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Use of context in updating affective representations of words in older adults

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A R T I C L E I N F O

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A B S T R A C T

Older adults (OAs) often prioritize positive over negative information during word processing, termed as positivity bias. However, it is unclear how OAs update the affective representation of a word in contexts. The present study examined whether age-related positivity bias influences the update of the affective representation of a word in different emotional contexts. In Experiment 1 (web-based), younger and older participants read positive and negative target words in positive and negative contexts and rated the valence of the target words. Negative contexts biased the ratings more than positive ones, reflecting a negativity bias during offline valence evaluation in both age groups. In Experiment 2 (EEG), another group of participants read positive and negative target words in positive and negative contexts first, and then the same target words again, and made valence judgment on the target words. OAs showed a larger P2 (180–300 ms) difference before and after contexts for positive target words than younger adults (YAs). This suggests OAs' early attention to positive features of words in contexts. YAs showed a larger late positive complex (LPC) difference for target words before and after negative contexts than before and after positive contexts, while older adults showed comparable LPC effects across all the conditions. This suggests that YAs use negative contexts to update the affective representation of a word, whereas OAs do so in both positive and negative contexts. Our findings supported a reduced negativity bias in OAs in using (emotional) contexts to update the affective neural representation of a word.

1. Introduction

Do younger and older adults differ in their processing of positive or negative word meanings embedded in different sentential contexts? Consider, for example, the word "*monster*". "*Monster*" in the sentence "*The monster looks scary to the children.*" is typically negative as a single word and further implies a threat or danger that needs to be attended to in the sentence. However, when combined with a different sentential context, such as "*The monster looks funny to the children.*", "*monster*" becomes less negative or even mildly positive in one's mental representation. For decades, studies have debated about whether positive or negative information garners more attention during word processing (Kauschke et al., 2019), termed as positivity or negativity bias. Additionally, age plays a role in these processing biases. For instance, younger adults often show a negativity bias during word and sentence processing (Delaney-Busch et al., 2016; Delaney-Busch & Kuperberg, 2013). Specifically, negative words, compared with positive and neutral words, usually led to more enhanced neural activity that is associated with attention. This is the case for single words as well as for words in contexts. In the present study, we investigated whether and how these age-dependent emotional bias influences the update of the affective representation of a word in emotionally loaded contexts, by using an explicit valence judgment task and event-related potentials (ERPs).

The processing of visual information has been found to be context-dependent, in emotionally loaded verbal contexts. For instance, when judging a morphed face with an equal blend of happiness and anger, participants reported the face to be angrier if it was paired up with the word "angry" than with the word "happy" (Halberstadt & Niedenthal, 2001). Neurally, having read sentences with (vs. without) fearful contents prior to a neutral scene, participants showed increased brain activation in the right anterior temporal pole during the viewing of the neutral scene, suggesting that linguistic information is active during visual scene perception (Willems et al., 2011). These studies showed that emotional words and sentences can shape one's perception and representation of ambiguous or neutral visual stimuli. However, few attempts have been made to examine the influence of linguistic contexts on the processing of emotional stimuli, e.g., emotional words, and what factors affect this process.

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Age may play a role in contextualized language use. According to the neural evidence in language processing literature, older adults show an age-related reduction in anticipating or integrating upcoming information with the prior context, such as the pre-activation of possible semantic features and/or specific lexical items (Federmeier et al., 2010; Wlotko et al., 2012). This age-related reduction is mediated by older adults' cognitive control abilities (Dave et al., 2018; Federmeier et al., 2010). However, according to the behavioral evidence in emotion processing literature, older adults are as able as younger adults in detecting inconsistent emotions in upcoming sentences based on emotional contexts. This indicated that both younger and older adults used emotional contexts to update their mental representation of the described state of affairs (i.e., situational models) (Soederberg & Stine, 1995). These mixed findings suggest that while there may be an age-related decline in non-emotional, there is likely no decline in emotional, contextualized language use. Accordingly, we propose that older adults may still efficiently use emotional contexts to update their affective representation of a word. An unresolved question to be examined here is whether differently valenced contexts can be used to update the affective representation of a word similarly across younger and older adults, given the age-related emotional bias.

1.1. Emotional bias in language processing between younger and older adults

According to the automatic vigilance hypothesis (AVH; Pratto & John, 1991), people tend to attend to negative information for evolutionary reasons, termed as negativity bias, as negative information threatens one's well-being and thus needs to be detected, attended to, and avoided rapidly (Dijksterhuis & Aarts, 2003; Estes & Verges, 2008; Kuperman et al., 2014). Supporting evidence of the AVH mainly comes from behavioral tasks, including lexical decision, valence judgment, and naming tasks. Generally, negative words showed slower lexical decisions, slower word naming, yet faster valence judgment, compared with arousal-matched positive words. In addition, in a color-word Stroop task using positive (e.g., *sincere*) and negative (e.g., *hostile*) words (Pratto & John, 1991), color naming was slower for negative than for positive words, regardless of word arousal levels. These studies showed that negative information attracts prolonged attention in language tasks, mostly in younger adults.

Recent meta-reviews suggest that the negativity bias declines over the lifespan (Reed et al., 2014; Yuan et al., 2019). Older adults in their 60 s and 70 s often showed greater attention to, or better memory for, positive stimuli than negative ones, i.e., a positivity bias, compared with younger adults (Mather, 2016; Mather, 2024). This can be explained by the socioemotional selectivity theory (SST; Carstensen, 2006): As people grow older, they tend to prioritize positive information, to achieve emotional well-being in their time-limited life. Studies supporting the SST mainly used memory and production tasks (Mikels & Shuster, 2016; Shamaskin et al., 2010). For instance, in a surprise recognition task of positively and negatively framed health-related texts (e.g., *Research shows that people who regularly check their cholesterol levels have an <u>increased</u>/<u>decreased</u> chance of recognizing their risks for other related health issues.*), older adults recalled more positive texts with a higher accuracy, compared with negative texts (Shamaskin et al., 2010). Most of these studies provided evidence for the impact of one's emotional bias on the processes <u>after</u> the activation of lexical-semantic representations (e.g., decision making or response execution). Different from past studies, we examined whether <u>during</u> word processing, emotional bias also influences the activations and updates of lexical-semantic representations.

1.2. ERP correlates of the processing of emotional words in isolation

ERPs provide a fine temporal resolution and can help elucidate the processing of affective representations of a word in isolation and in contexts (Lai et al., 2024). Recorded from the electroencephalography (EEG), ERPs capture time-locked neuronal activities that are phase-locked to a specific cognitive event of interest.

For younger adults, studies on single emotional word processing have reported the early posterior negativity (EPN), P2, N400, and the late positive complex/component (LPC). Many found that negative words elicit a more negative EPN (200–300 ms) than neutral words (Citron et al., 2013; Espuny et al., 2018; Herbert et al., 2008; Kissler et al., 2009; Schacht & Sommer, 2009a, 2009b; Scott et al., 2009). The EPN is associated with an arousal-driven, automatic processing of emotional features in the stimuli. A few studies also reported a more negative EPN for positive words (usually low- or moderately-arousing) than negative ones (Hinojosa et al., 2010; Palazova et al., 2011; Recio et al., 2014). According to Palazova et al. (2011) and Recio et al. (2014), this reflects a positivity bias in the initial stage of affective feature processing. In a similar time window, some studies found a more positive P2 to emotional (both positive and negative) than neutral words (Kanske & Kotz, 2007; Schacht & Sommer, 2009b). ERP researchers sometimes associate the P2 effect with the same functional significance as the EPN effect, despite differences in polarity and scalp distributions. Like the EPN, a few studies reported a more positive P2 for positive than negative words and interpreted it as a positivity bias (Kanske & Kotz, 2007). Next in the time course is the N400, a less commonly seen component that peaks at around 300–500 ms after word onsets. Emotional words, regardless of valence, often showed an attenuated N400 than neutral words (Kanske & Kotz, 2007; Ku et al., 2020; Sass et al., 2010). The reduced N400 effect reflects an affect-facilitated semantic retrieval, as the N400 is typically associated with semantic retrieval efforts. The LPC (450–800 ms) is the most robust emotionality effect, larger for emotional than neutral words (Hinojosa et al., 2010; Kanske & Kotz, 2007; Ku et al., 2020; Schacht & Sommer, 2009a). Related to a broad P3 family, the LPC effect reflects an attention reallocation towards or/and elaborative processing of affective features in the stimuli. In younger adults, the emotional LPC effect can be modulated by word concreteness, categories (i.e., adjectives, verbs, and nouns), and task types (Delaney-Busch et al., 2016; Kanske & Kotz, 2007; Palazova et al., 2011). When words are highly concrete, or when the task is an explicit emotion task (e.g., valence judgment), negative words usually elicit a more positive LPC than arousal-matched positive words, supporting a negativity bias (Delaney-Busch et al., 2016; Kanske & Kotz, 2007).

In older adults, only one study examined the age-related emotional bias in single emotional word processing. Ku et al. (2022) examined words with varied valence (positive, negative) and arousal (high, low) using a lexical decision task. They found a more negative N400 for low-arousing positive words than arousal-matched negative ones in older (but not younger) adults. The authors interpreted the enhanced N400 as an arousal-dependent positivity bias in older adults when retrieving the affective representation of a word, supporting the SST during meaning retrieval.

1.3. ERP correlates of the processing of emotional words in sentential contexts

At the sentence level, past ERP studies mainly focused on younger adults (Cao et al., 2019; Chou et al., 2020; Delaney-Busch & Kuperberg, 2013; Ding et al., 2016; Holt et al., 2009; León et al., 2010; Martín-Loeches et al., 2012; Moreno & Rivera, 2014; Moreno & Vázquez, 2011). Generally, negative words in contexts, regardless of whether they are affectively congruent with their context, elicited a more positive LPC than positive words in contexts, suggesting a negativity bias (Delaney-Busch & Kuperberg, 2013; Fields & Kuperberg, 2012; Holt et al., 2009). In terms of context effects, incongruent emotional content increases the depth of semantic analysis. For instance, Moreno and Rivera (2014) set up emotional expectation through contexts (e.g., *There was nothing special about the episode and it turned out to be very…<u>boring</u>/<u>interesting</u>.*). In addition to the N400, they reported a post-N400 frontal positivity (PNP), larger for emotionally incongruent than congruent target words. The authors suggested that the PNP effect reflects the effort needed to override a lexical prediction built up by the preceding affective context. Recently, Chou et al. (2020) manipulated both context constraint via valence (emotionally-biased vs. emotionally unbiased) and target word valence (emotional vs. neutral) in a coherent judgment task. Neutral target words in emotionally-biased contexts elicited a more positive P2 and LPC effect than those in emotionally unbiased contexts. Both the P2 and LPC effects were associated with the effect of emotional contexts in updating the lexical representations of the neutral target words.

1.4. The present study

The abovementioned review indicated that younger adults often attend to negative features of a word, in a post-lexical stage, as reflected by the enhanced LPC to negative words in comparison to positive words, regardless of context. Furthermore, the sentence ERP studies support two stages during the processing of emotionally incongruent content in sentences, in younger adults: (1) The P2/N400 effects reflect the detection, access, or/and integration of affective features of a word given its prior contexts, and (2) the PNP/LPC effects indicate the contextual update of the affective representation of a given word.

However, there were two gaps in knowledge. First, both of the abovementioned sentence ERP studies examined target words in-situ, given the prior context, which does not allow us to examine the changes in the affective representation of the same word before and after contexts. The only relevant study, if not none, is a behavioral study that examined the updating of the affective representation of a sentence, and focused again on only younger adults (Lüdtke & Jacobs, 2015). Younger adults rated the sentence "*The grandpa is lonely.*" as equally negative as "*The burglar is lonely.*", even though the topic word "*grandpa*" was positive based on the affective norms (Vo et al., 2009). The authors suggested that this reflects a negativity bias in younger adults when updating the affective representation of a sentence. Second, past ERP studies on emotional sentences focused mostly on the effects of contextual expectancy, as opposed to context valence. It is unclear whether positively or negatively valenced contexts attract more attention in retrieving and updating the affective representation of a word.

In response to these gaps in knowledge, we investigated (1) whether and how younger and older adults differentially use contexts to update the affective representation of an emotional word, and (2) whether and how the affective neural representation of a word changes depending on emotional valence of contexts. We focused on younger adults aged between 18 and 30 and older adults aged between 60 and 79, as the literature suggests that positivity bias seems to plunge at early ages around 20 s and peak between ages of 60 s and 70 s in one's lifespan (Carstensen et al., 2011). We did not consider much older age, to avoid factors such as health functioning and cognitive functioning (Gana et al., 2015; Isaacowitz & Smith, 2003). We created three-sentence vignettes, where the first sentence has a positive/negative target word, the second sentence has a positive/negative context in the form of an adjective, and the third sentence has the target word again. Unlike past ERP studies that compared the target words' affective representation between sentences/conditions, we compared the affective representation between the first and second occurrence of the target word within the same sentence. Experiment 1 was a web-based experiment, and experiment 2 was an EEG experiment. In both experiments, older adults and younger adults judged the emotional valence of the target words. Our overarching hypothesis was that emotional valence of the context affects the (second occurrence of the) affective representation of the target word. We further hypothesized that if the AVH holds, negative contexts should lead to more negative evaluations of all target words than positive contexts, regardless of target word valence. In contrast, if the SST holds, positive contexts should lead to more positive evaluations of both positive and negative target words than negative contexts. If neither holds, the very same word before and after positive and negative emotional contexts should show no difference.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Sixty younger adults (age range: 18–30 years) and 44 older adults (age range: 60–73 years) were recruited from either the psychology subject pool for course credits, or via Prolific and online advertisements and received $7.5 USD. All the participants were native English speakers currently living in the U.S., with normal or corrected-to-normal vision. None had language-related disorders, mental illness, or were on psychoactive medications likely to modulate emotional processes (e.g. antidepressants), based on self-report. The study was approved by The University of Arizona Institutional Review Board (IRB). All the participants gave informed written consents in accordance with the local ethics committee prior to participation. Due to the lack of pilot data and past studies for references to model random effects in a simulation to estimate the sample size in a linear mixed effect model, we checked Kauschke et al.'s (2019) review on emotional word processing within and across age groups where the sample sizes mostly ranged from 16 to 24. We then decided to increase the sample size to 36, as the current design included an additional factor of context valence (c.f., Lüdtke & Jacobs, 2015).

None of the participants were depressive based on the Beck Depression Index – second edition (BDI-II; Beck et al., 1996). Sixteen younger and two older participants were excluded due to a total BDI-II score larger than 14, the cutoff score for borderline depression. To examine the influence of affective traits on emotional word processing (Ku et al., 2020), participants completed the Positive and Negative Affect Schedule – trait version (PANAS; Watson et al., 1988), which includes two self-reported subscales for positive affect (PA) and negative affect (NA), respectively. Each participant indicated the level one generally feels this way to 20 items, each on a 5-point scale (1 = *not at all* to 5 = *extremely*).

None of the participants were cognitively impaired based on the Mini-Mental State Examination (MMSE; Folstein et al., 1975). All participants had MMSE scores larger than 26, which indicated no cognitive impairment. To examine the effect of cognitive ability on the positivity bias (Ku et al., 2022), participants completed the Digit Symbol Substitution Task (DSST) (Wechsler, 1997) as a general assessment of cognitive functions (Jaeger, 2018), and an abbreviated version of the Wisconsin Card Sorting Test (WCST) that specifically probes cognitive control, including inhibition (Greve, 2001). For the DSST, in each trial, participants needed to match a symbol to a number based on a key on the top of the screen, by pressing the corresponding number key on their keyboard, as quickly and accurately as possible, within 90 seconds. The number of correct responses was recorded. For the WCST, participants matched 64 cards, one at a time, to one of four sample cards on the top of the screen, along three dimensions of color, shape, and number. The computer would give feedback if the matching was correct or not after each response. After participants correctly matched five cards in a row, the computer would automatically change the matching criteria. The total number of the correct matches was recorded.

After data collection, eight younger participants and four older participants were excluded because they failed at the attention check trials. One older adult was excluded due to excessively long response time (i.e., more than 3 standard deviations above the mean from all participants), and one older adult was excluded due to equipment errors. The characteristics of the participants that were included in the final analyses are summarized in Table 1.

Table 1
Exp. 1 participant characteristics.

Mean (SD)	Younger adults	Older adults	*t*	*p*	Cohen's *d*
N	36	36	N/A	N/A	N/A
Age	19.69 (2.67)	65.39 (3.72)	N/A	N/A	N/A
Sex	M: 14, F: 21, Unidentified: 1	M: 16, F: 20	N/A	N/A	N/A
Education (Years)	13.35 (1.76)	16.47 (2.95)	−5.46	< .001	−1.28
BDI-II[a]	5.28 (4.08)	3.44 (3.33)	2.09	.041	0.49
PA[b]	35.42 (6.46)	35.22 (7.56)	.12	.907	0.03
NA[c]	18.28 (4.93)	12.08 (2.85)	6.52	< .001	1.54
MMSE[d]	29.11 (1.21)	29.56 (0.69)	−1.91	.062	−0.45
DSST[e]	61.83 (8.77)	54.97 (14.80)	2.39	.020	0.56
WCST[f]	42.14 (10.04)	35.31 (11.75)	2.65	.010	0.63

[a] Beck Depression Index-second edition
[b] Positive affect
[c] Negative affect
[d] Mini-Mental State Examination
[e] Digit Symbol Substitution Task
[f] Wisconsin Card Sorting Test

2.2. Materials

The stimuli consisted of 320 three-sentence vignettes (Table 2): 80 positive target words in positive contexts, 80 positive target words in negative contexts, 80 negative target words in positive contexts, and 80 negative target words in negative contexts. In each vignette, a target word appears at the subject position once in the first sentence and a second time in the third sentence. In the second sentence of each vignette, a positive/negative adjective acts as the context word to shift the valence of the target word.

Target words were selected from the affective norms for English words (Warriner et al., 2013). In this norm, subjective ratings of valence and arousal are measured with 9-point Likert scales (1 = *unhappy* to 9 = *happy*; 1 = *calm* to 9 = *aroused*). Target words are all low-arousing nouns (mean ratings < 5), as the positivity bias in older adults impacts low-arousing words more (Ku et al., 2022). The arousal ratings were matched between positive and negative target words ($t(158) = -1.19$, $p = .24$, Cohen's d = −0.19), and between younger and older adults in each condition (Positive words: $t(158) = 1.94$, $p = .11$, Cohen's d = 0.31; Negative words: $t(158) = 0.44$, $p = .66$, Cohen's d = 0.07), based on the same norms. On average, positive target words scored higher on valence ratings than negative ones ($t(158) = 56.84$, $p < .001$, Cohen's d = 8.99), as expected. Older adults showed higher valence ratings in positive ($t(158) = -3.09$, $p = .004$, Cohen's d = -0.01), and lower valence ratings in negative target words ($t(158) = 2.37$, $p = .019$, Cohen's d = 0.37), than younger adults. Word length ($t(158) = -0.04$, $p = .97$, Cohen's d = −0.01), frequency ($t(158) = 1.41$, $p = .16$, Cohen's d = 0.22), and concreteness ($t(158) = 1.55$, $p = .12$, Cohen's d = 0.24) were matched between conditions for target words, based on the Corpus of Contemporary American English (Davies, 2009), and the English Lexicon Project database (Balota et al., 2007; see Table 3).

To verify our manipulation of context word valence, the valence ratings for adjectival contexts were collected from the same affective norms above. Positive context words were rated as being more positive than negative ones in both the younger (Positive context words: Mean ± SD = 7.05 ± 0.7; Negative context words: Mean ± SD = 3.27 ± 0.91; $t(145) = 42.24$, $p < .001$, Cohen's d = 3.5) and older adults (Positive context words: Mean ± SD = 7.22 ± 0.75; Negative context words: Mean ± SD = 3.05 ± 0.82; $t(145) = 45.42$, $p < .001$, Cohen's d = 3.76). To rule out possible confounds from the adjectival word properties on the second occurrence of the target words, we matched between conditions the adjectives' word length (Positive context words: Mean ± SD = 7.57 ± 2.39; Negative context words: Mean ± SD = 7.99 ± 2.17; $t(159) = 1.76$, $p = .08$, Cohen's d = 0.14), frequency (Positive context words: Mean ± SD = 3.9 ± 0.73; Negative context words: Mean ± SD = 3.82 ± 0.72; $t(159) = -0.84$, $p = .40$, Cohen's d = −0.07), concreteness (Positive context words: Mean ± SD = 2.28 ± 0.55; Negative context words: Mean ± SD = 2.29 ± 0.56; $t(138) = 0.22$, $p = .83$, Cohen's d = 0.02), and word probability (Positive context words: Mean ± SD = $5.87 * 10^{-6} \pm 2.62 * 10^{-5}$; Negative context words: Mean ± SD = $2.98 * 10^{-6} \pm 1.97 * 10^{-5}$; $t(159) = -1.10$, $p = .27$, Cohen's d = −0.12), using the abovementioned corpora and the gpt-2 model. The gpt-2 model is a large-scale language model trained for next word prediction, and provides the probability of any word based on the preceding context.

The 320 vignettes were divided into two lists using a Latin Square rotation. Each list consists of 160 target words with 80 positive/negative

Table 2
Example stimuli.

Conditions	Positive target word (underlined)	Negative target word (underlined)
Positive context (italicized)	The **pianist** had a new performance. Her skills were ***remarkable***. The **pianist** practiced every day.	The **dentist** often worked with children. They found him ***trustworthy***. The **dentist** cared about them.
Negative context (italicized)	The **pianist** had a new performance. Her skills were ***rusty***. The **pianist** practiced every day.	The **dentist** often worked with children. They found him ***formidable***. The **dentist** cared about them.

Table 3
Stimulus characteristics.

Mean (SD)	Negative target word	Positive target word
Valence	3.20 (0.49)	7.14 (0.38)
Younger	3.34 (0.60)	7.02 (0.57)
Older	3.09 (0.71)	7.29 (0.52)
Arousal	4.13 (0.55)	4.02 (0.61)
Younger	4.13 (0.74)	4.15 (0.86)
Older	4.08 (0.70)	3.90 (0.79)
Concreteness	4.05 (0.87)	3.84 (0.81)
Length	6.75 (1.93)	6.76 (1.67)
Frequency	3.99 (0.72)	3.53 (0.77)
Word probability[a]	List 1: $3.96 * 10^{-6}$ ($1.62 * 10^{-5}$) List 2: $3.71 * 10^{-6}$ ($1.56 * 10^{-5}$)	List 1: $6.17 * 10^{-6}$ ($1.38 * 10^{-5}$) List 2: $6 * 10^{-6}$ ($1.24 * 10^{-5}$)

[a] Word probabilities were calculated for the second occurrence of the target words to capture the influence of different context words on the target words. The values were matched in each stimulus list, as each participant read only one of the two context words associated with each target word.

contexts. Within each list, the trials were pseudo-randomized such that no more than four consecutive trials came from the same condition. The list order was counterbalanced with participant number. As such, participants read each vignette of the same target word only once.

2.3. Procedure

Experiment 1 was conducted via Zoom. Participants gave informed consent first and then were interviewed by an experimenter for the MMSE. Next, participants completed the DSST and WCST via OpenSesame/OSWeb extension (Mathôt et al., 2012) with the experimenter's instructions, and filled out a web-based Qualtric survey on their language background, and the BDI-II/PANAS. See procedure under Participants.

For the main experiment, in the same web-based Qualtric survey (See Supplementary Material S1), participants were first presented with each target word in isolation and rated the valence of each target word on a 1–9 scale (1 = *very negative* to 9 = *very positive*), in a self-paced way. Next, they were presented with the context (the first two sentences in each vignette), with both sentences presented on the screen at once. They rated the valence of each target word embedded in the first sentence on the same 1–9 scale, in a self-paced way. To balance visual comfort and too much clicking, participants rated ~40 words or ~20 vignettes on a page, and then pressed a button to the next page. To avoid fatigue, participants could have a tiny break every ~6–7 items separated by a blank row. The entire experiment lasted for 75–90 minutes.

2.4. Data analysis

To examine the contextual update of affective representations of the target words, and to account for age differences on the valence ratings in the pre-experiment norming, valence ratings of each target word in isolation were subtracted from those ratings of the same target word embedded in the first two sentences of each vignette, for each item and each participant. To account for by-participant and by-item random variances, these difference ratings were entered into a linear mixed

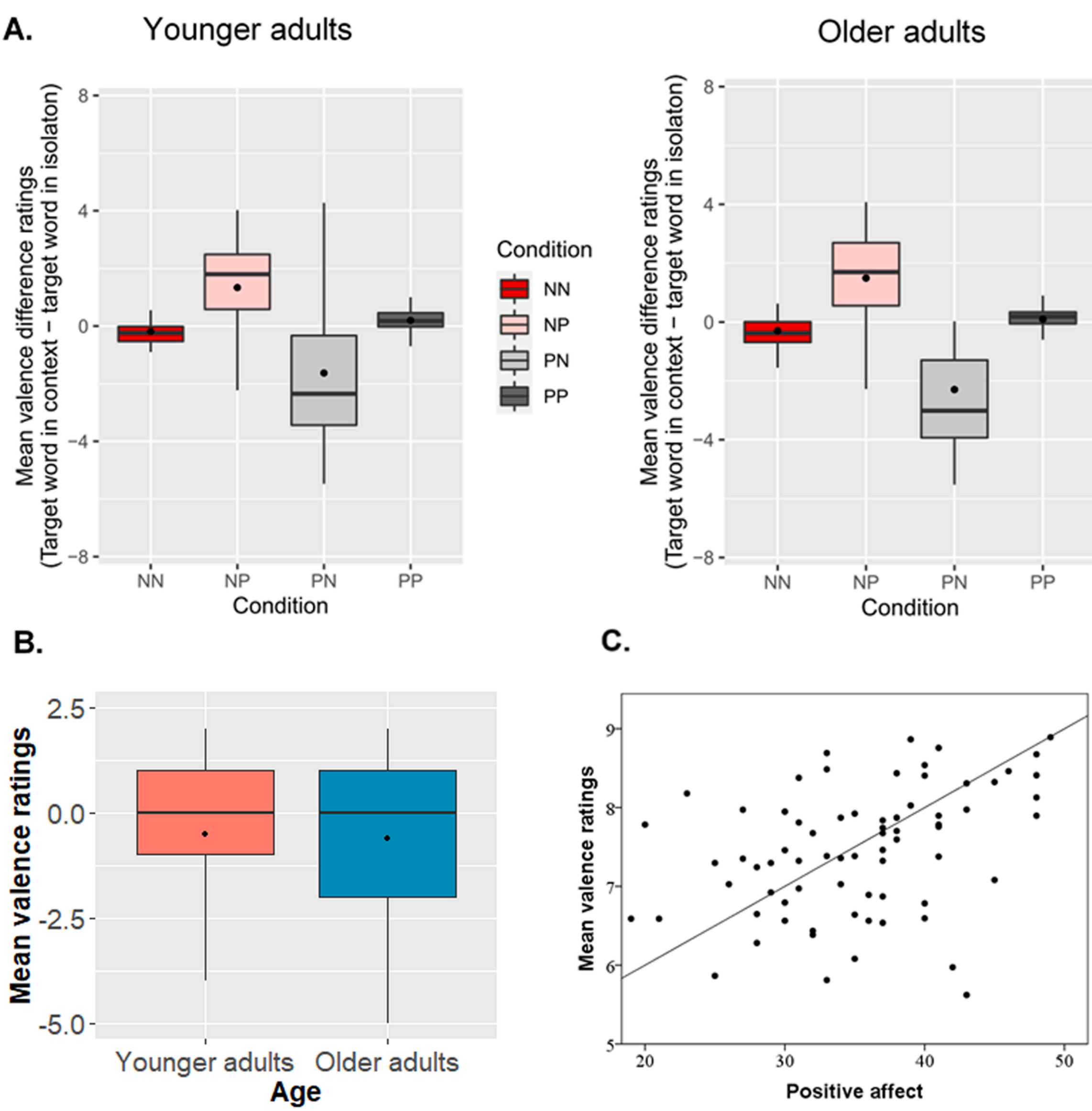

Fig. 1. (A) Boxplots for the Exp. 1 mean valence difference ratings (subtracted target words in isolation from target words in context) for negative target words in negative contexts (NN), negative target words in positive contexts (NP), positive target words in negative contexts (PN), and positive target words in positive contexts (PP), in younger adults (left panel) and older adults (right panel). Black dots and horizontal lines in the boxes denote the means and medians, respectively. (B) A boxplot for the mean valence difference ratings (collapsed across target and context word valence) in younger (in orange-pink) and older adults (in teal blue) (C) A correlation plot between the mean valence ratings for positive target words in positive contexts and positive affect.

effect regression model, as the dependent variable, using R (R Core Team, 2022; version 4.2) in RStudio (RStudio Team, 2022; version 2022.07) with the lme4 package (Bates et al., 2015). The fixed effects in the model included the categorical variables of Target (negative vs. positive), Context (negative vs. positive), Age (younger vs. older), and their interaction effects. For the random structure, we started out with the maximal model by including by-participant and by-item random intercepts, and Target, Context, and their interaction as by-participant random slopes, along with Context as by-item random slopes (Barr et al., 2013). The random slope with the smallest variance was removed each time if the model could not converge.

Independent variables were sum-coded (Target/Context word valence: negative = −0.5, positive = 0.5; Age: younger = −0.5, older = 0.5). A Box–Cox transformation test was conducted to identify an optimal transformation to improve normality of the distribution of the dependent variable (Box & Cox, 1964). Only significant coefficient t-statistics and p-values associated with the fixed effects were reported, via Satterthwaite's degrees of freedom method with the lmerTest package (Kuznetsova et al., 2017). Single contrasts were further conducted if an interaction effect was found, via the least-squares means method with the lsmean package (Lenth, 2016).

To rule out the possible influences of participants' cognitive and affective characteristics on their valence evaluation of target words in contexts, we further performed four multiple linear regression models, with participants' age, sex, education years, DSST scores, WCST scores, PA scores, and NA scores as independent variables/predictors, and the mean valence ratings from each of the four conditions as the dependent variables. Each dependent variable and the predictors were entered simultaneously in the model to determine which predictor could significantly account for the variance in the dependent variable, when holding other predictors constant.

3. Results

The results are summarized in Fig. 1. Based on the Box–Cox transformation test, no transformation was needed for the difference ratings, so the original difference ratings were entered into the model. Consistent with our design, the analysis showed a significant main context effect ($\beta = 1.88$, $t(72.01) = 6.23$, $p < .001$, Cohen's $f^2 = 0.27$). Regardless of target word valence, target words with positive contexts ($M = 0.78$, $SD = 2.17$) were rated more positive than those with negative contexts ($M = -1.1$, $SD = 2.69$), compared with target words in isolation. The main target effect was also significant ($\beta = -1.49$, $t(80.14) = -6.12$, $p < .001$, Cohen's $f^2 = 0.27$). Irrespective of context valence, positive target words in contexts ($M = -0.91$, $SD = 2.65$) were rated as being less positive than negative target words in contexts ($M = 0.59$, $SD = 2.36$), compared with target words in isolation.

In addition, there were interactions of Target x Context ($\beta = 0.45$, $t(116.97) = 3.50$, $p < .001$, Cohen's $f^2 = 0.14$): The rating differences were larger when negative target words were followed by positive ($M = 1.41$, $SD = 2.59$) vs. negative contexts ($M = -0.24$, $SD = 1.74$; $Z = -6.13$, $p < .001$, Cohen's d = 0.75). Similarly, the rating differences were larger when positive target words were followed by negative ($M = -1.96$, $SD = 3.16$) vs. positive contexts ($M = 0.15$, $SD = 1.36$; $Z = -6.15$, $p < .001$, Cohen's d = −0.87). This interaction indicated that the influence of negative contexts on positive target words was stronger than that of positive contexts on negative target words (Fig. 1A ; the difference between dark gray and light gray bar was larger than the difference between red and pink bar).

Due to high multicollinearity between Age and Context, we fitted a reduced model by removing Age interaction terms from the fixed effects (i.e., Rating ∼ Target * Context + Age). The results of the reduced model were consistent with the above. There was an additional age effect ($\beta = -0.11$, $t(70.47) = -2.09$, $p = .04$, Cohen's $f^2 < 0.001$). Regardless of target and context word valence, older adults ($M = -0.25$, $SD = 2.70$) rated the words in contexts as being more negative than the same words in isolation, compared with younger adults ($M = -0.07$, $SD = 2.53$) (Fig. 1B). The model comparison suggested no difference between the reduced and full model ($\chi^2 = 6.54$, df = 4, $p = .16$). To rule out the possible confounding from participants' demographic information, and cognitive/affective characteristics, six additional linear mixed models were fitted separately, by including sex, education years, DSST scores, WCST scores, PA scores, and NA scores, each in the interaction terms with Target and Context of the fixed effects from the above fitted reduced model. No significant effect or interaction involving these additional predictors was found (all p values > .079).

In the multiple regression models, PA (positive affect) significantly predicted the mean valence ratings of positive target words in positive contexts (adjusted R-square = 14.2 %, $F(7,64) = 2.67$, $p = .017$, Cohen's $f^2 = 0.02$). Higher positive affect ($\beta = 0.36$, $t = 2.70$, $p = .009$, semi-partial correlation $sr^2 = 0.09$) was associated with more positive ratings of positive topic words in positive contexts (Fig. 1C). No other significant models were found.

4. Discussion

We found that in both age groups, negative contexts led to more negative evaluations of positive target words than did positive contexts. Positive contexts led to more positive evaluations of negative target words than did negative contexts. Additionally, the effect of negative contexts was stronger than the effect of the positive contexts across the two age groups, as indicated by the interaction (i.e., slope differences) of Target and Context word valence in the linear mixed regression models. These results suggested that the context effect on the valence evaluation of the target words depends on target word and context valence, but not age: In both younger and older adults, target words and contexts with opposite valence influenced participants' evaluation more than those with the same valence. These effects were not modulated by participants' sex, educational backgrounds, cognitive ability (including inhibitory control), and affective states.

In addition, the multiple regression models showed that one's positive affect predicts the valence ratings of positive target words in positive contexts. We did not find a correlation between age and positive affect ($p = .36$), suggesting unique contribution of positive affective trait in explaining the variance in the valence ratings of positive target words in positive contexts. However, these results could be confounded by the age difference in the ratings of target words in isolation. The effect disappeared when we entered the "difference ratings" for positive target words in positive contexts, i.e., after subtracting the ratings for the positive target words in isolation from the same words in context, as the dependent variable in the regression model. Therefore, caution should be exercised when interpreting these results.

There are several points to consider in terms of the null age-dependent context effect, which led us to Experiment 2. First, the behavioral ratings only provided us with a coarse picture of post-lexical evaluations of valence features. In our survey design, each valence rating could take up to seconds. As negative content often leads to delayed disengagement of attention (Kauschke et al., 2019), it is possible that the ratings are more likely to show a stronger negativity bias in both the age groups. Second, according to the SST, older adults' positivity bias is related to their social motivations. Our remote participation in the web-based survey might be less socially motivated than in-person studies, which could smear out the age effects. Third, participants rated the stimuli in a self-paced way without the time limit on each rating. This differs from lab settings with a stricter control of the presentation duration and limited response time for each stimulus, which could limit the sensitivity of our measurement. Fourth, a post-hoc power analysis with the collected data was conducted. The result indicated that the achieved power for detecting the observed effect size of Target x Context x Age (Cohen's $f^2 = 0.004$) was 0.32. This suggests that the study might be underpowered to reliably detect such small effects, even with the obtained sample size. Future studies should recruit a larger sample to verify the current findings. Lastly but not least, the behavioral ratings could not inform us how contexts affect the processing of the affective neural representation of a word, during or before the lexical-semantic stage.

In Experiment 2, we used the real-time measure of continuous scalp EEG recording, recorded while participants came into the lab and read those vignettes. This paradigm allowed the tracking of the neural representations of the affective features in the very same target words before and after contexts. We predicted that, based on the AVH, younger adults would show an enhanced N400 and/or late positivity to negative (vs. positive) contexts, regardless of target word valence, as these ERP effects were linked to the depth of semantic processing/integration and the update of mental affective representations. Older adults, based on the SST, would show an increased N400 and/or late positivity to positive (vs. negative) contexts, irrespective of target word valence. We did not predict any EPN/P2 effects specifically, as no studies showed context-based emotion effects on the EPN, and very few findings on the P2 were mixed (Chou et al., 2020; Lai & Huettig, 2016).

5. Experiment 2

5.1. Methods

5.1.1. Participants

Forty-eight younger adults (age range = 18–25 years) and 35 older adults (age range = 60–77 years) participated. The younger participants were undergraduate students from the psychology subject pool and received course credits. The older participants were from senior community centers and online/newspaper advertisements and received $25 USD. The study was approved by the same local ethics committee as in Experiment 1 under the same protocol.

We calculated our sample size using G-power 3.1 (Erdfelder et al., 1996), based on the statistical power of 0.8 and alpha = 0.05. The result revealed that a total number of 20 participants in each age group is needed to reach a small to medium effect size on our interaction of interests in the omnibus repeated-measures ANOVA (i.e., Age (younger, older) x Target (positive, negative) x Context (positive, negative) x Region (anterior, central, posterior)). We assumed the partial eta square = 0.04 (equivalent to the Cohen's d of 0.4), as there were no prior ERP studies on older adults' positivity bias effect in updating the affective-neural representation of a word embedded in contexts.

Based on the same inclusion/exclusion criteria (see Experiment 1 Participants section), two younger participants were excluded due to a high BDI-II score of larger than 14. Eighteen younger and 7 older participants were excluded due to insufficient trials (< 60 %) after artefact rejection of the EEG data. This high rejection was likely due to the mask requirement during experiments due to COVID-19. The characteristics of the remaining participants that were entered in all analyses are summarized in Table 4.

Table 4
Exp. 2 participant characteristics.

Mean (SD)	Younger adults	Older adults	*t*	*p*	Cohen's *d*
N	28	28	N/A	N/A	N/A
Age	18.82 (1.47)	68.43 (4.25)	N/A	N/A	N/A
Sex	M: 11, F: 17	M: 11, F: 17	N/A	N/A	N/A
BDI-II[a]	2.61 (2.62)	3.96 (3.00)	−1.80	.077	−0.48
PA[b]	37.50 (4.27)	35.32 (7.72)	1.31	.197	0.35
NA[c]	16.32 (5.06)	12.82 (1.98)	3.41	.002	0.91
MMSE[d]	29.61 (0.83)	28.32 (5.64)	1.19	.238	0.32
DSST[e]	58.04 (7.08)	39.69 (7.25)	9.40	< .001	2.56
WCST[f]	42.32 (6.06)	37.15 (7.04)	2.90	.005	0.79

[a] Beck Depression Index-second edition
[b] Positive affect
[c] Negative affect
[d] Mini-Mental State Examination
[e] Digit Symbol Substitution Task
[f] Wisconsin Card Sorting Test

5.2. Materials

The materials were identical as in Experiment 1.

5.3. Procedure

Participants first completed informed written consent and a basic questionnaire on their language background. An elastic cap mounted with 32-channel Ag/AgCl electrodes was then fitted on the participant's head. After the EEG capping procedure, the participant was taken to a sound-attenuated booth and seated at a desk facing a computer screen 80–100 cm in front of them. The stimuli were presented visually in a white font (Font: Courier New; Point size: 20) against a black background via E-prime 3.0 software (Psychology Software Tools, Inc.).

An example trial is illustrated in Fig. 2. Each trial started with a central fixation cross for 500 ms, followed by a blank screen for 200 ms. Then, each vignette was presented word-by-word in a rapid serial visual presentation paradigm (target words and adjective context words: 260–420 ms depending on the word length; other words: 300 ms; interstimulus interval: 200 ms). Participants were instructed to read each word carefully and silently. A rating scale then came up on the center of the screen after a 700-ms blank in the end of each vignette. When cued by the scale, participants needed to judge how they felt about the target word in the vignette, as quickly as possible, by pressing a button (-1 = negative, 0 = neutral, 1 = positive) on a response box. After the response, a "blink or continue" screen would appear following a 300-ms blank so that participants could rest their eyes or take a quick break in a self-paced way.

Before the formal experiment, participants did eight practice trials to familiarize themselves with the procedure. The session lasted for about 50 minutes, divided into four 10-minute blocks, with a short break between blocks.

5.4. EEG acquisition

The electroencephalogram (EEG) was recorded from 32 electrodes placed on an electrode cap arranged in the 10–10 system (actiCAP, Brain Products GmbH, Gilching, Germany). The scalp EEGs were recorded with a sampling rate of 500 Hz, referenced to Cz during recording. A forehead electrode served as the ground. To avoid impulse artefacts, the online low pass filter was set to 140 Hz and the high pass filter was set as DC recording. The electrode impedance was kept below 10 kΩ.

5.5. ERP analysis

EEG recordings were processed offline with the EEGLAB toolbox (Delorme & Makeig, 2004) and the ERPLAB plugins (Lopez-Calderon & Luck, 2014) implemented in Matlab (Mathwork Inc.). For the ERP analysis, the EEG data were first bandpass filtered with frequency values set as 0.1–30 Hz. Data were re-referenced to the average of both mastoids (i.e., TP9 and TP10). Then, the continuous EEG data were epoched by setting the interval as 200 ms before and 1000 ms after the target onset, using the pre-stimulus interval of −200–0 ms as the baseline correction. An independent component analysis (ICA) with the runica algorithm implemented in EEGLAB was used to identify eye and muscle artefacts. Those components that had more than 90 % probability of being muscle or eye artefacts, as automatically labelled by using ICLabel plugin in EEGLAB, were removed from the data. Trials contaminated with artefacts due to peak deflections exceeding ± 75 mV, or excessive noises due to fatigue were rejected. The average trial acceptance rates were 73.91 % for younger adults and 73.46 % for older adults. No difference was found for the number of accepted trials between groups ($t(54) = 0.21, p = .83$). On average, 29–30 trials (out of 40 trials) for each

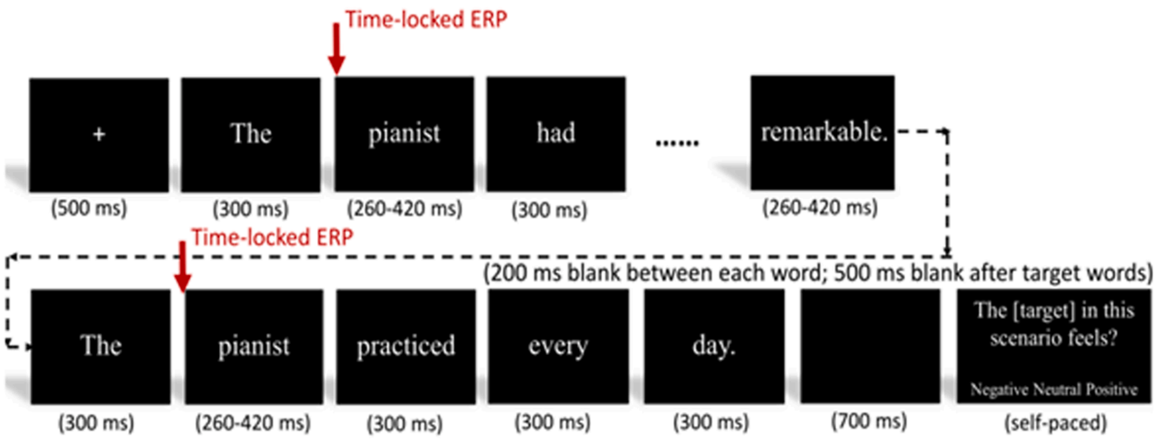

Fig. 2. An example trial with a valence judgment task at the end of each trial.

of the conditions were included in the following analyses across all the participants. Finally, the ERP data were averaged for each condition in the younger and older participants.

5.6. Statistical analysis

For the behavioral data, valence ratings with response times more than 3 standard deviations above/below all the participant's mean were excluded (1.95 % of total responses). The valence ratings were entered into a cumulative link mixed effect regression model, as the dependent variable. Unlike Experiment 1, the cumulative link mixed effect model from the oridinal package in R (Christensen, 2019) was used as the rating data violated the homoscedasticity assumption in linear mixed effect models, and showed categorical and ordinal features. The fixed effects in the model included Target (negative vs. positive), Context (negative vs. positive), Age (younger, older), and their interaction effects. Like Experiment 1, the random effects included by-participant and by-item random intercepts, and Target, Context, and their interaction as by-participant random slopes, along with Context as by-item random slopes.

For the ERP data, to examine the change in the affective representations of the target words, the mean ERP amplitudes of the first occurrence of the target words were subtracted from those of the second occurrence of the target words. The mean ERP amplitudes of the difference waves were exported from 180–300 ms, 300–500 ms, and 600–800 ms after the target word onsets, based on both the visual inspection of the waveform peaks, and recent literature on emotional word processing in isolation and in context (P200: 150–200 ms in Chou et al. (2020) and 250–350 ms in Delaney-Busch et al. (2016); N400: 300–500 ms in Chou et al. (2020) and Delaney-Busch & Kuperberg (2013); LPC: 600–900 ms in Chou et al. (2020), 500–700 ms in Delaney-Busch & Kuperberg (2013), and 500–800 ms in Delaney-Busch et al. (2016)). To characterize the spatial distribution of the ERP effects, a repeated-measures ANOVA (RM-ANOVA) of Age (younger, older) x Target (negative, positive) x Context (negative, positive) x Region (anterior, central, posterior) was conducted in each time window, using the difference wave amplitudes. Guided by visual inspection of the ERP waveforms and past literature on emotional word processing (e.g., Ku et al., 2022), ERP difference wave amplitudes were averaged over three electrodes in each of the three regions of interest: anterior (F3, Fz, F4), central (C3, Cz, C4), and posterior (P3, Pz, P4) sites. When the sphericity assumption was violated, the Greenhouse-Geisser correction was applied. The alpha levels were set as 0.05 for all statistical tests. To correct multiple comparisons, a false discovery rate of the same alpha level with the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995) was applied in all post-hoc comparisons.

To directly examine age effects, a two-fold strategy was used. First, we focused on the Region of Interest (ROI) analysis guided by the above omnibus analysis, which led us to collapse over the posterior electrodes (P3, Pz, P4) for the P2 and LPC effect. The mean difference wave amplitudes in the P2 and LPC time windows were entered into a three-way RM-ANOVA with Target and Context as within-subjects factors and Age as a between-subjects factor. Second, we conducted ROI-based regression analyses with difference wave amplitudes of Target (negative minus positive target words) and Context effects (negative minus positive contexts) in the P2, N400, and LPC windows as dependent variables. Predictor variables included participants' age, sex, PA scores, NA scores, DSST scores, and WCST scores.

6. Results

6.1. Behavioral results

The cumulative link mixed effect model analysis showed a significant target effect ($\beta = 0.95$, odd ratio = 2.58, $Z = 5.95$, $p < .001$, Cohen's $f^2 = 0.004$), context effect ($\beta = 3.4$, odd ratio = 30.01, $Z = 17.96$, $p < .001$, Cohen's $f^2 = 0.009$), and Target x Context interaction ($\beta = 0.8$, odd ratio = 2.22, $Z = 3.71$, $p < .001$, Cohen's $f^2 = 0.001$). Follow-up analyses showed that the rating was higher when negative target words were followed by positive ($M = 0.39$, $SD = 0.71$) vs. negative contexts ($M = -0.53$, $SD = 0.67$; $Z = 14.89$, $p < .001$, Cohen's d = 2.35). On the contrary, the rating was lower when positive target words were followed by negative ($M = -0.38$, $SD = 0.75$) vs. positive contexts ($M = 0.72$, $SD = 0.54$; $Z = -16.33$, $p < .001$, Cohen's d = −2.58). Like Experiment 1, this interaction indicated that the influence of negative contexts on positive target words was stronger than that of positive contexts on negative target words (Fig. 3).

There was also an interaction of Target x Age ($\beta = -0.27$, odd ratio = 0.76, $Z = -2.12$, $p = .034$, Cohen's $f^2 < 0.001$). In both the age group, negative target words (Younger adults: $M = -0.1$, $SD = 0.82$; Older adults: $M = -0.04$, $SD = 0.84$) were rated as being more negative than positive target words (Younger adults: $M = 0.19$, $SD = 0.85$, $Z = -6.34$, $p < .001$, Cohen's d = −1.69; Older adults: $M = 0.16$, $SD = 0.8$, $Z = -4.7$, $p < .001$, Cohen's d = −1.26).

To rule out possible influences from participants' sex and cognitive/affective characteristics, five additional mixed models were fitted separately, by including sex, DSST scores, WCST scores, PA scores, and NA scores, each in the interaction terms with Target x Context x Age group of the fixed effects in the mixed model. The above target effect, context effect, and Target x Context interaction still remained in all the models. Only an additional Target x Context x WCST scores interaction was found (See Supplementary Material S2).

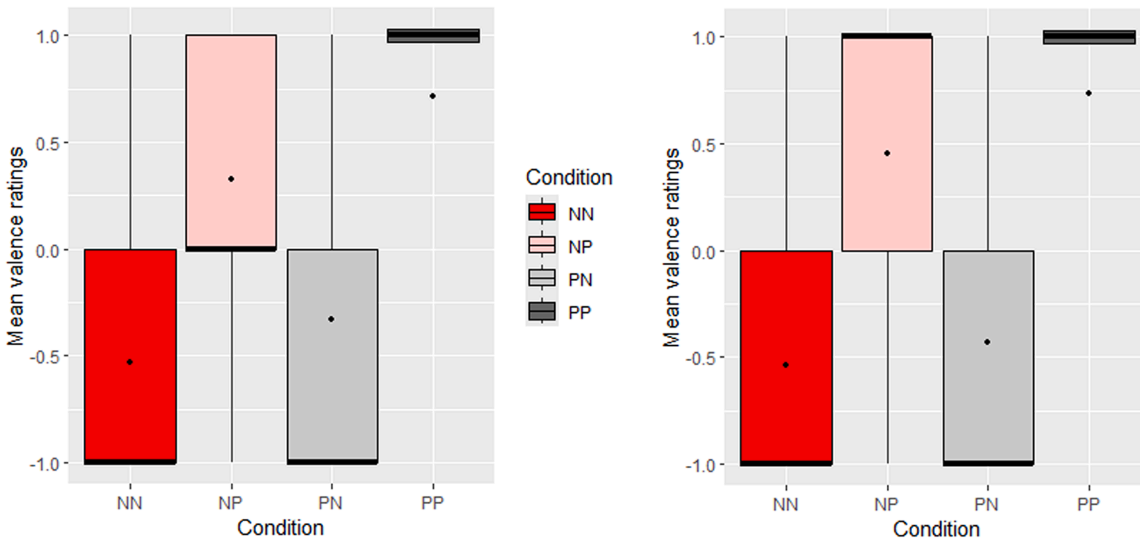

Fig. 3. Boxplots for the Exp. 2 mean valence ratings for negative target words in negative contexts (NN), negative target words in positive contexts (NP), positive target words in negative contexts (PN), and positive target words in positive contexts (PP), in younger adults (left panel) and older adults (right panel). Black dots and horizontal lines in the boxes denote the means and medians, respectively.

6.2. ERP results

The grand averaged ERP waveforms for the first and second occurrence of the target words based on 28 subjects each group are shown in Fig. 4A and 4B. For both the occurrences of the target word, all the participants showed clear visual N1 and P2 complexes, indicating normal early visual processing. Additionally, in younger adults, all the conditions showed ERP amplitude deflections starting from ~180 ms, identified as P2, N400s, and LPC. Consistent with Ku et al. (2022), in older adults, the first occurrence of negative target words showed a smaller N400 at ~350 ms and elicited a larger LPC at ~ 600 ms than the first occurrence of positive target words, regardless of context valence. In older adults, negative target words, when presented the second time after positive contexts, also elicited a larger negativity starting slightly earlier from ~180 ms, compared with the other conditions. To capture the change of affective representations of the target words, difference waves between the first and second occurrence of the target words were calculated, and are shown in Fig. 5A.

6.3. P2 (180–300 ms)

The RM-ANOVA showed an interaction of Context x Region x Age ($F(2, 108) = 4.27$, $p = .034$, $\eta^2 = 0.07$). Follow-up comparisons for this three-way interaction revealed no effect or interaction involving the factors of Context and Age. There was a Target x Age interaction ($F(1, 54) = 4.13$, $p = .047$, $\eta^2 = 0.07$). In older adults, the difference between the positive target words before and after contexts tended to be larger than the difference between the negative target words before and after contexts ($t(27) = 2.12$; $p = .086$, uncorrected $p = .043$, Cohen's d $= 0.36$). There was also a Target x Region interaction ($F(2, 108) = 6.88$, $p = .008$, $\eta^2 = 0.11$). In both younger and older adults, the difference between the negative target words before and after contexts was largest in the posterior region and smaller in the anterior region (anterior vs. central: $t(55) = -4.50$; central vs. posterior: $t(55) = -4.99$; anterior vs. posterior: $t(55) = -3.86$; all p values $< .001$; Cohen's d $= -0.6$, -0.67, and -0.52).

Given the interactions and results reported above, we conducted an ROI analysis focusing on the posterior region. The result showed a Target x Age interaction ($F(1, 54) = 6.17$, $p = .016$, $\eta^2 = 0.1$). Different from the above, within older adults, the P2 difference between the positive target words before and after contexts was larger than that in younger adults (OAs: $M_{diff} = 0.32$, $SD = 1.52$; YAs: $M_{diff} = -0.81$, $SD = 1.53$; $t(54) = -2.76$, $p = .016$, Cohen's d $= 0.74$, Fig. 5). Also, within younger adults, the P2 difference between the positive target words before and after contexts tended to be smaller than the difference between the negative target words before and after contexts (positive: $M_{diff} = -0.81$, $SD = 1.53$; Negative: $M_{diff} = 0.17$, $SD = 1.35$; $t(27) = -2.31$, $p = .058$, uncorrected $p = .029$, Cohen's d $= -0.44$).

After controlling for participants' sex, PA, NA, DSST, and WCST scores, the Target x Age interaction still remained ($F(1, 54) = 7.17$, $p = .01$, $\eta^2 = 0.13$), with an additional Target x NA (Negative affect) interaction ($F(1, 47) = 4.16$, $p = .047$, $\eta^2 = 0.81$). This means that in addition to age, participants' negative affect level also modulated the P2 differences for target words (See Regression results below for the influence of the continuous variable NA on the P2).

6.4. N400 (300–500 ms)

We did not find significant difference between the first and second occurrence of the target words and nor was there any age, context, and target interaction effects (all F values < 2.76, all p values $> .1$).

6.5. LPC (600–800 ms)

The RM-ANOVA showed a main context effect ($F(1, 54) = 4.62$, $p = .036$, $\eta^2 = 0.08$). For both younger and older adults, all target words after negative contexts ($M_{diff} = 0.07$, $SD = 1.86$) had a larger LPC change than those after positive contexts ($M_{diff} = -0.57$, $SD = 1.66$). There was also a Target x Region interaction ($F(2, 108) = 4.05$, $p = .039$, $\eta^2 = 0.07$). In both younger and older adults, the difference between the positive target words before and after contexts was larger in both the central and posterior regions than in the anterior region (anterior vs. central: $t(55) = -4.93$, $p < .001$, Cohen's d $= -0.66$; central vs. posterior: $t(55) = -1.68$, $p = .10$; anterior vs. posterior: $t(55) = -3.98$, $p < .001$, Cohen's d $= -0.53$). Similarly, this was also the case for the negative target words (anterior vs. central: $t(55) = -6.40$; central vs. posterior: $t(55) = -4.19$; anterior vs. posterior: $t(55) = -6.19$; all p values $< .001$; Cohen's d $= -0.86$, -0.56, and -0.82).

Parallel to the ROI analysis for P2, we also conducted the ROI analysis for LPC focusing on the posterior region. The result showed a main context effect ($F(1, 54) = 5.78$, $p = .02$, $\eta^2 = 0.1$), like the above findings in both the central and posterior regions.

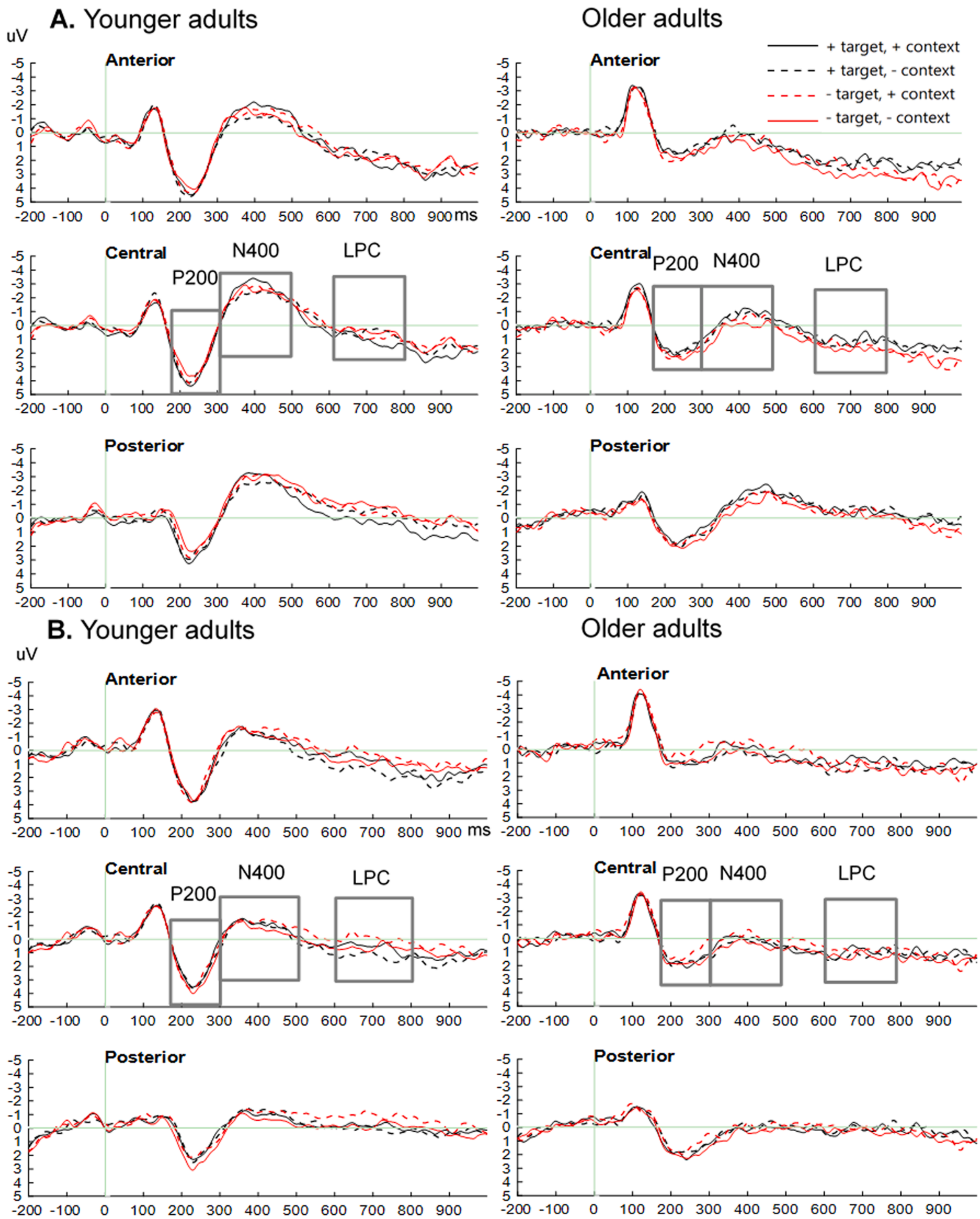

Fig. 4. Grand averaged ERP waveforms (N = 28 each group) for the first (panel A) and second (panel B) occurrence of the target words for positive target words in positive contexts (+ target, + context), positive target words in negative contexts (+ target, - context), negative target words in positive contexts (- target, + context), and negative target words in negative contexts (- target, - context), at anterior, central, and posterior scalp regions, in younger adults (left panel) and older adults (right panel).

Unlike the above, there was a marginal Context x Age interaction within the posterior region ($F(1, 54) = 3.07$, $p = .066$, $\eta^2 = 0.06$). In younger adults (but not older adults), the LPC difference between the first and the second occurrences of the target words was larger in negative contexts ($M_{diff} = 0.71$, $SD = 1.76$) than in positive contexts ($M_{diff} = -0.42$, $SD = 1.61$; $t(27) = -3.10$, $p = .02$, Cohen's d $= -0.59$) (Fig. 5). Older adults tended to show a larger LPC increase ($Mdiff = 0.62$, $SD = 1.86$) in response to all the target words in positive contexts, irrespective of target word valence, compared with younger adults ($Mdiff = -0.42$, $SD = 1.61$; $t(54) = -2.24$, $p = .058$, uncorrected $p = .029$, Cohen's d $= -0.6$).

After controlling for participants' sex, PA, NA, DSST, and WCST scores, the context main effect ($F(1, 47) = 4.5$, $p = .039$, $\eta^2 = 0.87$) still remained and the Context x Age interaction appeared significant ($F(1, 47) = 7.32$, $p = .009$, $\eta^2 = 0.14$), with an additional Context x NA (Negative affect) interaction ($F(1, 47) = 6.86$, $p = .012$, $\eta^2 = 0.13$).

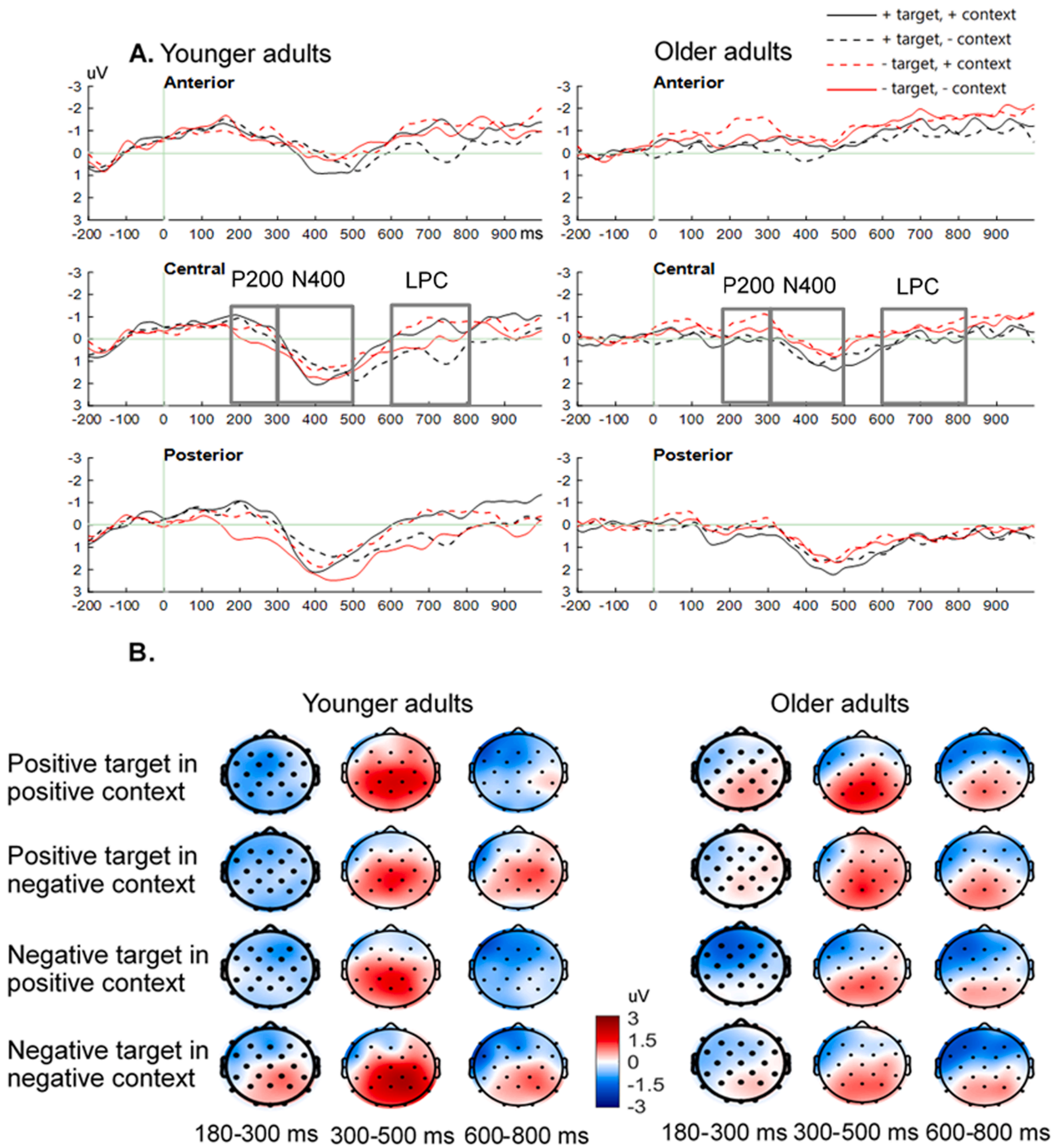

Fig. 5. (A) Grand averaged ERP waveforms (N = 28 each group) for the difference waves of the 2nd minus 1st occurrence of the topic words for positive target words in positive contexts (+ target, + context), positive target words in negative contexts (+ target, - context), negative target words in positive contexts (- target, + context), and negative target words in negative contexts (- target, - context), at anterior, central, and posterior scalp regions in younger adults (left panel) and older adults (right panel; low-pass filtered at 10 Hz for the visualization) (B) The scalp topographies of the P2, N400, and LPC effects from the difference waves in each condition, in younger and older adults. Note that for the N400 effects, the red area indicated a reduced N400 at the 2nd occurrence of the topic words, compared with the 1st occurrence of the same words.

6.6. *Regression results*

To directly examine age effects and the influence of negative affect (both continuous variables) on the observed P2 target effect, and LPC context effect, multiple linear regression models were conducted by entering the target effect size (i.e., difference amplitudes from negative minus positive target words) and context effect size (i.e., difference amplitudes from negative minus positive context words) into the dependent variable in the P2, N400, and LPC time windows. In the P2 time window, regression analyses showed a significant model only for the target effect (adjusted R-square = 16.2 %, $F(6, 47) = 2.71$, $p = .024$). In this model, age ($\beta = -0.70$, $t = -3.16$, $p = .003$, semi-partial correlation $sr^2 = 0.16$) and negative affect ($\beta = -0.33$, $t = -2.35$, $p = .023$, semi-partial correlation $sr^2 = 0.09$) separately predicted the size of the P2 of target effect, while controlling for participants' sex and cognitive/affective scores. Older age and higher negative affect were associated with smaller P2 differences between negative and positive target words (Figs. 5B and 6). In the N400 and LPC time window, no significant models were found.

7. Discussion

The first main finding is that age modulated Target word effects in the P2 window. Older adults used contexts (either positive or negative) to change the valence of the positive target words more than younger adults did, based on both the significant ROI-based RM-ANOVA and

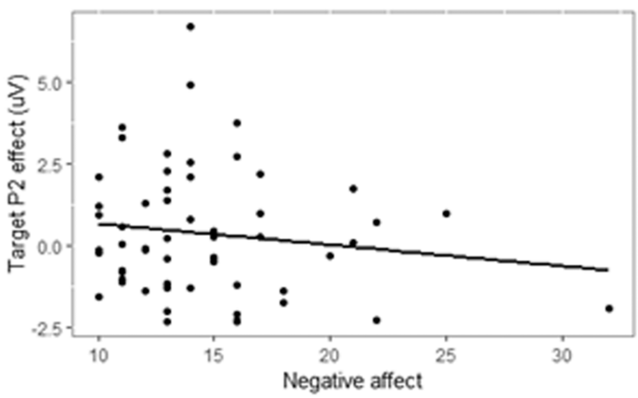

Fig. 6. Correlation plot of negative affect scores and ERP amplitude differences in posterior sites between negative and positive target words in the P2 time window.

regression results. In contrast, younger adults tended to use contexts to change the valence of the negative target words more than that of the positive target words. The second main finding is that age modulated Context effects in the LPC window. Younger adults used negative contexts to change the valence of target words (either positive or negative) more than they did positive contexts, but older adults didn't. Older adults tended to use both positive and negative contexts to change the valence of all the target words, and such effect was reflected in this late time window.

An unexpected novel finding is that the age-dependent Target effect on P2 was mediated by participants' negative affect. This is consistent with past literature that showed attenuated reactivity to both pleasant and unpleasant stimuli, in depressed or neurotic individuals with higher negative affect (Foti et al., 2010; Speed et al., 2015). Note that on average our older adults had lower negative affect (NA) than younger adults. However, it was the older age and higher negative affect that predicted a smaller Target effect on the P2. Because this outcome was not expected and not reliably found in the Context effect on the LPC, we refrained from discussing it further and leave it for future research to verify these findings and mediations.

The behavioral ratings in Experiment 2 showed an effect of target word and context word valence across younger and older adults, confirming our manipulation of the stimuli. We did not find age differences dependent on the contexts. One possible reason is that participants were asked to wait to rate the valence of the target word in contexts, until after having read the whole three-sentence vignette, as opposed to right after having read the contexts in the second sentence like in Experiment 1. This was done to avoid button pressing and muscle movement in the ERP time windows of interest. It is possible that during the wait, the content in the third sentence of each vignette may have influenced the valence evaluation. Additionally, unlike Experiment 1, participants did not provide individual ratings on the target words in isolation prior to reading the whole three-sentence vignette. This was part of our design, to avoid fatigue from long lab sessions and habituation effects.

7.1. General discussion

The current study investigated whether and how the affective neural representation of a word changes before and after emotional contexts, and whether age modulates this change. In a web-based experiment (Experiment 1) and an EEG experiment (Experiment 2), participants read and judged the valence of the target words embedded in positive and negative contexts in the three-sentence vignettes. In Experiment 1, we found that positive contexts biased the target word evaluation toward stronger positive ratings, whereas negative contexts led to stronger negative ratings. Such change was the largest when the context was negative, and the to-be-evaluated target word was positive. This possibly explains the target word effect, where regardless of context valence, positive target words were rated as being less positive than negative target words, compared with isolated target words. In Experiment 2, we found an age difference at P2: the P2 difference between the first and the second occurrences of the positive target words was larger in older adults than that in younger adults in all contexts. Within younger adults, they showed a larger P2 difference to negative target words than positive target words. In addition, the LPC difference between the first and the second occurrences of the target words was larger in negative contexts than in positive contexts in younger adults. In contrast, older adults showed a similar LPC difference to all the target words in negative contexts and positive contexts.

7.2. Affective neural representation of a word: ERP evidence

Our ERP findings revealed age differences in the processing of the affective neural representation of a word, supporting the strength and vulnerability integration (SAVI) model of aging that was built on the SST. Based on the SAVI model, older adults' positivity bias can be modulated by the stages of emotional experiences (i.e., before, during, or after the event; Charles, 2010). Due to reduced physiological flexibility, older adults have greater and/or more sustained emotional responses when experiencing emotional events, especially high-arousing ones, whereas they have more positive appraisal or better emotion regulation for low-arousing events, especially before or after the event, compared with younger adults. Our emotional contexts in the vignettes could be viewed as low- or moderate-arousing emotional events. The ERP results suggest that older adults did attend to positive content in the contexts more than younger adults, after the affective representations of the target words were retrieved. This possibly indicates older adults' increased positive appraisal or up-regulating of positive emotions.

Specifically, for the affective neural representation of a word, we found an age-dependent effect of target word valence on the P2: While younger adults showed a negativity bias, older adults showed a reduced negativity bias, on the P2. We argued that our P2 effects may reflect both an enhanced attention to specific valence features of the target words, or/and the update of the affective representation of the target word in contexts, both modulated by age. In the ERPs, we found two P2 effects on target words: (1) a larger P2 difference between the positive target words before and after contexts in older adults than in younger adults, and (2) a P2 difference between negative target words before and after contexts, which tends to be larger than the P2 difference between positive target words before and after contexts, within younger adults. These effects likely reflect an enhanced, age-dependent attention to different valence features at the word level, consistent with studies that reported P2 for attention, emotional salience, or/and context-based (feature) prediction (Donahoo et al., 2022; Fritz & Baggio, 2020; Lai & Huettig, 2016). Alternatively, as our P2 effects were based on difference waves, they may reflect the change of the affective representation of the target word due to the context. This is consistent with Chou et al. (2020), where they found a larger P2 to the neutral target words preceded by emotional than neutral contexts. The authors linked their P2 to the update of affective representations in the neutral target words, similar to the combinatorics account that argues that the meaning of a complex structure (e.g., a phrase like "remarkable pianist") is determined by combining the meaning and syntactic properties of its parts (e.g., "remarkable" and "pianist" respectively) (Neufeld et al., 2016). Expanding their study, our findings suggest that such change, update, or combinatorial processes, can be restricted to target words of a certain valence, dependent on age.

In addition, we found an age-dependent effect of context word valence on the LPC. Similar to the P2 effect, younger adults showed a negativity bias, whereas older adults showed a reduced negativity bias, on the LPC. Unlike the P2 effect, we argued that this observed LPC effect do not reflect attention. Rather, it only reflects the update of the affective representation of our target words in contexts. This is in consistent with most of the studies that associated the LPC to the contextually driven update of word-level or discourse level representations (c.f., Introduction).

We did not find any N400 effect. There are three possible explanations: First, both the adjective context and the target word are emotional, and emotional processing affects semantic processing. This explanation is based on past findings, where the N400 effect was reduced (Chou et al., 2020; Delaney-Busch & Kuperberg, 2013). For instance, no N400 effect was found in the target word "diamond" in "Colin saw a *stunning/terrifying* object on the ground. He realized it was a *diamond* right away". Second, it is possible that our null N400 effect is due to the equally plausible emotional contexts paired with the given target words between the two conditions, suggesting similar efforts needed for affective meaning integration. Unlike past studies using emotional sentences that are highly implausible or with semantic violation/anomaly, e.g., "*The loved/gratuitous sister arrives*" (León et al., 2010; Martín-Loeches et al., 2012), we made an effort to match the probability of the adjective context words, as a proxy of word plausability to predict the N400 effect (Szewczyk & Federmeier, 2022), between conditions, in order to rule out any (non-affective) lexical influence on the following target words. A third possible explanation is that the null N400 effect in the current study was attenuated by the high arousal status that participants became after the context adjectives and before the second occurrence of the target words. Based on the norming data, participants felt more intense/arousing for the adjective context words compared with the first occurrence of the target words. At the word level, N400 effects was found to be modulated by arousal, as our past study showed that both younger and older adults showed similar N400 effects to high-arousing words, regardless of valence (Ku et al., 2022).

Overall, these results point to a reduced negativity bias in older adults both at the word level and the context level, supporting a weak version of the SST (i.e., a reduced negativity bias rather than a positivity bias). This means that older adults attend to both positive and negative features similarly, both in the upcoming word and in its prior contexts before making the valence evaluation rating, to maximize their positive emotional experiences, as argued by the SST. In contrast, our data reflect a negativity bias in younger adults, both at the word and context level, supporting the AVH. Younger adults consistently attend to negative features both in the upcoming word and in its prior contexts, even before making the valence evaluation rating (see the discussion below).

7.3. Affective evaluation of a word: behavioral evidence

Across the age groups in Experiment 1 and 2, negative contexts affected participants' ratings of target words more than positive contexts. As discussed above (c.f., Discussion in Experiment 2), the two experiments differed in that there was the additional, third sentence of each vignette in Experiment 2 that was not present in Experiment 1. In addition, there were also procedural differences (delayed response) between experiments. Despite these differences, the mean difference ratings between negative (vs. positive) contexts on positive target words were larger than those between positive (vs. negative) contexts on negative target words, in both the age groups (Fig. 3). This indicates that regardless of age, the influence of negative contexts on positive target words was stronger than that of positive contexts on negative target words. Based on the AVH, negative information tends to attract prolonged attention due to evolutionary reasons, as it usually conveys threatening signals. Such negativity bias reflects prioritization of threat avoidance over reward approach in our valence evaluation task where attention resources are allocated to affective features of the words explicitly (Reed et al., 2014; Yuan et al., 2019)

It was unexpected to find negativity bias during evaluative valence rating in older adults. This finding may be further driven by the fact that the adjective context word was placed near the end of the second sentence of each vignette. According to the AVH account, the strength of the negativity bias appears to be stronger than the positivity bias strength, when the goal (e.g., word) is close in space or time (Cacioppo et al., 1997; Rozin & Royzman, 2001). Because each adjective context word appeared almost right before the valence rating task, it may have led to a (similar) negativity bias in younger and older adults. Future studies can manipulate the position of the adjective context word and test its influence on the valence evaluation of the target word.

Our findings are consistent with Lüdtke and Jacobs (2015), a behavioral study on younger adults showing that negative adjectives in a simple sentence (i.e., subject + auxiliary verb + adjective) influence the evaluation processes of their nominal subjects more than positive and neutral adjectives. Additionally, Kuhlmann et al. (2016) found that, compared with non-bivalent noun-noun-compounds in German, bivalent compounds (e.g., *bomb-sex*) were rated more negative whenever one of the constituents in the compound was negative, in younger adults. Expanding both the above studies, the current data showed that the negativity bias in the evaluation processes not only exerts over a longer context, i.e., across constituents and a single sentence, but also extends to older adults.

Across the two experiments, we collected several cognitive and affective measures that are directly relevant to emotion processing. Among these measures, negative affect is linked to our P2 effects in Experiment 2 (c.f., Discussion in Experiment 2), but not the LPC effects nor the valence evaluation in neither experiment. This suggests that the influence of negative affect on the affective representation of a word is more automatic/bottom-up, rather than top-down. Additionally, despite age differences on negative affect, our participants were all non-depressive based on the BDI-II scores, possibly reducing the effect on valence evaluation with the current small size sample. Of note is that younger adults showed, numerically, higher BDI-II scores in Experiment 1 than in Experiment 2. This is likely because participants in Experiment 1 were recruited during the COVID-19 pandemic. Consistent with a recent study from Carstensen, et al. (2020), older adults across our experiments showed greater well-being (i.e., less negative affect) even during the pandemic when they were at a greater risk, supporting a reduced negative bias effect.

We did not find any modulation of general cognitive ability (as measured by the DSST) on the observed effects in the ERP data or behavioral ratings across the two experiments. This indicates that older adults, despite having lower cognitive ability in our sample, can still update the affective representation of a word in emotional contexts accordingly. However, we found modulations of one specific cognitive ability, that is, inhibitory control (as measured by the WCST) in the later stage of word judgment. Supporting this possibility, numerically, the rating data in Experiment 2 showed that participants with lower inhibitory control (usually older adults) gave more positive ratings to the positive target words in negative contexts, and also more positive ratings to the negative target words in positive contexts, compared with those with higher WCST scores (See Supplementary Material S2). This suggests that a positivity bias on valence evaluation depends on one's inhibitory control ability rather than age, which should be further verified in future research.

Our findings have theoretical implications for the constructionists' view of emotion (c.f., Barrett, 2011; Barrett, 2017; Russell & Barrett, 1999). According to the view, emotion (e.g., fear) is *constructed* when incoming sensory inputs (e.g., the word stimulus "*dentist*") are categorized by emotion concept knowledge within a perceiver. These emotion concepts are learned from past experiences, but the process of categorization highly depends on the to-be-evaluated situation (e.g., the contexts in our study). Such "situated conceptualization" is instantaneous, continuous, and dynamic. Our findings further show that this situated conceptualization depends on different attentional focus that changes with age. Specifically, younger adults tend to foreground negative information in the to-be-evaluated situation, while older adults do so less. For instance, when reading "The *pianist* had a new performance. Her skills were *remarkable/rusty*.", younger adults are more sensitive to "rusty" than "remarkable", even though 'pianist" is a mildly positive word. In contrast, older adults are sensitive to both words in the same scenario.

To put our study in a broader context of semantic processing, our data from valence ratings suggest that the update of the valence representation of a word is not based on a linear combination of the valence values of each constituent in the sentence. This is indicated by (1) nearly no change of the valence values for emotionally-consistent conditions (i.e., positive target words in positive contexts, negative target words in negative contexts), compared with a prominent change of valence values in emotionally-inconsistent conditions (i.e., positive target words in negative contexts, negative target words in positive contexts), and (2) the negativity bias in valence evaluation across the age groups, as discussed in Experiment 1 and 2. This contrasts with the view of general semantic combinatorics which posits that the meaning of a sentence is determined by the sum (combination) of its syntactic and semantic parts (Frege, 1892).

There are limitations and future directions. First, circadian effects on affect vary across age (Mather, 2024), but we did not limit the time of day for participant arrival to the EEG sessions. While some have reported that older adults showed greater positivity affect than younger adults in both the morning and afternoon, future studies can explore how circadian effects influence emotional bias in updating the affective representation of a word. Second, participants with depression and cognitive impairments were excluded in the current study. This could limit the ecological validity and the generalization of the findings to broader populations in the real world. Future studies should recruit a larger sample size with different levels of cognitive and emotional functioning (e.g., inhibitory control ability, negative affect) to examine their relationship with the update of the affective representation of a word in contexts.

8. Conclusions

Younger and older adults update affective neural representation of an emotional word in the same affective context differently. Supporting the automatic vigilance hypothesis (AVH), younger adults quickly disengage from positive target words and attend to negative target words in all emotional contexts. Afterwards, they attend to negative contexts more. In contrast, older adults quickly attend to positive target words in all emotional contexts, and at a later stage, both the positive and negative contexts, which suggests a weak version of the positivity bias. These results support the socioemotional selectivity theory (SST), but not the AVH. At the behavioral level, negative contexts affect both younger and older adults' valence evaluation more than positive contexts. Our study thus indicates that emotional bias could influence the affective neural representation of a word initially and the valence evaluation later on in different ways.

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Declaration of generative AI and AI-assisted technologies in the writing process

The authors did not use generative AI and AI-assisted technologies for the preparation of the current manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.biopsycho.2025.109003.

Data availability

Data and materials regarding the present research are available in the following OSF repertoire: https://osf.io/mesnz/?view_only=0f1199251040483daacb51cb05296c3a

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