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Contribution of Metamemory Beliefs to Age-Related Differences in the Effect of Emotion on Judgments of Learning

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With the global aging of the population, the importance of understanding the characteristics and mechanisms of developmental changes in later life has grown. The present study explored age-related differences in the effect of emotion on judgments of learning (JOLs) in Chinese participants and delved deeper into the mechanisms underlying this effect. Experiment 1 observed that older participants showed a positivity effect on JOLs, whereas young participants demonstrated an emotional salience effect on JOLs, reflecting age-related differences in the effect of emotion on JOLs. To investigate the mechanisms underlying these age-related differences, Experiment 2 measured participants' metamemory beliefs about the effect of emotion on memory and found that older participants held a belief of the positivity effect, whereas young participants possessed a belief of the emotional salience effect. Experiment 3 collected data of beliefs and JOLs from the same participants and provided further evidence highlighting the contribution of metamemory beliefs to age-related differences in the effect of emotion on JOLs. These findings are essential for advancing the theoretical framework of metamemory and for extending lifespan theory of socioemotional selectivity.

Public Significance Statement

This study uncovers the vital roles of metamemory beliefs in the positivity effect on judgments of learning (JOLs) in older adults and the emotional salience effect on JOLs in young adults. Given that metacognition plays a salient role in subjective well-being, the observed age-related effects of emotion on JOLs and metamemory beliefs are essential for understanding factors that shape subjective well-being in later life.

Keywords: positivity effect, judgments of learning, metamemory belief, emotion

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The data contained in this project are publicly available on the Open Science Framework at https://osf.io/hpjmq/. The ideas and data appearing in the article have not been disseminated before (e.g., at a conference or meeting, posted on a listserv, shared on a website). All experiments reported in the present study were approved by the Ethics Committee of Faculty of Psychology at Beijing Normal University (file number 202201040001). Written informed consents were obtained from all participants. All authors agreed with the content and gave explicit consent to submit this study. The authors declare that they have no conflicts of interest.

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continued

With the global aging of the population, understanding the characteristics and mechanisms of developmental changes in later life has become increasingly important. Human aging, long thought to be accompanied by a decline in physical and cognitive functioning (Radomski & Morrison, 2014), has been found to be a more malleable process in which some abilities remain intact or even become better, such as emotion regulation (Carstensen & Mikels, 2005; Charles & Carstensen, 2007). One encouraging finding is the positivity effect, which refers to age-related increase in preference for positive over negative (and neutral) information (Carstensen & Mikels, 2005; Isaacowitz & Blanchard-Fields, 2012; Mather & Carstensen, 2005; Reed et al., 2014).

The positivity effect has been viewed as an adaptive well-being regulatory strategy for older adults, serving to assist in emotion regulation and to promote subjective well-being in later life (for a review, see Isaacowitz & Blanchard-Fields, 2012). Although the positivity effect on fundamental cognitive processes has been well-documented, it remains largely unknown whether these effects extend to more complex, higher order abilities such as metacognition (Sanders & Berry, 2021; Tauber & Dunlosky, 2012). The primary objectives of the present study are to explore age-related differences in the effect of emotion on metacognitive monitoring and to delve deeper into the mechanisms underlying this effect.

Age-Related Differences in the Effect of Emotion on Cognition

Emotion plays a critical role in successful adaptation throughout the lifespan (Charles & Carstensen, 2007). Numerous researchers have focused on examining age-related differences in the effect of emotion on cognition. The *socioemotional selectivity theory*, a lifespan theory of motivation that explains how individuals' goals are influenced by their perception of time, proposes that older adults prioritize emotion-related goals (such as pursuing positive experiences and avoiding negative states) as they perceive time as limited. As a result, when processing emotionally charged information, older adults tend to show a preference for positive over negative (and neutral) information (Carstensen & Mikels, 2005). In contrast, young adults prioritize knowledge-related goals due to their perception of open-ended time (Carstensen, 1995; Carstensen et al., 1999) and typically display a preference for negative information (i.e., a negative bias) or show equal preference for both positive and negative information over neutral information, a phenomenon known as the *emotional salience effect* (Murphy & Isaacowitz, 2008; Yin et al., 2023).

Empirical studies have provided compelling evidence supporting age-related differences in the effect of emotion on various cognitive functions, including working memory (Mikels et al., 2005), autobiographical memory (Kennedy et al., 2004), attention (Nikitin & Freund, 2011), and decision making (Kim et al., 2008). For instance, Charles et al. (2003) found that, in a learning task, older adults recalled a greater number of positive images compared to negative and neutral ones, reflecting the positivity effect in older adults. In contrast, young adults recalled an equal number of positive and negative images, and fewer neutral images, reflecting the emotional salience effect in young adults.

Age-Related Differences in the Effect of Emotion on Judgments of Learning

Although previous research provided solid evidence for age-related differences in the effect of emotion on cognition, it remains unclear whether these differences extend to more complex, higher order processes such as metacognition (Sanders & Berry, 2021; Sun & Jiang, 2023; Tauber & Dunlosky, 2012). Delving into this question would contribute to a better understanding of the causes underlying subjective well-being in later life (Sanders & Berry, 2021), because metacognition plays a salient role in subjective well-being (Hertzog & Hultsch, 2000; Norman, 2020; Toffalini et al., 2015). Recent studies have begun to explore the effect of emotion on judgments of learning (JOLs; i.e., metacognitive estimates of the likelihood that a given item will be successfully remembered on a later test) in young adults (Efklides, 2006, 2016; Witherby et al., 2021; Yin et al., 2023). However, only a few studies have investigated age-related differences in the emotional effect on JOLs, and the observed findings are largely inconsistent (Gallant et al., 2019; Sanders & Berry, 2021; Sun & Jiang, 2023; Tauber & Dunlosky, 2012).

A scattering of primary studies examining the positivity effect on JOLs in older adults have yielded conflicting results. Some studies failed to observe a positivity effect on JOLs among older adults, suggesting that the positivity effect may not extend to metacognitive judgments (e.g., Gallant et al., 2019; Tauber & Dunlosky, 2012). For instance, Tauber and Dunlosky (2012; Experiment 1) found that older participants ($n = 30$) provided higher JOLs for negative words than for neutral ones, but there was no significant difference in JOLs between negative and positive words ($p = .060$, $d = 0.11$). Sanders and Berry (2021) suspected that the nonsignificant positivity effect on JOLs observed by Tauber and Dunlosky (2012) might have resulted from low statistical power, due to the small sample size ($n = 30$) and limited number of trials ($n = 30$). To address this, Sanders and Berry (2021) increased the number of study words ($n = 90$) and recruited a larger sample of older participants ($n = 43$). Intriguingly, they found a positivity effect on JOLs in older adults, with older adults providing higher JOLs for positive than for negative words. Recently, Sun and Jiang (2023) replicated the positivity effect on JOLs in older adults when using visual images as stimuli.

While findings on the positivity effect on JOLs in older adults remain mixed, previous research consistently showed that young adults provided higher JOLs for both positive and negative stimuli

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compared to neutral ones, indicating a reliable emotional salience effect on JOLs (Sanders & Berry, 2021; Tauber & Dunlosky, 2012; Yin et al., 2023; Zimmerman & Kelley, 2010). For instance, a recent meta-analysis by Yin et al. (2023) detected a medium-sized (g = 0.62) emotional salience effect on JOLs in young adults. More critically, Yin et al. (2023) found a significant moderating effect of age on the emotional effect on JOLs, with the emotional salience effect being stronger in young than in older adults. However, due to the limited number of available studies, this meta-analysis could not examine the interaction between age (young vs. older) and emotional valence (positive vs. negative). Given that previous findings on age-related differences in the effect of emotion on JOLs are inconsistent, further research is needed to test the reliability of these differences.

Potential Mechanisms Underlying Age-Related Differences in the Effect of Emotion on JOLs

Although previous findings on the positivity effect on JOLs in older adults are inconsistent, they do point toward a possibility of age-related differences in the effect of emotion on JOLs (Sanders & Berry, 2021; Yin et al., 2023). However, to our knowledge, no research has investigated the mechanisms underlying these age-related differences. The dual-process model of metamemory (Koriat, 1997; Koriat et al., 2004) proposes two distinct modes to explain how emotion impacts JOLs. On the one hand, emotion may influence JOLs in an experience-based (nonanalytic) manner. Specifically, when encoding emotionally charged information, individuals may experience variations in processing fluency, physiological arousal, or attention (Hamann, 2001; Hourihan & Bursey, 2017), which in turn influence their JOLs. On the other hand, emotion can affect JOLs through a theory-based (analytic) approach (Tauber et al., 2017; Witherby & Tauber, 2018). That is, individuals hold *a priori* metamemory beliefs that stimuli with specific emotion (e.g., positive emotion) are easier to remember than those with other emotion (e.g., neutral or negative emotion), resulting in different JOLs for different stimuli.

Several studies have explored the mechanisms underlying the emotional salience effect on JOLs in young adults, but the findings have been inconsistent (Pierce et al., 2023; Undorf & Bröder, 2020; Witherby et al., 2022; Witherby & Tauber, 2018). For instance, Witherby and Tauber (2018) found that young participants' JOLs were insensitive to three types of negative (i.e., afraid, angry, sad) facial expressions, even though participants believed that angry expressions were more memorable than afraid and sad expressions. This finding suggests that young participants did not rely on their *a priori* beliefs when making JOLs. In contrast, Pierce et al. (2023) found that young adults' beliefs exhibited a similar pattern to their JOLs: Young adults believed that emotional words were more memorable than neutral ones, and they constructed their JOLs accordingly. In one of their experiments (Pierce et al., 2023; Experiment 4), they assessed the relative contributions of beliefs and experience (i.e., processing fluency) to JOLs. These results indicated that beliefs, rather than fluency, were the primary factors driving the emotional salience effect on JOLs in young adults.

To summarize, while previous findings on the mechanisms underlying the emotional salience effect on JOLs in young adults are mixed, existing evidence, such as that from Pierce et al. (2023), does suggest that *a priori* beliefs play a crucial role. Further research is needed to explore age-related differences in the effect of emotion on JOLs and to elucidate the mechanisms underlying these differences.

Overview of the Present Study

Given the inconsistent findings on age-related differences in the effect of emotion on JOLs, the first purpose of the present study is to investigate the robustness of the positivity effect on JOLs in older adults and the emotional salience effect on JOLs in young adults. The present study adopted the same paradigm as in Sanders and Berry (2021) but explored aged-related differences in the emotional effect on JOLs in a different cultural context (i.e., Chinese participants). Previous research exploring age-related positivity effects on cognition, such as memory and attention, has discussed the influence of social cultures (e.g., Fung et al., 2008, 2019). Findings suggest that age-related positivity effects on cognition are more consistently observed in Western cultures, while Asian cultures show mixed results—potentially due to a stronger emphasis on maintaining interpersonal harmony (Fung et al., 2019). However, research on the emotional effect on JOLs has largely been confined to Western contexts. Expanding this investigation to broader cultural contexts is crucial for understanding the relationship between aging and subjective well-being.

The second aim is to unravel the mechanisms underlying age-related differences in the effect of emotion on JOLs by examining the contribution of metamemory beliefs. To foreshadow, the present study replicated the results of Sanders and Berry (2021). Specifically, Experiment 1 found that older participants demonstrated a positivity effect on JOLs, whereas young participants demonstrated an emotional salience effect on JOLs. Experiment 2 then measured participants' *a priori* beliefs about the effect of emotion on memory. We expect that young and older participants hold different beliefs about the effect of emotion on memory. Specifically, young participants may hold an emotional salience belief that both positive and negative stimuli are more memorable than neutral ones. In contrast, older adults are hypothesized to hold a positivity belief that positive stimuli are easier to remember than negative and neutral ones. Finally, Experiment 3 collected data of both beliefs and JOLs from the same participants to further elucidate the role of beliefs in age-related differences in the effect of emotion on JOLs.

Experiment 1

Method

Transparency and Openness

We report how we determined our sample sizes; describe all data exclusions, all manipulations, and all measures in the study; and follow Journal Article Reporting Standards (Kazak, 2018). All data, analysis code, and research materials are publicly available on the Open Science Framework at https://osf.io/hpjmq/ (Yin, 2024). All data were collected in 2023 in China. Data were analyzed using JASP Version 0.17.1 (an open-source statistical software program; https://jasp-stats.org), R Version 4.3.0 (R Core Team, 2021), and SPSS Version 26.0 (Hayes, 2009; Hayes & Preacher, 2010). This study was not preregistered.

Design and Participants

Experiment 1 involved a 2 (Age Group: Young Adults vs. Older Adults) × 3 (Emotion: Positive vs. Negative vs. Neutral) mixed-factor design, with emotion manipulated within-subjects. A power analysis was conducted using G* Power (Faul et al., 2007) based on the effect size (Cohen's $d = 0.58$) observed by Sanders and Berry (2021), which indicated that 26 older participants were required to detect a significant (two-tailed, $\alpha = .05$) difference in JOLs between positive and negative words in older adults (i.e., a significant positivity effect on JOLs in older adults) at .80 power. To be more conservative, we set our sample size at 40 participants per group, following Sanders and Berry (2021). Finally, 45 older Chinese participants were recruited through online posters and received 40 renminbi as compensation. Data from two participants were unsaved due to computer failure and hence excluded from final analyses. Additionally, 44 young Chinese participants were recruited from Beijing Normal University participant pool and received 40 renminbi as compensation. The final sample consisted of 43 older ($M = 68.09$, $SD = 3.32$; 29 female) and 44 young ($M = 21.96$, $SD = 2.23$; 36 female) participants. Table 1 displays the demographic and cognitive data for all experiments.

All participants were invited to participate if they were in good health (i.e., free of neurological disorders, chronic illnesses, or psychiatric disorders) and had normal or corrected-to-normal vision. All experiments in the present study were approved by the Ethics Committee of Faculty of Psychology at Beijing Normal University (File Number 202201040001). Written informed consents were obtained from all participants.

Materials

In total, 204 two-character Chinese words were selected from the MEgastudy of Lexical Decision in Simplified CHinese database (Tsang et al., 2018), which included valence and arousal ratings collected from participants aged 18–62 (Xu et al., 2022). Twenty-four words served as practice and buffer words, incorporating a mixture of positive, negative, and neutral words. The remaining 180 words were divided into four lists, with 45 words in each list. Within each list, there were 15 positive words ($M = 2.17$, $SD = 0.16$, on a scale ranging from −3 = *extremely negative* to +3 = *extremely positive*), 15 negative words ($M = -2.31$, $SD = 0.21$), and 15 neutral words ($M = 0.09$, $SD = 0.15$), with substantial difference in valence between each pair of emotion category (i.e., all $ps < .001$). The mean arousal levels for positive ($M = 2.86$, $SD = 0.34$, on a scale ranging from 0 = *very low arousal* to 4 = *very high arousal*) and negative ($M = 2.90$, $SD = 0.34$) words did not differ, $M_{\text{diff}} = 0.04$, $SE = 0.06$, $p = 1.000$, Cohen's $d = 0.14$. But both arousal levels for positive, $M_{\text{diff}} = 1.39$, $SE = 0.06$, $p < .001$, Cohen's $d = 4.39$, and negative, $M_{\text{diff}} = 1.43$, $SE = 0.06$, $p < .001$, Cohen's $d = 4.52$, words were higher than that for neutral words ($M = 1.47$, $SD = 0.26$).

Positive, negative, and neutral words were matched on word frequency (positive: $M = 28.26$, $SD = 46.83$; negative: $M = 29.96$, $SD = 42.46$; neutral: $M = 31.62$, $SD = 45.32$), $F < 1$; number of strokes (positive: $M = 16.62$, $SD = 4.70$; negative: $M = 17.63$, $SD = 4.58$; neutral: $M = 16.60$, $SD = 3.93$), $F(2.177) = 1.08$, $p = .343$, $\eta_p^2 = 0.01$; and familiarity (positive: $M = 6.27$, $SD = 0.36$; negative: $M = 6.19$, $SD = 0.33$; neutral: $M = 6.24$, $SD = 0.41$), $F < 1$.

A series of cognitive tests were used for cognitive screening. The Mini-Mental State Examination (MMSE; Folstein et al., 1975), a classic tool for assessing cognitive impairment in clinical settings, was used to evaluate cognitive abilities of orientation, registration, attention/calculation, recall, language, and copying. The maximum score of MMSE is 30, and a score of 24 or below suggests cognitive impairment (Folstein et al., 1975; Radomski & Morrison, 2014). Notably, all participants in this study scored above 25, indicating no significant cognitive impairment. In addition, processing speed was measured via a digit comparison test (Liu et al., 2020), working memory was assessed using a backward digit span test (GrÉGoire & Van der Linden, 1997), and verbal fluency was evaluated using a vocabulary test, where participants were asked to name as many animals, fruits, and vegetables as possible during 1 min (Wechsler et al., 1997).

Procedure

The procedure consisted of two parts: a learning task programmed using *PsychoPy v2022.2.5* (https://www.psychopy.org) and a series of cognitive tests administered via a paper-and-pen format.

Table 1

Demographic and Cognitive Characteristics of Participants

	Experiment 1			Experiment 2			Experiment 3		
Measure	Older adult	Young adult	p, Cohen's d	Older adult	Young adult	p, Cohen's d	Older adult	Young adult	p, Cohen's d
N	43	44		30	30		45	45	
Age range	62–75	18–26		62–73	18–26		64–81	18–29	
Mean age	68.09 (3.32)	21.96 (2.23)		66.87 (2.86)	21.23 (2.05)		68.22 (3.34)	21.80 (2.40)	
Years of education	12.21 (2.14)	16.23 (2.13)	<.001, −1.88	11.90 (2.11)	16.13 (1.83)	<.001, −2.14	12.02 (2.62)	16.36 (1.99)	<.001, −1.86
MMSE	28.19 (1.30)	28.98 (0.93)	.002, −0.70	28.47 (1.55)	29.53 (0.73)	.001, −0.88	28.69 (0.93)	29.36 (0.80)	<.001, −0.77
Processing speed	22.09 (5.49)	42.16 (5.26)	<.001, −3.73	20.13 (6.04)	39.30 (8.33)	<.001, −2.63	22.80 (6.09)	37.00 (7.53)	<.001, −2.08
Working memory	5.28 (1.30)	8.25 (1.22)	<.001, −2.36	5.43 (1.59)	8.20 (1.47)	<.001, −1.81	5.64 (1.00)	8.36 (1.33)	<.001, −2.30
Verbal fluency	16.47 (2.75)	18.71 (3.16)	<.001, −0.76	16.35 (3.43)	19.92 (2.67)	<.001, −1.16	16.64 (2.66)	20.71 (3.33)	<.001, −1.35

Note. Means, standard deviations (in parentheses); significance levels (p values) and effect sizes (Cohen's ds) of the differences between young and older participants. All participant scored above 25 on MMSE, indicating no significant cognitive impairment. Scores on the digit comparison test ranged from 0 to 48, with higher scores indicating superior processing speed. Scores on the backward digit span test ranged from 2 to 10, with higher scores reflecting better working memory ability. Scores on the vocabulary test ranged from 0 to 28, with higher scores indicating greater verbal fluency. MMSE = Mini-Mental State Examination (Folstein et al., 1975).

In the learning task, participants were informed that they would study words and make JOLs before completing a memory test. Prior to the main experiment, participants were required to complete a practice task in which they studied four words individually. Each word was presented for 2.5 s, after which participants were instructed to make a JOL on a 6-point scale (1 = "*Sure I will not remember it*"; 6 = "*Sure I will remember it*") to predict the likelihood of remembering the word on a later test. JOL-making was self-paced. After all four words had been studied and rated, participants engaged in a distractor task (math problems; e.g., *7 + 8 = __?*) for 15 s. Then, participants completed a forced-choice recognition test in which two words (i.e., target–lure) were displayed on-screen, and they were given unlimited time to identify which word they had previously studied.

During the formal experiment, participants underwent two blocks of learning tasks, in which two lists were randomly selected as target lists for learning, while the other two lists were presented as lures in the forced-choice recognition test. Within each block, participants were assigned to study a randomly selected list of 45 words, which included 15 positive, 15 negative, and 15 neutral words. After each word was presented for 2.5 s, participants made a JOL on a 6-point scale. JOL-making was self-paced. Following studying and making JOLs for all 45 words, a 20-s distractor task was administered. Subsequently, participants engaged in a memory test in which two words (i.e., an old word selected from the studied list and a new word selected from the paired lure list) were displayed on the screen, and they were asked to identify which word was old (i.e., studied). There was no time pressure and no feedback in the final test.

To balance the final test, half of the targets were shown on the left side of the screen and the other half on the right. Additionally, the valences of the targets and lures were fully crossed. That is, five positive targets were randomly paired with five positive lures, five with five negative lures and five with five neutral lures, and so on, resulting in a total of nine types of target–lure pairs. To mitigate primacy and recency effects, two buffer words were included at both the beginning and end of the study list. Data from primacy and recency buffers were excluded from analyses.

After finishing the learning task, participants completed a series of cognitive tests, including MMSE (Folstein et al., 1975), a digit comparison test (Liu et al., 2020), a backward digit span test (GrÉGoire & Van der Linden, 1997), and a vocabulary test (Wechsler et al., 1997).

Statistical Analyses

JASP Version 0.17.1 (https://jasp-stats.org) was used to perform Bayesian and frequentist mixed analyses of variance (ANOVAs) with age group (older adults vs. young adults) as the between-subjects factor and emotion (positive vs. negative vs. neutral) as the within-subjects factor. All parameters were set as default (van Doorn et al., 2021). The Bayes factor (BF) provides relative evidence in favor of the alternative hypothesis over the null one. $BF_{10} > 3$ indicates that the observed results support the alternative over the null hypothesis, and $1 < BF_{10} < 3$ provides weak evidence in favor of the alternative hypothesis. Conversely, $BF_{10} < 0.33$ indicates that the observed results support the null over the alternative hypothesis, and $0.33 < BF_{10} < 1$ provides weak evidence in favor of the null hypothesis. Additionally, BF_{incl} was reported to assess the main effects and interaction effects, indicating the extent to which the data support including a specific effect in the model compared to excluding it.

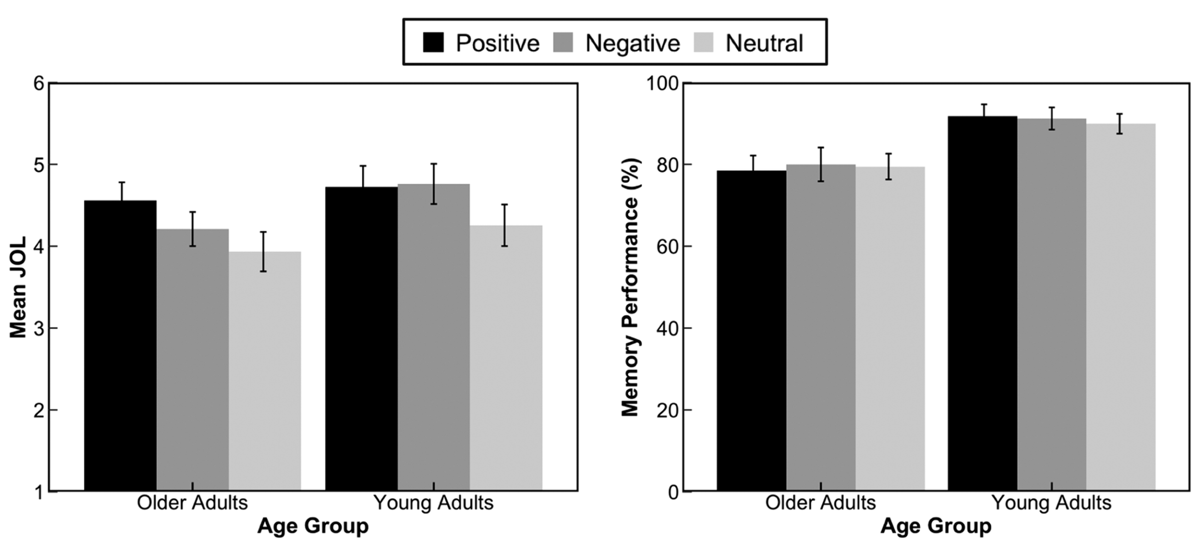
Results

Judgments of Learning

JOLs were averaged across the two blocks by each emotion category to examine age differences in the effect of emotion on JOLs (see the left panel of Figure 1). Bayesian and frequentist mixed

Figure 1

Mean JOLs as a Function of Age Group and Emotion in Experiment 1 (Left Panel), and Recognition Performance as a Function of Age Group and Emotion in Experiment 1 (Right Panel)



Note. Error bars represent ± standard error. JOL = judgment of learning.

ANOVAs showed a main effect of age group, $F(1, 85) = 4.85$, $p = .030$, $\eta_p^2 = .05$, $BF_{incl} = 2.09$, with young participants providing overall higher JOLs than older participants. There was also a main effect of emotion, $F(2, 170) = 44.92$, $p < .001$, $\eta_p^2 = .35$, $BF_{incl} = 6.39 \times 10^{12}$. Importantly, there was a significant interaction between age group and emotion, $F(2, 170) = 5.22$, $p = .006$, $\eta_p^2 = .06$, $BF_{incl} = 6.04$.

Specifically, for older participants, JOLs were higher for positive than for neutral words, $M_{diff} = 0.63$, 95% CI [0.37, 0.88], $p < .001$, Cohen's $d = 0.84$, $BF_{10} = 405{,}856$, and higher for positive than for negative words, $M_{diff} = 0.35$, 95% CI [0.10, 0.60], $p < .001$, Cohen's $d = 0.47$, $BF_{10} = 111.01$, reflecting a positivity effect on JOLs in older adults (Sanders & Berry, 2021). In addition, JOLs were higher for negative than for neutral words, $M_{diff} = 0.28$, 95% CI [0.02, 0.53], $p = .009$, Cohen's $d = 0.37$, $BF_{10} = 7.27$.

In contrast, for young participants, JOLs were higher for positive than for neutral words, $M_{diff} = 0.47$, 95% CI [0.22, 0.72], $p < .001$, Cohen's $d = 0.56$, $BF_{10} = 452{,}586$, and higher for negative than for neutral words, $M_{diff} = 0.51$, 95% CI [0.26, 0.76], $p < .001$, Cohen's $d = 0.60$, $BF_{10} = 24{,}584$. Critically, JOLs for positive and negative words did not differ, $M_{diff} = -0.03$, 95% CI [−0.28, 0.22], $p = 1.000$, Cohen's $d = -0.04$, $BF_{10} = 0.18$, reflecting an emotional salience effect on JOLs in young adults (Sanders & Berry, 2021; Tauber & Dunlosky, 2012).

Recognition Performance

Recognition performance in each condition is depicted in the right panel of Figure 1. Bayesian and frequentist mixed ANOVAs showed a significant main effect of age group, $F(1, 85) = 32.64$, $p < .001$, $\eta_p^2 = .28$, $BF_{incl} = 67{,}451$, indicating superior recognition performance for young participants compared to older participants. There was no main effect of emotion, $F(2, 170) = 0.46$, $p = .631$, $\eta_p^2 = .01$, $BF_{incl} = 0.06$. The age group by emotion interaction was not statistically detectable, $F(2, 170) = 1.15$, $p = .320$, $\eta_p^2 = .01$, $BF_{incl} = 0.20$. These findings are consistent with those of Sanders and Berry (2021), who also found no age-related differences in the effect of emotion on memory in learning tasks with the requirement of making JOLs.

Discussion

Experiment 1 replicated the main findings of Sanders and Berry (2021), revealing an age-related difference in the effect of emotion on JOLs. Specifically, older participants exhibited a positivity effect on JOLs, whereas young participants demonstrated an emotional salience effect on JOLs. However, emotion had no detectable impact on recognition performance in either young or older participants. This finding on memory performance may be attributed to methodological limitations, such as the probability that making JOLs reactively changes actual memory performance or that the recognition task may be too easy to perform (Sanders & Berry, 2021). We further discuss these possible reasons in the General Discussion section.

Experiment 2

Experiment 2 aimed to investigate the mechanisms underlying age-related differences in the effect of emotion on JOLs by assessing the role of metamemory beliefs. We predict that aged-related differences in the emotional effect on JOLs may result from the fact that young and older adults hold different beliefs about the effect of emotion on memory. Older participants may hold *a priori* beliefs that positive stimuli are easier to remember than negative and neutral ones, whereas young participants may believe that positive and negative stimuli are equally easier to remember than neutral ones.

Method

Design and Participants

A 2 (Age Group: Young Adults vs. Older Adults) × 3 (Emotion: Positive vs. Negative vs. Neutral) mixed-factor design was employed, with emotion manipulated within-subjects. According to a pilot study (Cohen's $d = 0.76$), a power analysis indicated that 16 older participants were sufficient to detect a significant (two-tailed, $\alpha = .05$) difference in beliefs between positive and negative words at .80 power. To be more conservative, we set our sample size at 30 participants per group, in line with conventions in previous research examining participants' beliefs about the effects of other cues on memory (e.g., Fan et al., 2021; Su et al., 2018). Finally, 30 young ($M = 21.23$, $SD = 2.05$; 27 female) and 30 older ($M = 66.87$, $SD = 2.86$; 19 female) participants were recruited.

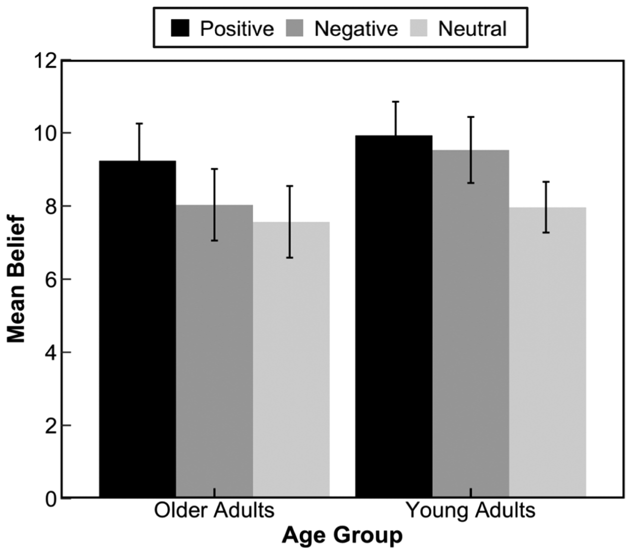
Procedure

A classical belief survey was employed to assess participants' *a priori* beliefs about the effect of emotion on memory, ensuring that they were not exposed to stimuli to eliminate the influence of processing experience on the construction of JOLs. Participants were initially instructed to imagine themselves taking part in a memory task in which they would learn 45 two-character Chinese words and subsequently complete a memory test. They were told that 15 of the words were positive in valence (i.e., words that depict happy things), 15 of the words were negative in valence (i.e., words that depict upsetting things), and 15 of the words were neutral. Participants were asked to predict how many words of each type (i.e., positive, negative, and neutral words) they believed they would remember in a later memory test, writing a number from 0 to 15 for each category. These estimates were made without a time limit. Six versions of the survey were created to counterbalance the order of emotion descriptions and estimates. After completing the belief survey, participants proceeded to the cognitive tests, identical to those in Experiment 1.

Results

As illustrated in Figure 2, the results pertaining to participants' beliefs about memory performance for words with different emotions revealed an age-related difference. Specifically, older participants demonstrated a belief in the positivity effect, whereas young participants showed a belief in the emotional salience effect. Bayesian and frequentist mixed ANOVAs showed no main effect of age group, $F(1, 58) = 1.90$, $p = .173$, $\eta_p^2 = .03$, $BF_{incl} = 0.77$. But there was a main effect of emotion, $F(2, 116) = 45.74$, $p < .001$, $\eta_p^2 = .44$, $BF_{incl} = 6.36 \times 10^{11}$. More importantly, there was a

Figure 2
Mean Beliefs as a Function of Age Group and Emotion in Experiment 2



Note. Error bars represent ± standard error.

significant interaction between age group and emotion, $F(2, 116) = 4.46$, $p = .014$, $\eta_p^2 = .07$, $BF_{incl} = 3.42$.

Specifically, older participants believed they could remember more positive words than neutral ones, $M_{diff} = 1.67$, 95% CI [1.01, 2.32], $p < .001$, Cohen's $d = 0.60$, $BF_{10} = 58{,}853$, and more positive words than negative ones, $M_{diff} = 1.20$, 95% CI [0.54, 1.86], $p < .001$, Cohen's $d = 0.43$, $BF_{10} = 107.25$. They believed there was no difference in recall between negative and neutral words, $M_{diff} = 0.47$, 95% CI [−0.19, 1.12], $p = .255$, Cohen's $d = 0.17$, $BF_{10} = 0.83$. These results confirm our prediction that older participants hold *a priori* beliefs in the positivity effect.

In contrast, young participants believed that positive words were more memorable than neutral ones, $M_{diff} = 1.97$, 95% CI [1.30, 2.64], $p < .001$, Cohen's $d = 0.83$, $BF_{10} = 752{,}983$, and that negative words were more memorable than neutral ones, $M_{diff} = 1.57$, 95% CI [0.90, 2.24], $p < .001$, Cohen's $d = 0.66$, $BF_{10} = 1{,}231$. Additionally, their beliefs about positive and negative words did not differ, $M_{diff} = 0.40$, 95% CI [−0.27, 1.07], $p = .442$, Cohen's $d = 0.17$, $BF_{10} = 0.60$. These results confirm our prediction that young participants hold *a priori* beliefs in the emotional salience effect.

Discussion

The results of Experiment 2 indicated that older adults held a belief in the positivity effect, while young adults held a belief in the emotional salience effect. These findings mirrored the patterns of the emotional effects on JOLs observed in Experiment 1, suggesting that age-related differences in the effect of emotion on JOLs may derive from divergent metamemory beliefs between older and young adults.

An additional observation is the slight discrepancy between the JOL results in Experiment 1 and the belief results in Experiment 2. In Experiment 1, older participants provided higher JOLs for negative words compared to neutral words, while Experiment 2 found no difference in older participants' beliefs about how many negative and neutral words they thought they would remember. This discrepancy might be attributed to sampling error, and it is also possible that beliefs play a partial role in age-related differences in the effect of emotion on JOLs.

Experiment 3

Given that JOL and belief data were collected from different samples in Experiments 1 and 2, it remains premature to draw firm conclusions regarding the role of metamemory beliefs in age-related differences in the emotional effect on JOLs. Experiment 3 was conducted to collect JOL and belief data from the same sample, aiming to further investigate the role of beliefs in age-related differences in the effect of emotion on JOLs.

Method

Design and Participants

A 2 (Age Group: Young Adults vs. Older Adults) × 3 (Emotion: Positive vs. Negative vs. Neutral) mixed-factor design was employed, with emotion manipulated within-subjects. Following Experiment 1, the sample size was set to 40 participants per group. Forty-five young and 46 older participants were recruited. Data from one older participant were excluded because she had difficulty understanding the meaning of making JOLs. The final sample consisted of 45 young ($M = 21.80$, $SD = 2.40$; 37 females) and 45 older ($M = 68.22$, $SD = 3.34$; 32 females) participants.

Procedure

The procedure consisted of three parts: a belief survey, a series of cognitive tests, and a learning task. First, participants were instructed to complete the same belief survey as in Experiment 2, predicting how many words of each type (i.e., positive, negative, and neutral) they would be able to remember in a later memory test. Second, they completed cognitive tests. Following these tests, participants were instructed to complete the learning task, which was identical to that used in Experiment 1.

Results

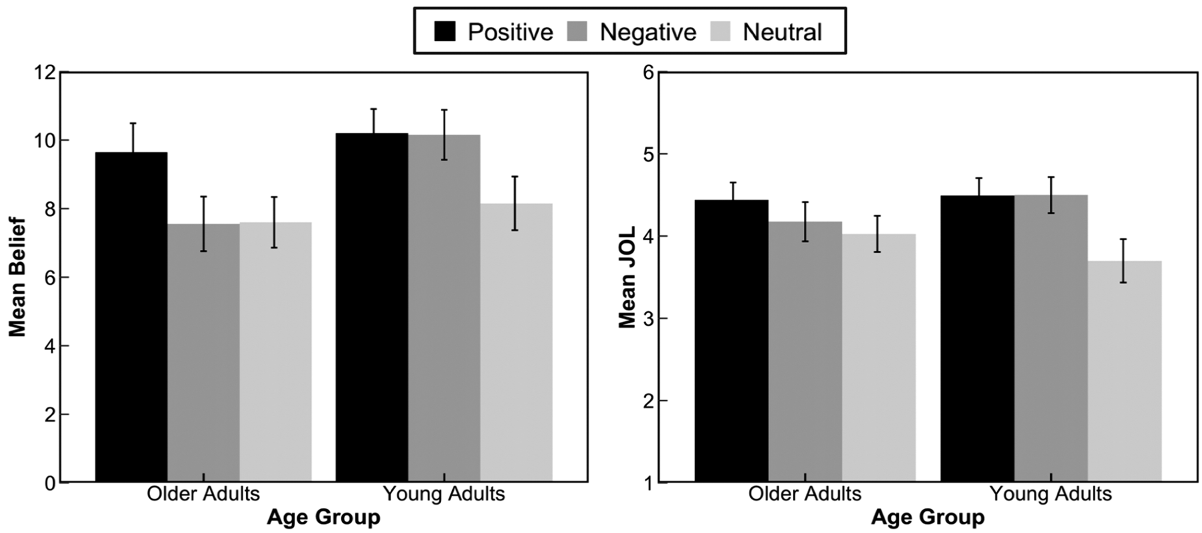
Beliefs

As demonstrated in the left panel of Figure 3, the belief results replicated those observed in Experiment 2, highlighting the presence of an age-related difference in the emotional effect on belief. Bayesian and frequentist mixed ANOVAs showed a main effect of age group, $F(1, 88) = 5.65$, $p = .020$, $\eta_p^2 = .06$, $BF_{incl} = 2.79$, and a main effect of emotion, $F(2, 176) = 74.68$, $p < .001$, $\eta_p^2 = .46$, $BF_{incl} = 1.57 \times 10^{17}$. Importantly, there was a significant interaction between age group and emotion, $F(2, 176) = 24.88$, $p < .001$, $\eta_p^2 = .22$, $BF_{incl} = 2.76 \times 10^7$.

Specifically, older participants believed they could remember more positive words than neutral ones, $M_{diff} = 2.04$, 95% CI [1.55, 2.54], $p < .001$, Cohen's $d = 0.75$, $BF_{10} = 7.07 \times 10^9$, and more positive words than negative ones, $M_{diff} = 2.09$, 95% CI

Figure 3

Mean Beliefs as a Function of Age Group and Emotion in Experiment 3 (Left Panel), and Mean JOLs as a Function of Age Group and Emotion in Experiment 3 (Right Panel)



Note. Error bars represent ± standard error. JOL = judgment of learning.

[1.60, 2.58], $p < .001$, Cohen's $d = 0.77$, $BF_{10} = 1.38 \times 10^{11}$. Additionally, they believed there was no difference in recall between negative and neutral words, $M_{diff} = -0.04$, 95% CI [−0.54, 0.45], $p = 1.000$, Cohen's $d = -0.02$, $BF_{10} = 0.17$. These results confirm our prediction that older participants hold a belief in the positivity effect.

In contrast, young participants believed that positive words were more memorable than neutral ones, $M_{diff} = 2.04$, 95% CI [1.39, 2.70], $p < .001$, Cohen's $d = 0.81$, $BF_{10} = 559{,}349$. They also believed that negative words were more memorable than neutral ones, $M_{diff} = 2.00$, 95% CI [1.35, 2.65], $p < .001$, Cohen's $d = 0.79$, $BF_{10} = 3.59 \times 10^{6}$. Additionally, their beliefs about positive and negative words did not differ, $M_{diff} = 0.04$, 95% CI [−0.61, 0.70], $p = 1.000$, Cohen's $d = 0.02$, $BF_{10} = 0.17$. These findings confirm our prediction that young participants hold a belief in the emotional salience effect.

Judgments of Learning

As illustrated in the right panel of Figure 3, the pattern of JOL results closely mirrored that of the belief results, indicating that both older and young participants primarily based their JOLs on metamemory beliefs. Bayesian and frequentist mixed ANOVAs showed that there was no main effect of age group, $F < 1$, but there was a main effect of emotion, $F(2, 176) = 59.59$, $p < .001$, $\eta_p^2 = .40$, $BF_{incl} = 1.61 \times 10^{15}$. More importantly, there was a significant interaction between age group and emotion, $F(2, 176) = 15.81$, $p < .001$, $\eta_p^2 = .15$, $BF_{incl} = 27{,}271$.

Specifically, for older participants, JOLs for positive words were higher than those for neutral words, $M_{diff} = 0.41$, 95% CI [0.28, 0.55], $p < .001$, Cohen's $d = 0.54$, $BF_{10} = 5.42 \times 10^{6}$, and also higher than those for negative words, $M_{diff} = 0.27$, 95% CI [0.13, 0.40], $p < .001$, Cohen's $d = 0.35$, $BF_{10} = 1{,}432$, reflecting a positivity effect on JOLs. Additionally, JOLs for negative words were also higher than for neutral words, $M_{diff} = 0.15$, 95% CI [0.01, 0.29], $p = .029$, Cohen's $d = 0.19$, $BF_{10} = 2.72$, which slightly differed from the belief results showing no difference in memorability between negative and neutral words.

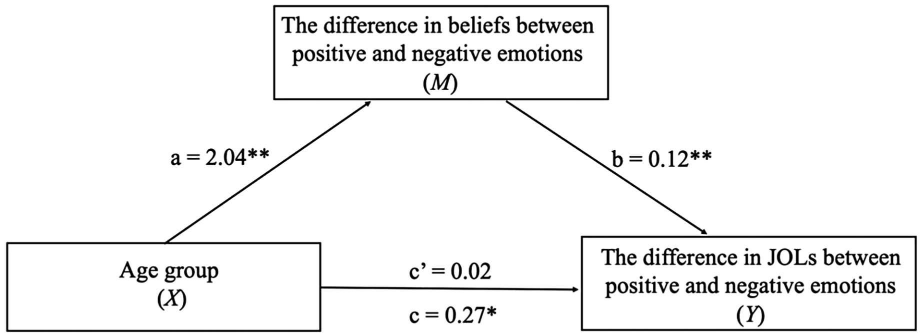
For young participants, JOLs for positive words were higher than those for neutral words, $M_{diff} = 0.79$, 95% CI [0.54, 1.04], $p < .001$, Cohen's $d = 0.99$, $BF_{10} = 2.18 \times 10^{9}$; JOLs for negative words were also higher than those for neutral words, $M_{diff} = 0.80$, 95% CI [0.55, 1.05], $p < .001$, Cohen's $d = 1.00$, $BF_{10} = 225{,}391$. Critically, there was no difference in JOLs between positive and negative words, $M_{diff} = -0.01$, 95% CI [−0.26, 0.24], $p = 1.000$, Cohen's $d = -0.01$, $BF_{10} = 0.16$. These results jointly reflect an emotional salience effect on JOLs in young adults.

Contribution of Metamemory Beliefs to Age-Related Differences in the Effect of Emotion on JOLs

As previously noted, the patterns of JOL results closely mirrored those of beliefs for both older and young participants. Inspired by the socioemotional selectivity theory, a mediation analysis was conducted to further explore whether the difference in beliefs about positive and negative emotions accounts for the relationship between age group and the difference in JOLs between positive and negative emotions. The mediation analysis employed the Hayes method (Hayes, 2009; Hayes & Preacher, 2010), which uses bootstrapping to estimate and test the indirect effect. To be specific, age group (X; with young participants coded as 0, and older participants coded as 1) was treated as the independent variable. The difference in beliefs between positive and negative emotions (= belief about positive emotion − belief about negative emotion) served as the mediator (M). The difference in JOLs between positive and negative emotions (= JOLs for positive emotion − JOLs for negative emotion) was treated as the dependent variable (Y). For the bootstrap procedure, 5,000 samples were selected using unrestricted random sampling.

Figure 4

Mediating Effect of Beliefs in Age-Related Differences in the Effect of Emotion on JOLs



Note. All presented effects are unstandardized. The coefficient *a* represents the effect of age group (with young participants coded as 0, and older participants coded as 1) on the difference in beliefs about positive and negative emotions (= belief about positive emotion − belief about negative emotion); *b* is the effect of the difference in beliefs about positive and negative emotions on the difference in JOLs for positive and negative emotions (= JOLs for positive emotion − JOLs for negative emotion); *c′* indicates the direct effect of age group on the difference in JOLs for positive and negative emotions; *c* is the total effect of age group on the difference in JOLs for positive and negative emotions. JOLs = judgments of learning; M = mediator; X = independent variable; Y = dependent variable.
$^{*}p < .05$. $^{**}p < .01$.

As illustrated in Figure 4, the results showed that the bootstrap parameter estimates were 0.02, 95% CI [−0.23, 0.28] for the direct effect; 0.25, 95% CI [0.10, 0.41] for the indirect effect; and 0.27, 95% CI [0.06, 0.49] for the total effect, resulting in a ratio of 0.926 between the indirect and the total effect (i.e., 92.6% of the total effect of age group on the difference in JOLs between positive and negative emotions was successfully explained by the mediating effect of beliefs). To conclude, these results suggested that the difference in beliefs can largely explain age-related differences in the effect of emotion on JOLs.

Recognition Performance

Bayesian and frequentist mixed ANOVAs showed that young participants remembered more words than older participants, $F(1, 88) = 53.90$, $p < .001$, $\eta_p^2 = .38$, $BF_{incl} = 6.71 \times 10^7$ (see Figure 5). There was no statistically detectable main effect of emotion, $F(2, 176) = 1.57$, $p = .210$, $\eta_p^2 = .02$, $BF_{incl} = 0.15$. The age group by emotion interaction was also nonsignificant, $F(2, 176) = 1.64$, $p = .197$, $\eta_p^2 = .02$, $BF_{incl} = 0.29$.

Discussion

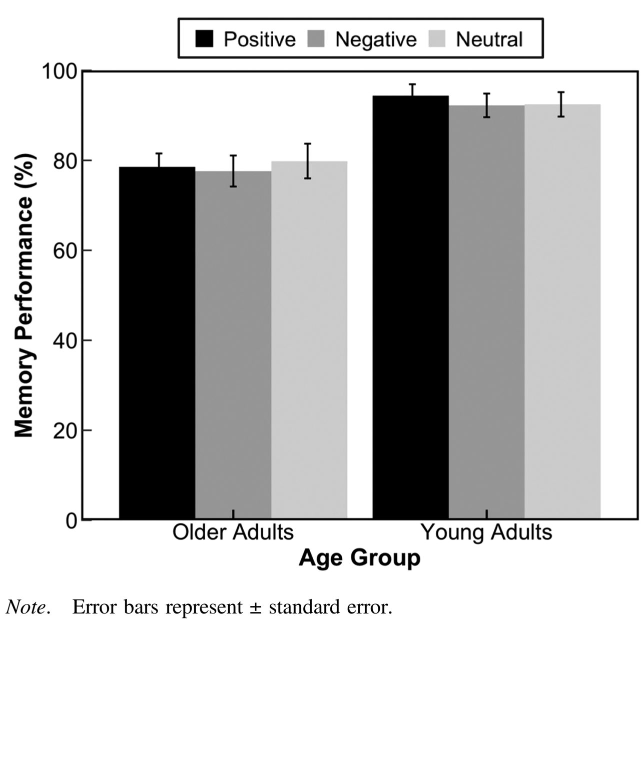
Experiment 3 expanded the existing evidence and provided new insights into the underlying mechanisms of age-related differences in the effect of emotion on JOLs by collecting data from the same sample. The results illustrated that older adults hold *a priori* beliefs in the positivity effect, which subsequently influence their JOLs, leading to a positivity effect on JOLs. In contrast, young adults hold beliefs in the emotional salience effect, which similarly influence their JOLs, resulting in an emotional salience effect on JOLs. The mediation results further confirmed the contribution of metamemory beliefs to age-related differences in the effect of emotion on JOLs.

General Discussion

The present study investigated age-related differences in the effect of emotion on metacognitive judgments, using high-powered sample sizes and a large number of experimental trials. It not only replicated age-related differences in the emotional effect on JOLs in Chinese participants, but also illuminated the role of metamemory beliefs in these differences. To be specific, the present study

Figure 5

Mean Recognition Memory Performance as a Function of Age Group and Emotion in Experiment 3



Note. Error bars represent ± standard error.

consistently observed a positivity effect on JOLs in older participants, as well as an emotional salience effect on JOLs in young participants (Experiments 1 and 3). Furthermore, it established that metamemory belief is a key factor contributing to age-related differences in the effect of emotion on JOLs (Experiments 2 and 3). These findings are consistent with the main principles of prevailing theories in metamemory, such as the dual-process theory (Koriat et al., 2004), as well as the lifespan theory of socioemotional selectivity (Carstensen, 1995; Carstensen et al., 1999).

By conducting high-powered experiments, the present study found that older adults consistently assigned higher JOLs to positive words compared to negative and neutral words, indicating a robust positivity effect on JOLs. In contrast, young adults provided higher JOLs for both positive and negative words than for neutral words, with no difference in JOLs between positive and negative words, revealing a stable emotional salience effect on JOLs. These results align with those of Sanders and Berry (2021), who proposed that previous studies failing to observe a positivity effect on JOLs in older adults may have been limited by insufficient statistical power. Given the interplay between cognition and metacognition (Nelson & Narens, 1990), where metacognitive judgments influence the selection and execution of relevant control processes (Metcalfe & Finn, 2008; Yang et al., 2017), older adults' metacognitive judgments may drive them to focus more on positive information over negative and neutral ones. This focus could ultimately enhance memory performance for positive information, as evidenced by robust findings in previous memory and attention studies (Charles et al., 2003; Murphy & Isaacowitz, 2008; Reed et al., 2014). The interrelated age differences in the emotional effect on cognition and metacognition may interact and jointly contribute to higher levels of well-being in late adulthood.

The present study is the first to investigate the role of *a priori* beliefs in age-related emotional effects on JOLs. The findings revealed that age differences in the effect of emotion on beliefs intimately mirrored age differences in the effect of emotion on JOLs, suggesting that both older and young adults construct their JOLs based on their metamemory beliefs. Specifically, older adults hold *a priori* beliefs that positive information is easier to remember than negative information, while young adults believe that positive and negative information are equally memorable. These distinct beliefs subsequently influence their JOLs. Indeed, the mediation results from Experiment 3 indicated that 92.6% of aged-related differences in the effect of emotion on JOLs (i.e., the difference in JOLs between positive and negative emotions) could be explained by aged-related differences in beliefs.

Several studies support the contribution of metamemory beliefs to the effect of emotion on JOLs, although these studies have primarily focused on the emotional salience effect on JOLs in young adults (Pierce et al., 2023; Undorf & Bröder, 2020; Witherby et al., 2022; Yin et al., 2023). For instance, Pierce et al. (2023) found that metamemory beliefs, rather than processing fluency, were the key factors underlying the emotional salience effect on JOLs in young adults. These findings, combined with those observed in the present study, underscore the importance of considering emotion as a salient cue within the theoretical framework of metamemory.

It is also important to note a slight discrepancy between the JOL and belief results among older participants in the present study. Specifically, older adults provided higher JOLs for negative words compared to neutral ones, whereas no corresponding difference was observed in their beliefs. This discrepancy suggests that *a priori* beliefs may play a partial, rather than complete, role in JOL formation. According to the dual-process model of metamemory, emotion may affect JOLs through beliefs, processing experience, or a combination of both (Koriat, 1997; Koriat et al., 2004). Given that emotional information tends to capture greater attention (Hamann, 2001), elicit higher levels of physiological arousal, and induce stronger subjective feelings (Hourihan & Bursey, 2017) compared to neutral information, it is plausible that processing experience also contributes to JOL formation. Moreover, while the present study found that older adults' JOLs were higher for negative than for neutral words, Sanders and Berry (2021) reported no such difference in their U.S.-based study. Therefore, the present discrepancy between JOL and belief ratings for negative and neutral words among older participants may be attributable to cultural differences. Further research is needed to thoroughly investigate the contributions of beliefs and processing experience to the emotional effect on JOLs, as well as to assess the generalizability of these findings across different cultures.

One limitation of the present study is that emotional words and neutral words were not matched for arousal, with arousal levels for positive and negative words being higher than those for neutral words. Consequently, the role of arousal in the effect of emotion on JOLs cannot be entirely ruled out. Preliminary findings, however, suggest that valence, rather than arousal, plays a more significant role in JOL formation (Tauber et al., 2017; Yin et al., 2023). For instance, Tauber et al. (2017) found that both young and older adults' JOLs were influenced by valence but not by arousal. Similarly, a meta-analysis by Yin et al. (2023) showed that arousal did not moderate the emotional salience effect on JOLs. Nevertheless, it would be premature to dismiss the potential influence of arousal on age-related differences in the emotional effect on JOLs. Further research is needed to investigate how valence and arousal, either separately or jointly, contribute to the effect of emotion on JOLs.

The present study did not observe an age-related positivity effect on recognition performance, which contrasts with findings from memory studies that reported reliable age-related positivity effects (Charles et al., 2003; Murphy & Isaacowitz, 2008; Reed et al., 2014). This counterintuitive result may be attributed to the requirement of making JOLs, as none of the previous JOL studies found age-related differences in the effect of emotion on memory, regardless of whether the final test format was free recall (Tauber & Dunlosky, 2012), old/new recognition (Sun & Jiang, 2023), or two-alternative forced-choice recognition (Sanders & Berry, 2021). Existing research consistently indicates that making item-by-item JOLs can retrospectively alter memory performance, demonstrating that memory can be reactive to metacognitive judgments—a phenomenon termed the *reactivity effect* (Li et al., 2024; Mitchum et al., 2016; Zhao et al., 2022, 2023; Zheng et al., 2024). For instance, a meta-analysis by Double et al. (2018) showed that making JOLs enhances retention of word lists compared to not making JOLs. Therefore, it is possible that making JOLs enhances participants' awareness of the differences in learning difficulty among emotionally charged stimuli (Mitchum et al., 2016), prompting them to allocate more resources to memorizing difficult stimuli (e.g., neutral stimuli). This, in turn, would lead to the absence of an emotional effect on memory.

It is also possible that the requirement of making item-by-item JOLs diverted participants' attention away from the encoding task (Yin et al., 2023). Previous research has demonstrated that processing constraints are important moderators of the age-related positivity effect on memory, with older adults exhibiting a positivity effect only when they are fully attentive or have sufficient cognitive resources to perform the memory task (Isaacowitz & Blanchard-Fields, 2012; Reed et al., 2014). It is evident that simultaneously making JOLs and performing the memory task present a considerable challenge for older adults (Tauber & Witherby, 2019), potentially leading to the nonsignificant emotional effect on memory.

Another possible explanation is that the memory task in the present study may have been too easy, leading to ceiling effects in participants' recognition performance, particularly among young adults ($M = 92\%$, $SD = 9\%$ for young adults; $M = 79\%$, $SD = 12\%$ for older adults). This explanation is consistent with findings from Sanders and Berry (2021), which also showed no Age Group × Emotion interaction in recognition performance. Additionally, it is possible that the test format moderates the age-related positivity effect. For instance, recognition tests may not be optimal for examining the age-related positivity effect on memory (for a review, see Murphy & Isaacowitz, 2008). Future studies should consider using different memory tasks, such as free recall, to further investigate these explanations and more rigorously compare the effects of emotion on memory with and without the requirement of JOLs. Furthermore, future research should focus on the role of JOLs (and beliefs) in age-related positivity effect on memory, exploring how the interplay between cognition and metacognition contributes to these age-related differences.

Overall, the present study provides robust evidence for age-related differences in the effect of emotion on JOLs. More importantly, it is the first study to uncover the vital role of metamemory beliefs in the positivity effect on JOLs in older adults and the emotional salience effect on JOLs in young adults. These findings are essential for advancing the theoretical framework of metamemory and extending the lifespan theory of socioemotional selectivity. Moreover, age-related differences in the emotional effect on metacognitive judgments may function as emotion regulation strategies that contribute to age differences in affective outcomes, such as well-being. Future research should explore whether the age-related positivity effect on metacognition underlies the positive emotional outcomes observed in older adults.

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