures with nonhuman contexts ($ps < .05$), LA-pictures with human contexts ($ps < .05$), and neutral pictures with human contexts ($ps < .001$), which were consistent with the four-way interaction results.

The significant two-way interactions related to age were also significant for age * context ($F(1, 52) = 4.99$, $p = .03$, $\eta^2 = .09$), age * arousal ($F(1, 52) = 8.60$, $p = .005$, $\eta^2 = .15$), and age * valence ($F(1.83, 94.98) = 5.71$, $p = .006$, $\eta^2 = .10$). The age difference was significant for pictures with nonhuman contexts ($p < .001$), LA-pictures ($p < .001$), negative and neutral pictures ($ps < .05$).

We also included gender as a factor in the full factorial ANOVA. However, the results showed gender effect ($F(1,50) = 1.33, p = .26, \eta^2 = .03$) and gender-related interactions were not significant ($ps > .20$).

Corrected recognition

Both negative ($.56 \pm .16$ for younger, $.46 \pm .14$ for older) and positive ($.59 \pm .15$ for younger, $.48 \pm .15$ for older) pictures were remembered better than the neutral ones ($.27 \pm .20$ for younger, $.24 \pm .13$ for older). We first performed the full factorial analysis (valence * arousal * context * age) to get the main effects of each factor and their interactions. The four-way and three-way interactions were not significant ($ps > .10$). There were significant interactions of context * age ($F(1, 52) = 10.07, p < .001, \eta^2 = .29$). As shown in Figure 4, the two groups of subjects had comparable memory performance for pictures without the human context, $p = .37$, but the older adults had lower memory performance for pictures with a human context, $p < .001$. This suggests that the difference in memory associated with aging was obvious for pictures with human contexts. In addition, the comparable memory performance in the nonhuman context ensured that the positivity bias in the two groups was not due to general memory difference.

The interaction of context by arousal was significant ($F(1, 52) = 6.63, p = .01, \eta^2 = .11$), because LA-pictures were recognized better than HA-pictures under the nonhuman condition for both groups, $p < .001$ (Figure 4). There were significant interactions between valence and arousal ($F(1,87, 97.02) = 3.42, p = .04, \eta^2 = .07$) (Mauchly's $p = .03$, epsilon used from the Huynh-Feldt = .93), between valence and context ($F(1.89, 97.84) = 15.03, p < .001, \eta^2 = .22$) (Mauchly's $p = .04$, epsilon used from the Huynh-Feldt = .94), which indicated that the positive pictures were recognized better than the negative ones for LA-pictures ($p < .001$) and pictures under the nonhuman condition ($p < .05$). These suggest that the positivity bias is modulated by arousal and context in both groups of subjects.

Next to further explore the positivity bias in each group, we conducted the second ANOVA of context by emotion. Consistent with the full ANOVA, the results showed that there was significant interaction between context and emotion, $F(3.77, 94.21) = 4.98, p < .001, \eta^2 = .17$ (Mauchly's $p = .04$, epsilon used from the Huynh-Feldt = .94) for the younger adults and $F(4,108) = 4.90, p < .001, \eta^2 = .15$ for the older adults. Further analysis showed that for younger adults, LA-positive pictures were remembered better than LA-negative ones. This pattern manifested in both the human ($p = .02$) and nonhuman context conditions ($p < .001$) (Figure 4). For the older adults, the positivity bias only appeared for LA-pictures in the nonhuman context condition, $p = .01$. In addition, context influenced memory for emotional stimuli but not for neutral stimuli. Neutral pictures were recognized at comparable levels whether the context included human information in both groups ($ps > .10$).

We also included gender as a factor in the full factorial ANOVA. However, the results showed that gender effect ($F(1,50) = 0.01, p = .92, \eta^2 = .00$) and gender-related interactions were not significant ($ps > .30$).

Estimates of recollection process

For the estimate of recollection, the full factorial analysis (valence * arousal * context * age) showed significant four-way interactions ($F(2, 104) = 3.82, p = .025, \eta^2 = .07$). Simple effect analyses showed that the LA-positive pictures were recollected better than the LA-negative ones for the younger adults. This pattern was manifested in both the human ($p = .02$) and nonhuman context conditions ($p = .03$). For the older adults, the positivity bias only appeared for the LA-pictures in the nonhuman context condition, $p = .04$ (Figure 5). There were no significant three-way interactions ($F_s < 2, p_s > .20$). As for the two-way interactions, there were significant interactions between valence and context ($F(2, 104) = 7.70, p = .001, \eta^2 = .13$), valence and arousal ($F(2, 104) = 5.47, p = .006, \eta^2 = .10$) and context and arousal ($F(1, 52) = 4.19, p = .05, \eta^2 = .08$). Further simple effects showed that both negative and positive pictures had more recollection contribution than the neutral pictures ($p_s < .001$), but the recollection contributed more to positive (vs. negative) pictures under nonhuman context ($p < .05$) and under low-arousal condition ($p < .03$).

The ANOVA for each group (emotion by context) obtained the same results (interaction $F(3.09, 77.26) = 2.57, p = .043, \eta^2 = .09$ for the younger adults (Mauchly's $p = .01$, epsilon used from the Huynh-Feldt = .88) and $F(4, 108) = 2.86, p = .027, \eta^2 = .10$ for the older adults), suggesting that the context and arousal modulate the recollection process in both groups of subjects. The simple effects also showed that age differences were not significant in all conditions ($p_s > .10$).

Estimates of familiarity process

For the estimate of familiarity, the full factorial analysis (valence * arousal * context * age) did not show significant four-way and three-way interactions ($F_s < 2, p_s > .20$). There were significant two-way interactions between context * age ($F(1, 52) = 7.57, p = .008, \eta^2 = .13$) and valence * age ($F(2, 104) = 3.76, p = .03, \eta^2 = .07$). As shown in Figure 6, younger adults had more familiarity contributions than older adults for negative pictures ($p < .001$) and pictures with human contexts ($p < .02$). It suggests that the difference in memory accompanying aging only appears for negative pictures with human contexts. There were also significant interaction of context * valence ($F(2, 104) = 9.80, p < .001, \eta^2 = .16$), and arousal * valence ($F(2, 104) = 3.38, p = .04, \eta^2 = .06$). Further analysis showed that both the negative and positive pictures had higher familiarity estimates than the neutral ones ($p_s < .001$), and comparable familiarity estimates ($p_s > .50$) under the human context.

The ANOVA for each group showed significant interaction between context and emotion, $F(4, 100) = 2.14, p = .08$, marginal, $\eta^2 = .08$ for the younger adults and $F(4, 108) = 3.23, p = .015, \eta^2 = .11$ for the older adults. There were no significant differences between the negative and positive pictures for the younger adults ($p_s > .10$). However, for the older adults, the positive pictures were given higher familiarity estimates than negative ones in the nonhuman condition ($p = .07$) (Figure 6). This suggests that the positivity bias relies on both recollection and familiarity processes in older adults.

Correlation analysis for the corrected recognition with anxiety scores

Older adults had lower trait anxiety and state anxiety scores than younger adults, and we considered using trait and state anxiety scores as a covariate. However, adjusting for group differences with a covariate analysis is always a questionable procedure if the adjustment in means is producing an independent variable that only exists in the world of covariance adjustment. That is, the variance attributable to the independent variable is adjusted as well as the variance attributable to the dependent variable. We thus performed the correlation analysis within each group between the dependent variables and the state and trait scores (Table 3). The results showed that for the trait score, the correlations were not significant ($ps > .10$), and the pattern of correlations was similar for the two groups. For the state scores (i.e., the score after the test minus the score before the test), most correlations were not significant either ($ps > .10$) and had similar pattern for the two groups, except the following. One was that the HA-positive pictures with human contexts had significantly positive correlation with the state scores for the younger adults ($r = .39, p < .05$), but had significantly negative correlation for the younger adults ($r = -.49, p = .02$). That is, the more the anxiety change was, the higher the memory for the HA-positive pictures for the younger adults, but the lower the memory for the older adults. The other was that the LA-negative pictures without human contexts had significantly positive correlation with the state score for the younger adults ($r = .43, p < .05$), but the LA-positive pictures with human contexts had significantly positive correlation for the older adults ($r = .42, p < .05$).

Overall, the age differences in trait and state anxiety likely do contribute to the age differences in memory performance as they are part of the aging context; they are not the only contributor, or even the major contributor, but they are part of the context of emotional management and aging. It would not be so large as to adjust the group differences and interactions for the memory performance.

Correlation analysis for memory performance with neuropsychological assessments

To clarify whether memory performance and the positivity bias were modulated by different mechanisms, we performed a correlation analysis for the memory performances and the neuropsychological assessments for the older adults. We found that the MQ score from the WMS was positively correlated with the corrected recognition value ($p = .01$), d' value ($p = .04$), corrected recognition of the HA-negative ($p = .04$), LA-negative ($p = .005$) and LA-positive ($p = .03$) pictures with human contexts, but it was not significantly correlated with recognition for pictures without human contexts (Table 4). In contrast, the preservative responses and errors from the WCST were negatively correlated with the positive pictures without human contexts, in both the high-arousal ($ps < .03$) and low-arousal ($ps < .07$) pictures, but there was no significant correlation with pictures with human contexts.

In addition, we correlated the test scores with difference scores for recognition of positive and negative pictures (i.e., bias score) in older adults. The results showed that the bias score did not correlate with neuropsychological scores whether the pictures included human contexts or not ($rs < .2, ps > .3$). This was because the memory for both negative and positive pictures was significantly correlated with MQ for pictures with human contexts. In contrast, the bias score for LA-pictures without human contexts was significantly correlated with PE

($p = .04$) and percent of PE ($p = .03$) (Table 4). This suggests that the positivity bias in the older adults is associated with executive functions, whereas memory for the pictures with human contexts is associated with general memory functions. We did not find a significant correlation between scores in WCST, WMS and the positivity bias in younger adults, mainly because of their high scores on the neuropsychological assessments.

DISCUSSION

In this study, we investigated the extent to which factors of arousal and contextual information influence the positivity effect with age. The novel finding was that both younger and older adults showed positivity bias with different patterns. The younger adults showed a positivity bias for the LA-pictures, irrespective of the contextual information. The older adults showed a significant positivity bias for the LA-pictures without human context. In addition, the positivity bias was mainly driven by the recollection process in younger adults, and it was driven by both recollection and familiarity processes in older adults. The recognition for the positive pictures in the nonhuman condition was negatively correlated with the preservation scores of the WCST, and recognition of the pictures with human contexts was correlated with general memory abilities in older adults. This study highlights the importance of arousal and contextual information in modulating emotional memory in different age groups, and suggests that there are different mechanisms for memorizing pictures with and without human contexts in older adults.

Low-arousal and the positivity bias

Previous studies have suggested that the positivity bias appears with low-arousal stimuli, but most studies reporting this finding used a recall task (e.g., Kensinger, 2008; Tomaszczyk & Fernandes, 2013). In the recognition task, the positivity bias for low-arousal pictures has only appeared for younger adults in some studies (e.g., Mickley & Kensinger, 2009). In addition, as effects of arousal and context are not dissociated, it is unclear whether the low-arousal bias reflects a contextual effect. The current study clarified that the positivity bias in the recognition task was modulated by arousal and contexts in younger and older adults. Younger adults showed a significant positivity bias for low-arousal pictures irrespective of contextual information, but the positivity bias in older adults restricted to LA-pictures without human contexts.

We obtained the results by controlling for various factors. First, negative and positive pictures were rated as comparable in arousal. This ensured that the positivity bias was not confounded by arousal level, which may be one of the reasons that Waring & Kensinger (2009) did not find a positivity bias for older adults using picture recognition. Second, the factors of MEQ and anxiety level were controlled for, and the low-functioning and memory-impaired older adults were excluded. Third, the recognition performance was comparable between the younger and older adults for the nonhuman condition. This excluded the confounding of an overall memory difference in comparing younger and older adults.

We also found that the memory for LA-positive pictures and the bias score for LA-pictures without human contexts were significantly correlated with preservative errors on the WCST for the older adults. This suggests that the more the cognitive control functions (smaller the

preservative scores) are, the better the memory for LA-positive pictures is, and the higher the positivity bias is. Consistently, studies have shown that older adults allocate more attention to positive (vs. negative) IAPS pictures and faces in full attention, but this pattern is reversed when they are in a divided attention condition (Knight et al., 2007). In addition, we used an emotional judgment task in this study, so subjects focused on their emotional state to facilitate emotional regulation (Emery & Hess, 2008; Yang & Ornstein, 2011). Taken together, these results supported the SST view that older adults recruit more cognitive control in emotional regulation, leading to more processing of positive stimuli than negative ones (Scheiben & Carstensen, 2010).

Nonhuman contextual information and the positivity bias

Based on previous findings, it is debatable whether human or social contexts enhance or diminish a positivity effect/bias, and only a few studies have addressed this issue (e.g., Hess et al., 2013; Richter et al., 2010). Our study supported the view that contextual information diminishes the positivity bias in older adults, because the positivity bias is limited to a nonhuman context for the older adults. Social context is an important factor for modulating emotional processing and regulation (Adolphs, 2010a). Different from pictures without human contexts, pictures with human contexts include information about social interaction, which leads to different types of processing from nonsocial stimuli, such as threatening vigilance (Sanders, 2003), empathy or self-referential processing (Gutches, Kensinger, Yoon, & Schacter, 2007; Symons & Johnson, 1997). These processes are automatic (Adolphs, 2010a; Frith & Frith, 2012) and remain stable with age in adulthood (Hess et al., 2013). The automatic processing may conflict with goal-driven, top-down processing that is hypothesized to drive the positivity bias/effect (Hess et al., 2013), and diminish the positivity bias.

The correlational results also suggest that there are two mechanisms for emotional memory in the older adults regarding to social contexts. For stimuli in the nonhuman context, the controlled processing played an important role, and the emotional regulation was associated with higher memory performance for positive stimuli relative to negative. Thus, the fewer preservative responses and errors are, the better memory for positive pictures in nonhuman contexts is. Mather & Knight (2005) also found that only participants with higher scores in cognitive control exhibited a positivity effect for recalling pictures. In contrast, for stimuli in the human context, automatic processing dominated and determined memory for the LA-positive and LA-negative pictures. Memory for pictures with human contexts was associated with MQ scores, suggesting that the pictures with human contexts are processed automatically rather than by controlled regulation.

One interesting finding was that the older adults did not show a positivity bias for the LA-pictures with a human context, whereas younger adults did. We consider that different picture contents have different significance to younger and older adults. It has been suggested that when the stimuli are related to people's lives, the self-referential may be enhanced, which favors automatic processing, and enhances memory for these stimuli. In social contexts, the LA-negative pictures are more relevant for the older people's lives, such as sad scenes (Streubel & Kunzmann, 2011). In contrast, the LA-positive pictures are more

associated with younger adults' lives, such as social parties. When viewing films about age-typical losses (e.g., loss of loved ones), older adults reported stronger feelings of sadness (Kunzmann & Grühn, 2005), whereas younger adults experience fewer sad and heart-breaking events like losing loved ones. Therefore, the LA-positive pictures are more meaningful for the younger adults, leading to an enhanced memory for these pictures (vs. LA-negative pictures). In contrast, the LA-negative pictures are more meaningful for the older adults, leading to comparable memory for LA-negative and LA-positive pictures with human contexts. It is possible that the positivity bias depends on the extent to which the stimuli related to their lives (Schryer & Ross, 2012). Stimuli that are highly relevant to subjects' lives are remembered better whether they are negative or positive, but they may be remembered by different mechanisms according to contextual information.

Recollection and familiarity processes for the positivity bias

The results of the process estimation showed significant interaction between context and emotion for both groups. Further analysis showed that for younger adults, the recollection contribution was larger for LA-positive than that of LA-negative pictures irrespective of human contexts. For older adults, the contribution of recollection and familiarity was larger for LA-positive than that of LA-negative pictures in nonhuman contexts. It suggests that the positivity bias is mainly driven by recollection in the younger adults, and it is mainly driven by both recollection and familiarity processes in the older adults.

Although few studies have estimated recollection and familiarity processes for the positivity bias/effect, Mickley & Kensinger (2008) suggested that emotional valence influences the estimates of both processes. Memory for negative items is more associated with recollection, whereas memory for positive items is more associated with a familiarity process. Others have suggested a small difference for valence and recollection benefits more from emotional stimuli, while the familiarity process is largely unaffected (e.g., Ochsner, 2000; Dolcos, LaBar, & Cabeza, 2005). For example, in Dolcos et al. (2005), subjects remembered more emotional pictures than neutral ones even after one year, and the emotional effect in the amygdala and hippocampus was associated with recollection rather than the familiarity process. Our study provided direct evidence that the positivity bias was associated with the contribution of recollection. Both younger and older adults remembered the detailed information of positive pictures. Older adults also had higher familiarity estimates for positive (vs. negative) pictures in the LA-pictures without human contexts, suggesting that they may also rely on familiar information of the stimuli to make recognition judgment.

Age difference and the positivity effect

The group difference regarding to age was the following. First, we did not find a significant age-based positivity effect in memory performance, because the interaction between age and emotion was not significant. Both younger and older subjects showed enhanced memory performance for positive than negative pictures in low-arousal conditions. Therefore, we preferred the terminology of the positivity bias instead of the positivity effect to interpret our results. Second, the rating results showed that the older adults rated the LA-pictures without human contexts more positively than the younger adults, which is consistent with previous findings (e.g., Streubel & Kunzmann, 2011). Third, older adults recognized fewer pictures

with human contexts than younger adults, but the two groups were comparable in memory performance for pictures without human contexts. Fourth, older adults relied less on the familiarity process than younger adults for pictures with human contexts.

In this study, we matched memory performance for pictures without human contexts in two groups. The manipulation of testing memory in different delays was based on our pilot data and previous studies (e.g., Jacques et al., 2009; Ritchey et al., 2011; Gruhn et al., 2005). The reasons for the manipulation were the following. First, the objective of this study was to explore whether the positivity bias was modulated by arousal and context in younger and older adults. Because memory performance of younger adults is generally better than that of older adults, it is possible that the absence of the positivity bias in younger adults in previous studies is due to the limited space for the enhancing effect of emotion (Jacques et al., 2009). Second, the contribution of recollection is dominant after encoding in younger adults, which is difficult to analyze the difference between the contribution of recollection and familiarity (Mickley et al., 2008).

The manipulation of different delays should not influence the conclusion of the positivity bias because the two groups were analyzed separately. By matching their memory performance in nonhuman condition, we argued that the positivity bias is not specific to older adults only. Younger adults also showed the positivity bias at least in some conditions and relied on recollection even after 24-hour. Some previous studies have also found a positivity bias for both younger and older adults in recognizing faces (Leigland, Schulz, & Janowsky, 2004) and low-arousal pictures (Tomaszczyk & Fernandes, 2013; Streubel & Kunzmann, 2011). Younger adults could also recruit emotional regulation for the low-arousal pictures. In addition, we found that older adults had worse memory performance, and relied less on familiarity than younger adults for pictures with human contexts, even the test delay was longer for younger adults. These results suggest that age-related memory loss is mainly associated with stimuli with social significance, which relied more on automatic processing rather than processing of controlled regulation.

Nevertheless, we acknowledged that different delays may limit the interpretation of some results of age difference, which we did not handle because of the limited number of pictures. For example, we did not find the significant age difference in recollection contribution. Age-related memory loss is mainly associated with the recollection process, as older adults have difficulty retrieving contextual or detailed information (Yonelinas, 2002), although the familiarity contribution is also impaired in older adults in some studies using remember-know and ROC procedures (Duarte et al., 2008; Perfect, Williams, & Andertonbrown, 1995; Prull, Dawes, Martin, Rosenberg, & light, 2006). In our study, the memory performance for younger adults declined over time by longer delays, and recollection contribution may decline as well (Sadeh, Winocur & Moscovitch, 2014). This could lead to comparable recollection process between younger and older adults. In addition, we did not find the positivity effect with age. Although it is unlikely that older adults showed the similar pattern in 1-day delay as younger adults, further studies are needed to elucidate whether younger and older adults showed similar patterns when they were tested at both short and long delays with enough number of trials.

The positivity bias and negativity bias

For both younger and older adults, the negative and positive pictures were recognized better than neutral pictures, showing enhanced emotional effects. Both groups recognized the negative and positive pictures at comparable levels in general. This pattern was consistent with previous findings (e.g., Dolcos et al., 2004), especially when highly arousing stimuli were used. On the other hand, we did not find the significant negativity bias in both groups, although negative and positive pictures were both recognized better than neutral pictures. To diminish confounding for emotional effects, we controlled factors such as valence, arousal and contents in pictures. However, other factors may influence emotional processing as well. For instance, pictures with human context seemed to differ from those without human context in both rating and memory performance. They were rated more negative and remembered better than those without human contexts. Including human context may enhance self-referential processing, change the balance of automatic and controlled processing in emotional memory, and lead to either negative or positive bias. For those with human context, positive pictures could be remembered better if they are significant in meaning for subjects (e.g., the positivity bias for younger adult). The same pattern may apply for negative pictures. However, how the factor of self-referential processing modulates the negativity or positivity bias needs further investigation.

In addition, studies have shown that other emotional (e.g., depression) (Williams et al., 2007) and mood (Biss & Hasher, 2012) states influence emotion memory. For example, compared to younger adults, older adults have more positive mood and less negative mood (Biss & Hasher, 2012), which suggests that better mood in older adults may be one of the reasons for positivity effect. It is interesting to explore in future whether these factors are interacted with arousal and context to modulate positive or negative bias.

CONCLUSIONS

In conclusion, the current study showed that the positivity bias appeared in both younger and older adults, and the positivity bias was related to different mechanisms concerning picture contexts. Both groups of subjects showed a positivity bias for low-arousal pictures, but the positivity bias was restricted to low-arousal pictures without a human context in older adults. The recognition of positive pictures in the nonhuman picture context condition was correlated with cognitive control assessment, and recognition of pictures with human contexts was correlated with general memory assessment in older adults. This study highlights the importance of arousal and contextual information in modulating emotional memory in different age groups.

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References

- Adolphs R. Conceptual challenges and directions for social neuroscience. *Neuron*. 2010a; 65(6):752–767. DOI: 10.1016/j.neuron.2010.03.006 [PubMed: 20346753]
- Adolphs, R. What does the amygdala contribute to social cognition?. In: Kingstone, A., Miller, MB., editors. *Year in Cognitive Neuroscience 2010*. Vol. 1191. 2010b. p. 42–61.
- Biss RK, Hasher L. Happy as alark: morning-type younger and older adults are higher in positive affect. *Emotion*. 2012; 12(3):437–441. [PubMed: 22309732]
- Charles ST, Carstensen LL. Social and emotional aging. *Annual Review of Psychology*. 2010; 61:383–409.
- Charles ST, Mather M, Carstensen LL. Aging and emotional memory: The forgettable nature of negative images for older adults. *Journal of Experimental Psychology-General*. 2003; 132(2):310–324. DOI: 10.1037/0096-3445.132.2.310 [PubMed: 12825643]
- Denburg NL, Buchanan TW, Tranel D, Adolphs R. Evidence for preserved emotional memory in normal older persons. *Emotion*. 2003; 3(3):239–253. DOI: 10.1037/1528-3542.3.3.239 [PubMed: 14498794]
- Dolcos F, LaBar KS, Cabeza R. Interaction between the amygdala and the medial temporal lobe memory system predicts better memory for emotional events. *Neuron*. 2004; 42(5):855–863. [PubMed: 15182723]
- Dolcos F, LaBar KS, Cabeza R. Remembering one year later: Role of the amygdala and the medial temporal lobe memory system in retrieving emotional memories. *Proceedings of the National Academy of Sciences of the United States of America*. 2005; 102(7):2626–2631. DOI: 10.1073/pnas.0409848102 [PubMed: 15703295]
- Duarte A, Henson RN, Graham KS. The effects of aging on the neural correlates of subjective and objective recollection. *Cerebral Cortex*. 2008; 18(9):2169–2180. DOI: 10.1093/cercor/bhm243 [PubMed: 18165281]
- Eichenbaum H, Yonelinas AP, Ranganath C. The medial temporal lobe and recognition memory. *Annual Review of Neuroscience*. 2007; 30:123–152. DOI: 10.1146/annurev.neuro.30.051606.094328
- Emery L, Hess T. The impact of aging and mood on veridical and false memories. *Gerontologist*. 2008; 48:290–290.
- Fernandes M, Ross M, Wiegand M, Schryer E. Are the memories of older adults positively biased? *Psychology and Aging*. 2008; 23(2):297–306. DOI: 10.1037/0882-7974.23.2.297 [PubMed: 18573004]
- Frith, CD., Frith, U. Mechanisms of social cognition. In: Fiske, ST, Schacter, DL., Taylor, SE., editors. *Annual Review of Psychology*. Vol. 63. 2012. p. 287–313.
- Gallo DA, Korthauer LE, McDonough IM, Teshale S, Johnson EL. Age-related positivity effects and autobiographical memory detail: Evidence from a past/future source memory task. *Memory*. 2011; 19(6):641–652. DOI: 10.1080/09658211.2011.595723 [PubMed: 21919591]
- Gruhn D, Smith J, Baltes PB. No aging bias favoring memory for positive material: Evidence from a heterogeneity-homogeneity list paradigm using emotionally toned words. *Psychology and Aging*. 2005; 20(4):579–588. DOI: 10.1037/0882-7974.20.4.579 [PubMed: 16420133]
- Gutchess AH, Kensinger EA, Yoon C, Schacter DL. Ageing and the self-reference effect in memory. *Memory*. 2007; 15(8):822–837. DOI: 10.1080/09658210701701394 [PubMed: 18033620]
- Hedden T, Gabrieli JDE. Insights into the ageing mind: A view from cognitive neuroscience. *Nature Reviews Neuroscience*. 2004; 5(2):87–U12. DOI: 10.1038/nrn1323 [PubMed: 14735112]
- Hess TM, Popham LE, Dennis PA, Emery L. Information content moderates positivity and negativity biases in memory. *Psychology and Aging*. 2013; 28(3):853–863. DOI: 10.1037/a0031440 [PubMed: 23421322]
- Horne JA, Ostberg O. A self assessment questionnaire to determine morningness eveningness in human circadian rhythms. *International Journal of Chronobiology*. 1976; 4(2):97–110. [PubMed: 1027738]
- Kensinger EA. Age differences in memory for arousing and nonarousing emotional words. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences*. 2008; 63(1):P13–P18.

- Kensinger EA, Corkin S. Two routes to emotional memory: Distinct neural processes for valence and arousal. *Proceedings of the National Academy of Sciences of the United States of America*. 2004; 101(9):3310–3315. [PubMed: 14981255]
- Kensinger EA, Garoff-Eaton RJ, Schacter DL. Effects of emotion on memory specificity in young and older adults. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences*. 2007; 62(4):P208–P215.
- Kensinger EA, Leclerc CM. Age-related changes in the neural mechanisms supporting emotion processing and emotional memory. *European Journal of Cognitive Psychology*. 2009; 21(2–3): 192–215.
- Knight M, Seymour TL, Gaunt JT, Baker C, Nesmith K, Mather M. Aging and goal-directed emotional attention: Distraction reverses emotional biases. *Emotion*. 2007; 7(4):705–714. DOI: 10.1037/1528-3542.7.4.705 [PubMed: 18039037]
- Kunzmann U, Gruhn D. Age differences in emotional reactivity: The sample case of sadness. *Psychology and Aging*. 2005; 20(1):47–59. DOI: 10.1037/0882-7974.20.1.47 [PubMed: 15769213]
- Leclerc CM, Kensinger EA. Neural processing of emotional pictures and words: a comparison of young and older adults. *Developmental Neuropsychology*. 2011; 36(4):519–538. Pii 936796534. DOI: 10.1080/87565641.2010.549864 [PubMed: 21516546]
- Leigland LA, Schulz LE, Janowsky JS. Age related changes in emotional memory. *Neurobiology of Aging*. 2004; 25(8):1117–1124. DOI: 10.1016/j.neurobiolaging.2003.10.015 [PubMed: 15212836]
- Mather M, Carstensen LL. Aging and motivated cognition: the positivity effect in attention and memory. *Trends in Cognitive Sciences*. 2005; 9(10):496–502. DOI: 10.1016/j.tics.2005.08.005 [PubMed: 16154382]
- Mather M, Knight M. Goal-directed memory: The role of cognitive control in older adults' emotional memory. *Psychology and Aging*. 2005; 20(4):554–570. DOI: 10.1037/0882-7974.20.4.554 [PubMed: 16420131]
- Mickley KP, Kensinger EA. Emotional valence influences the neural correlates associated with remembering and knowing. *Cognitive Affective & Behavioral Neuroscience*. 2008; 8(2):143–152. DOI: 10.3758/cabn.8.2.143
- Mickley KR, Kensinger EA. Phenomenological characteristics of emotional memories in younger and older adults. *Memory*. 2009; 17(5):528–543. Pii 911703062. DOI: 10.1080/09658210902939363 [PubMed: 19468956]
- Nashiro K, Sakaki M, Mather M. Age differences in brain activity during emotion processing: reflections of age-related decline or increased emotion regulation? *Gerontology*. 2012; 58(2):156–163. DOI: 10.1159/000328465 [PubMed: 21691052]
- Ochsner KN. Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of Experimental Psychology-General*. 2000; 129(2):242–261. DOI: 10.1037//0096-3445.129.2.242 [PubMed: 10868336]
- Ozubko JD, Gopie N, MacLeod CM. Production benefits both recollection and familiarity. *Memory & Cognition*. 2012; 40(3):326–338. DOI: 10.3758/s13421-011-0165-1 [PubMed: 22127849]
- Perfect TJ, Williams RB, Andertonbrown C. Age-differences in reported recollective experience are due to encoding effects, not response bias. *Memory*. 1995; 3(2):169–186. DOI: 10.1080/09658219508258964 [PubMed: 7796303]
- Prull MW, Dawes LLC, Martin AM, Rosenberg HF, Light LL. Recollection and familiarity in recognition memory: Adult age differences and neuropsychological test correlates. *Psychology and Aging*. 2006; 21(1):107–118. DOI: 10.1037/0882-7974.21.1.107 [PubMed: 16594796]
- Reed AE, Carstensen LL. The theory behind the age-related positivity effect. *Frontiers in psychology*. 2012; 3
- Ritchey M, Bessette-Symons B, Hayes SM, Cabeza R. Emotion processing in the aging brain is modulated by semantic elaboration. *Neuropsychologia*. 2011; 49(4):640–650. DOI: 10.1016/j.neuropsychologia.2010.09.009 [PubMed: 20869375]
- Rowe G, Hirsh JB, Anderson AK. Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences of the United States of America*. 2007; 104(1): 383–388. DOI: 10.1073/pnas.0605198104 [PubMed: 17182749]

- Sadeh T, Ozubko JD, Winocur G, Moscovitch M. How we forget may depend on how we remember. *Trends in Cognitive Sciences*. 2014; 18(1):26–36. DOI: 10.1016/j.tics.2013.10.008 [PubMed: 24246135]
- Sander D, Grafman J, Zalla T. The human amygdala: an evolved system for relevance detection. *Reviews In The Neurosciences*. 2003; 14(4):303–316. [PubMed: 14640318]
- Scheibe S, Carstensen LL. Emotional aging: recent findings and future trends. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences*. 2010; 65(2):135–144. DOI: 10.1093/geronb/ebp132
- Schryer E, Ross M. Evaluating the valence of remembered events: The importance of age and self-relevance. *Psychology and Aging*. 2012; 27(1):237–242. DOI: 10.1037/a0023283 [PubMed: 21463052]
- Spaniol J, Voss A, Grady CL. Aging and emotional memory: cognitive mechanisms underlying the positivity effect. *Psychology and Aging*. 2008; 23(4):859–872. DOI: 10.1037/a0014218 [PubMed: 19140656]
- St Jacques PL, Dolcos F, Cabeza R. Effects of aging on functional connectivity of the amygdala for subsequent memory of negative pictures: a network analysis of functional magnetic resonance imaging data. *Psychological Science*. 2009; 20(1):74–84. DOI: 10.1111/j.1467-9280.2008.02258.x [PubMed: 19152542]
- Streubel B, Kunzmann U. Age differences in emotional reactions: arousal and age-relevance count. *Psychology and Aging*. 2011; 26(4):966–978. DOI: 10.1037/a0023424 [PubMed: 21517185]
- Symons CS, Johnson BT. The self-reference effect in memory: A meta-analysis. *Psychological Bulletin*. 1997; 121(3):371–394. DOI: 10.1037/0033-2909.121.3.371 [PubMed: 9136641]
- Thomas RC, Hasher L. The influence of emotional valence on age differences in early processing and memory. *Psychology and Aging*. 2006; 21(4):821–825. DOI: 10.1037/0882-7974.21.4.821 [PubMed: 17201502]
- Tomaszczyk JC, Fernandes MA. A Positivity effect in older adults' memorability judgments of pictures. *Experimental Aging Research*. 2013; 39(3):254–274. DOI: 10.1080/0361073x.2013.779178 [PubMed: 23607397]
- Waring JD, Kensinger EA. Effects of emotional valence and arousal upon memory trade-offs with aging. *Psychology and Aging*. 2009; 24(2):412–422. DOI: 10.1037/a0015526 [PubMed: 19485658]
- Williams LM, Gatt JM, Schofield PR, Olivieri G, Peduto A, Gordon E. 'Negativity bias' in risk for depression and anxiety: Brain-body fear circuitry correlates, 5-HTT-LPR and early life stress. *Neuroimage*. 2009; 47:804–814. [PubMed: 19446647]
- Yang L, Li J, Spaniol J, Hasher L, Wilkinson AJ, Yu J, et al. Aging, culture, and memory for socially meaningful item-context associations: an east-west cross-cultural comparison study. *Plos One*. 2013; 8(4)
- Yonelinas AP. Recognition memory ROCs for item and associative information: The contribution of recollection and familiarity. *Memory & Cognition*. 1997; 25(6):747–763. DOI: 10.3758/bf03211318 [PubMed: 9421560]
- Yonelinas AP. The nature of recollection and familiarity: a review of 30 years of research. *Journal of Memory and Language*. 2002; 46(3):441–517. DOI: 10.1006/jmla.2002.2864

Figure 1.
Stimulus examples in each condition.

Figure 2.

Procedures of study and test session. During the study phase (A), the picture was presented on the center of the screen while the subjects evaluated their valence. During the test phase (B), subjects performed a memory recognition task followed by confidence rating. (Gray color for illustration only).

Figure 3. Rating results for both younger and older adults. The left graph illustrates the results for pictures with human contexts, and the right illustrates the results for those without human contexts. The error bars represent the standard errors of the means.

Figure 4.

Corrected recognition for both younger and older adults. The positive pictures were recognized better than the negative counterparts for LA-pictures in younger adults, and for LA-pictures without human contexts in older adults. The error bars represent the standard errors of the means. The lines above the bar represent the difference (negative vs. positive) was significant under certain condition ($p < .05$).

Figure 5.

Estimates of recollection process for both younger and older adults. The results were similar to those of corrected recognition. The error bars represent the standard errors of the means. The lines above the bar represent the difference (negative vs. positive) was significant under certain condition ($p < .05$).

Familiarity

Figure 6.

Estimates of familiarity process for both younger and older adults. Older adults showed higher familiarity estimates for LA-positive than LA-negative pictures in nonhuman condition. The error bars represent the standard errors of the means. The lines above the bar represent the difference (negative vs. positive) was significant under certain condition ($p < .05$).

Table 1

Characterization of participants

Test	Younger adults		Older adults		df	t	p
	M	SD	M	SD			
Age	20.12	1.68	71.29	5.28	52	-47.25	.00
Education	14.21	1.18	14.42	1.47	52	0.42	.68
MMSE	29.21	0.79	28.32	1.32	39	2.57	.01
MEQ	50.27	9.83	61.75	9.13	44	-4.11	.00
STAI							
State1	32.27	6.21	28.29	6.22	44	2.17	.04
State2	33.05	7.75	27.67	6.75	44	2.52	.02
Trait	38.14	7.12	32.50	6.62	44	2.78	.01
WAIS-II-R							
Similarities	12.89	1.2	12.14	2.19	39	1.35	.19
Vocabulary	13.37	1.01	14.14	1.46	39	-1.93	.06
Digit-Symbol coding	16.74	1.79	10.09	2.29	39	10.24	.00
Picture completion	12	1.67	10.45	1.74	39	2.89	.01
WMS-II-R							
Experience	4.95	0.23	5	0	39	-1.08	.29
Orientation	5	0	4.95	0.21	39	0.93	.36
Mental-1 to 100	9.84	3.13	10.57	2.75	38	-0.78	.44
Mental-100 to 1	14	0.75	9.64	2.82	39	6.54	.00
Mental-accumulation	13.16	1.01	10.18	2.58	39	4.72	.00
Picture recall	12.68	1.86	9.77	2.62	39	4.05	.00
Recognition	9.84	3.3	9.59	2.75	39	0.27	.79
Reconstruction	12.53	0.7	9.27	2.53	39	5.42	.00
Association	12.05	1.43	7.27	3.44	39	5.64	.00
Story	13.05	1.54	1.41	2.02	39	4.65	.00
Digit span	16.89	2.31	10.41	2.72	39	8.16	.00
MQ	120	9.8	111.59	10.64	39	2.62	.01
WCST							

Test	Younger adults		Older adults		df	t	p
	M	SD	M	SD			
Total number	75.95	5.6	103.83	17.92	41	-6.52	.00
Total errors	10.53	4.03	26.63	14.05	41	-4.83	.00
Perservative responses (PE)	6.84	3.99	16.96	8.79	41	-4.64	.00
Perseverative errors (PR)	5.16	2.85	14.08	7.56	41	-4.87	.00
Nonperseverative errors	5.37	2.79	12.54	7.88	41	-3.78	.00
Conceptual level	0.84	0.06	0.68	0.15	41	4.43	.00

Scores of WAIS were raw scores, while these of WMS were scale scores after transformation.

Table 2

Results of material ratings

		Human context					Nonhuman context				
		High A Negative	High A Positive	Low A Negative	Low A Positive	Neutral	High A Negative	High A Positive	Low A Negative	Low A Positive	Neutral
Valence	MEAN	2.68	6.24	3.37	6.56	4.43	3.10	6.57	3.75	6.53	4.96
	SD	0.61	1.10	0.62	0.64	0.61	0.76	0.80	0.58	0.72	0.59
Arousal	MEAN	6.53	6.51	5.21	5.05	4.56	6.16	6.06	4.80	4.52	4.14
	SD	0.80	1.04	0.90	1.30	0.93	0.88	1.09	0.85	1.32	1.04

Table 3

Correlation results between memory performance and anxiety scores

		Human context				Nonhuman context					
		High A Negative	High A Positive	Low A Negative	Low A Positive	Neutral	High A Negative	High A Positive	Low A Negative	Low A Positive	Neutral
Trait	Younger	0.06	0.05	-0.02	-0.09	0.35	0.08	-0.27	-0.04	0.27	0.07
	Older	-0.19	-0.16	-0.35	0.07	0.05	0.01	-0.30	-0.34	0.05	0.03
State	Younger	0.19	0.40 [*]	0.10	0.18	0.20	-0.11	0.15	0.43 [*]	0.34	0.27
	Older	0.12	-0.49 [*]	0.03	0.42 [*]	0.35	-0.01	0.08	-0.27	0.13	0.10

Note:

^{*} denotes $p < 0.05$.

Table 4
Correlation results between memory performance and neuropsychological assessments in older adults

Human context										
Hit-FA	d'	High A Negative	High A Positive	High A Bias	Low A Negative	Low A Positive	Low A Bias	Neutral		
PR	-0.24	-0.37	-0.19	-0.26	-0.04	-0.12	-0.15	-0.03	0.17	
PR%	-0.33	-0.46*	-0.30	-0.32	0.04	-0.22	-0.16	0.05	0.09	
PE	-0.16	-0.27	-0.11	-0.17	-0.04	-0.10	-0.07	0.03	0.19	
PE%	-0.18	-0.33	-0.15	-0.18	0.00	-0.18	-0.05	0.12	0.12	
MQ	0.53*	0.45*	0.46*	0.29	-0.23	0.59*	0.49*	-0.05	0.17	
Nonhuman context										
		High A Negative	High A Positive	High A Bias	Low A Negative	Low A Positive	Low A Bias	Neutral		
PR		-0.22	-0.53*	-0.24	0.08	-0.41*	-0.38	0.34		
PR%		-0.28	-0.55*	-0.22	0.08	-0.38	-0.36	0.33		
PE		-0.15	-0.46*	-0.25	0.14	-0.42*	-0.43*	0.32		
PE%		-0.14	-0.46*	-0.27	0.19	-0.40*	-0.45*	0.33		
MQ		0.05	0.29	0.19	0.19	0.33	0.14	-0.09		

Note: PR% refers to PR number / total number; PE% refers to PE number / total error;

* denotes $p < 0.05$.