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The Time Course of Age-related Emotional Preference in Task-irrelevant Affective Processing*

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Abstract Studies of the age-related positivity effect have demonstrated that older adults have a generalized preference to positive stimuli or avoidance to negative stimuli compared with younger adults. However, it remains unclear when and how this positive effect occurs in task-irrelevant affective processing in the aging brain. The present study investigated age-related emotional preference in one task-irrelevant affective stimuli processing by event-related brain potentials (ERPs) measurement with a specific focus on the time course of older adults' emotional processing and regulation. Younger and older adults completed a modified oddball task in which the deviant stimuli were affective faces. In the relatively early time window, the brain activities were not modulated by emotional valence in younger adults, yet the sad stimuli elicited a larger P3a than the happy and neutral ones in older adults. In the late time window, the sad stimuli elicited a larger positive slow wave than the happy stimuli in younger adults. Contrarily, at the later processing stage older adults' valence differences were eliminated. In general, we found time course differences in how older adults processed task-irrelevant affective stimuli compared with the young, and an age-related positivity effect occurred in the late time window, manifested as a negativity preference in younger and no preferences in older adults. These results provided evidence for supporting socioemotional selectivity theory from an ERP approach.

Key words emotional positivity effect, aging, event-related brain potentials, oddball, time course
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It has been claimed that, although aging is commonly associated with a decline of cognitive function, emotional regulation remains stable or even enhanced across the adult lifespan[1]. This aging effect has been characterized as either a preference for positive stimuli or a preference to avoid negative stimuli for older adults, and this age-related positivity effect has been reported in various domains including memory, attention, decision making, etc.[2-6].

According to socioemotional selectivity theory[7], there is a shift from knowledge-pursuit goals toward emotional-regulation goals as people age. Older adults perceive time as limited and prioritize emotionally-meaningful goals, thus the positive effect emerges as positively valenced stimuli are considered more emotionally meaningful. With regard to this emotional goal, Mather and colleagues[8-9] have further asserted that cognitive control plays a key role in this age-related positivity effect such that only older adults with sufficient cognitive control are able to display age-related positivity effects. Otherwise, as in divided-attention experimental conditions, older adults no longer show a positivity effect in memory[8], or the reversal of typical positivity effect may occur[9]; that is, their preferences resemble those of younger adults with general human negativity dominance from evolutionary

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perspective [10]. Accordingly, the implementation of age-specific emotional preference in older adults is temporally-delayed, as the processes need time to fully access cognitive resources.

Contrary to socioemotional selectivity theory, which emphasizes the selective processes between knowledge and emotional goals, dynamic integration theory [11-12] identifies a dynamic balance between emotional optimization and differentiation, and worsened cognitive function associated with age complicates attempts to maintain both. Therefore, older adults compensate by favoring the optimization of positivity and avoiding emotional differentiation complexity. From this perspective, the difficulty associated with integrating and accepting negative feelings with age should be time course invariant and emerge immediately upon stimulus onset, as positivity is a generic response and is not superimposed on existing negative responses[5].

On account of this temporal element, the time course of emotional stimuli processing should be carefully considered so that the effect of differentially-accessed cognitive resources on any age-related positivity effects may be measured. The former theory suggests that whether the general human automatic negative preference or the age-related positivity bias is observed changes as a function of the time course due to differences in cognitive resources accessed over time, but the latter theory predicts constant positivity effects over time. To date, only one study has directly investigated the time course of age-related preferences by eye-tracking measurement [5]. They asked participants to observe face pairs and recorded their gaze patterns. Age-related preferences toward happy faces only occurred 500 ms or later after stimulus onset and increased linearly, suggestive of socioemotional selectivity theory. However, older adults' slower eye movement could have delayed the appearance of positivity preferences, which may have contributed to the failure to observe differences between age groups in the early time course.

Other than eye-tracking measurement, event-related brain potentials (ERPs) could be another powerful tool for addressing the time course issue of age-related preferences toward emotional stimuli. The modified oddball paradigm with classic ERP components uses a sequence of standard and target stimuli interrupted by infrequent deviant emotional stimuli, and it has been used to investigate emotional processing theories in several previous studies. The deviant stimuli elicit P3a, a subcomponent of the P300 reflecting an involuntary switch of attention from the primary task to distracters modulated by different emotional valences; the infrequently-presented target stimuli elicit P3b, reflecting the subsequent memory processes engaged in stimulus information storing [13]. This modified oddball paradigm with clear ERP index is an effective means of investigating the time course of age-related emotional preferences.

The goal of the present study was to use time-sensitive ERP measures associated with emotional stimuli to examine the age differences of brain activities modulated by valence, with a specific focus on the time course of older adults' emotional processing and regulation. Participants completed a modified oddball task in which their primary task was to detect bigger geometric figures (target stimuli) out of normal ones (standard stimuli), and the deviant stimuli were emotional faces that did not require explicit response. In task-irrelevant emotional processing, we predicted that at the early stage when emotional stimuli were involuntarily processed, the sad faces would attract more attention and elicit a larger P3a compared with happy and neutral ones in both younger and older adults as negative information is generally more salient for humans. In contrast, at the later stage when the emotional-regulation goal has been activated in older adults, the general human negative preferences could be suppressed resulting in no valence differences in brain potentials of older adults.

1 Materials and methods

1.1 Participants

Sixteen younger adults(mean age=21.6, SD=3.89; range: 17～26 years; eight females) and sixteen older adults (mean age=69.7, SD=3.20; range: 61～75 years; nine females) participated in the ERP study and received monetary compensation for their participation. Younger adults were recruited from two local universities, and older adults were from the community centers nearby. All were right-handed with normal or corrected-to-normal vision and had no known reading or neurological disorders, and older adults had high scores on the Mini-Mental Status Examination [14] (mean score = 28.75, SD = 1.44), consistent with intact cognitive function. One participant whose MMSE score was 25 (i.e. below the

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standard cut-off score, 26) was determined not to have mild cognitive impairment by clinical neuropsychiatrists and was included in the study. Older adults scored significantly lower than the young on the depression and anxiety emotional measurements (CES-D, STAI-State, and STAI-Trait)[15-16], indicating that older adults had less negative feelings in daily life. In addition, older adults showed some signs of deteriorated cognitive ability in terms of reduced processing speed (Trail making A) [17] and fluid intelligence (Block Design) [18], but they did not differ from younger adults in crystallized intelligence (Similarities)[18]. Participants' descriptive characteristics are summarized in Table 1.

This study was approved by the ethics committees of the Institute of Psychology, Chinese Academy of Sciences. Signed informed consent has been obtained from each participant, and for one participant aged 17 also has informed consent signed by her parents.

Table 1 Age differences in all variables

Variables	Younger adults		Older adults		*P*
	Mean	*SD*	Mean	*SD*	
Years of education	15.06	2.24	13.69	2.89	0.143
Self-health report	1.88	0.72	2.19	0.91	0.290
CES-D	14.81	8.52	4.63	3.28	< 0.001
STAI-State	30.81	6.05	26.63	4.67	< 0.050
STAI-Trait	40.75	9.81	29.69	6.91	< 0.010
Trail making A	19.53	4.60	33.75	8.64	< 0.001
Trail making B	31.08	8.61	63.23	18.17	< 0.001
Digit symbol substitution	74.88	6.86	40.06	10.02	< 0.001
Block design	37.81	8.64	30.56	6.18	< 0.001
Similarities	19.44	2.76	17.94	3.86	0.215

All values represent raw, non-standardized scores.

1.2 Stimuli

The task used a total of 800 stimuli of three types: simple geometric figures served as standard items (n = 560, 70%), similar geometric figures 20% larger than the standard items served as targets (n = 120, 15%), and images from the normalized Chinese Affective Picture System (CAPS)[19] served as deviants (n = 120, 15%). The stimuli were assigned to four blocks, and within each block standard stimuli were one of four blue geometric figures (*i.e.* square, circle, triangle, or diamond). The deviant stimuli contained 10 each of three kinds of valenced stimuli (*i.e.* neutral, happy, and sad faces) in each block, and each deviant stimulus was repeated exactly once in the task. Although these pictures had been normalized, in the present study they were selected out of CAPS on the basis of re-normalized valence and arousal ratings from both younger (n = 15) and older adults (n = 15) who did not participate in the ERP experiment. Valence rating was comparable for both younger and older adults, and the valence effect was significant (F (2, 76) = 1492.44, P < 0.001). As expected, post-hoc tests revealed that the lowest valence was assigned to sad pictures, an intermediate valence was assigned to neutral ones, and the highest valence was assigned to happy ones, all P < 0.001 . For arousal ratings, there was a significant interaction between age and valence (F (2, 76) = 9.24, P < 0.001). For the happy pictures, older adults reported higher arousal than younger adults (F (1, 38)= 16.32, P < 0.001), while the sad and neutral faces were comparably-rated between groups (sad, F (1, 38) = 1.91, P = 0.175; neutral, F (1, 38) = 0.03, P = 0.855). To summarize, in the valence dimension, the two groups had the same across-category valence judgments; in the arousal dimension, older adults reported more arousal for the happy pictures than did the young (Table 2). Because of this subjective rating differences, arousal rating for happy pictures were initially included as a covariate in group comparisons, but they were later dropped from the analyses because they were not found to exert any significant effects on ERP analyses. All the stimuli were pseudo-randomized

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within each block for each participant, such that (1) the mean ratings of valence and arousal of three kinds of affective faces did not differ from one block to another; (2) neither target nor deviant stimuli occurred as the initial item in any presented series; (3) neither target nor deviant stimulus categories occurred more than three times consecutively.

Table 2 Valence and arousal ratings of the 60 pictures from CAPS

	Valence (Mean±*SD*)			Arousal (Mean±*SD*)		
	Happy	Neutral	Sad	Happy	Neutral	Sad
Younger adults	4.22±0.21	2.81±0.20	1.54±0.27	3.48±0.32[1)]	2.48±0.24	3.97±0.22
Older adults	4.26±0.20	2.83±0.13	1.49±0.26	3.89±0.32	2.56±0.12	3.95±0.27

The valence rating scale ranged from very sad (1) to very happy (5); the arousal rating scale ranged from very tranquil (1) to very exciting (5). [1)] Happy pictures were rated as less arousing by younger adults than older adults.

1.3 Procedure

After participants signed an informed consent form and received applications for ERP recording, they were seated in a comfortable chair approximately 60 cm from the computer screen in a dimly-lit, sound-attenuated room. They were asked to react as quickly as possible by pressing the spacebar when they detected geometric figures larger than the standard ones. Participants were not asked to judge or otherwise respond to the deviant stimuli. Each stimulus was displayed sequentially on the center of the computer screen (17″) on a black background. The standard and target stimuli were presented for 500 ms, occupying about 5° of horizontal visual angle, while the deviant pictures were presented for 750 ms, occupying about 10° of horizontal visual angle [20]. The stimulus-onset asynchrony (SOA) varied randomly between 900～1 000 ms. Example trails from the oddball task are shown in Figure 1. Prior to the experimental blocks, participants received two practice blocks including 30 items. The experimental session lasted about 30 min.

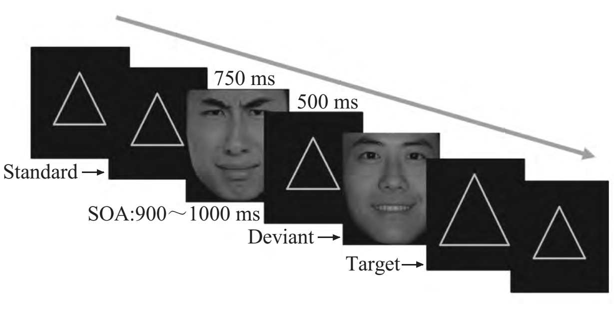

Fig. 1 Examples of trails from the oddball task

The standard and target stimuli were presented for 500 ms, while the deviant pictures were presented for 750 ms. The stimulus-onset asynchrony (SOA) varied randomly between 900～1 000 ms.

1.4 ERP recording and analysis

The EEG was recorded from 64 Ag/AgCl electrodes mounted in an elastic cap (Quick-Cap, NeuroScan Inc., USA). Recordings were referenced to the left mastoid, but re-referenced to linked mastoids offline. The horizontal electrooculogram (EOG) was recorded from electrodes placed at the outer canthus of each eye, and the vertical EOG was recorded from electrodes placed above and below the participants' left eye. Electrode impedances were kept below 5 kΩ. The EEG and EOG were amplified with online high-low band pass filtering (0.05～100 Hz) and recorded continuously with a digitization rate of 1 000 Hz.

ERPs were computed for each participant, condition, and electrode site. A 30 Hz low-pass filter was applied offline to the continuous EEG data. The epoch interval was 1 000 ms, ranging from 100 ms before the onset of the deviant stimuli to 900 ms after it. Epochs with EEG exceeding ±100 μV were excluded from the averages through artifact rejection. The overall rejection rate was 4.32% for younger adults and 3.86% for the older ones, equal for all three kinds of affective pictures in both groups (younger adults, Happy: 5.31%, Neutral: 4.06%, Sad: 3.75%; older adults, Happy: 4.84%, Neutral: 2.97%, Sad: 2.97%). Two time windows were chosen on the basis of visual inspection and earlier studies: (a) 270～420 ms in younger adults and 320～470 ms in older adults for P3a effects and (b) 500～700 ms in younger adults and 650～850 ms in older adults for positive slow wave (PSW) of deviant stimuli. All statistical analyses were performed on the mean amplitudes in the selected time windows. ERPs were analyzed separately for midline and lateral electrodes. Omnibus ANOVAs for lateral

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electrodes included four within-subject factors: time window (P3a, PSW), hemisphere (left, right), region (frontal, central, parietal), and valence (happy, neutral, sad); and one between-subject variable age group (older adults, younger adults). Crossing the variables of region and hemisphere yielded six regions of interest (ROIs), with two electrodes for each ROI: left frontal (F3, F5); left central (C3, C5); left parietal (P3, P5); right frontal (F4, F6); right central (C4, C6); and right parietal (P4, P6). Omnibus ANOVAs for midline electrodes included three within-subject factors: electrode (Fz/Cz/Pz), time window, and valence; and one between-subject variable age group. Only effects involving valence are reported. The Greenhouse-Geisser correction was applied when evaluating effects with more than one degree of freedom in the numerator. In these cases, the original degrees of freedom and probability levels and estimates of effect size are reported.

2 Results

2.1 Behavioral data

No group differences in overall task performance between groups were found. All participants had a high accuracy rate which was defined as the percentage of correct responses on the judgment of the target stimuli minus the false alarms in the standard and deviant conditions (both groups were above 97.00%; $t(30)=-0.80$, $P = 0.433$). The mean response time did not differ significantly between age groups in the target condition; older adults' RTs were (507.32 ± 34.52) ms and younger adults' RTs were (509.73 ± 41.30) ms ($t(30) = -0.18$, $P = 0.859$). The comparable behavior performance lessened the possibility that performance could have influenced mood, eliciting as a consequence a negative bias in the group performing less well[9].

2.2 ERP data

Figure 2 shows grand average ERPs elicited by the standard, target, and three valences of deviant stimuli for both younger and older adults at three representative electrodes, and Figure 3 illustrates the mean amplitudes of the ERP components for different valence in both groups at electrode Fz and the topographies for valence effect in relatively early and late time windows. As shown in Figure 2, in both groups, compared with the standard, target stimuli elicited a broadly-distributed positive-going wave, and deviant stimuli also elicited a positive-going wave (P3a) exhibiting shorter latency and larger peak amplitude than that elicited by the target. As shown in Figure 3, the sad picture elicited a larger P3a compared to the neutral and happy ones in the early time window in older adults, whereas the three valences had no amplitude difference in younger adults. However, in the late time window, the wave pattern was reversed between the two groups; no between-valence differences were observed for older adults, but sad

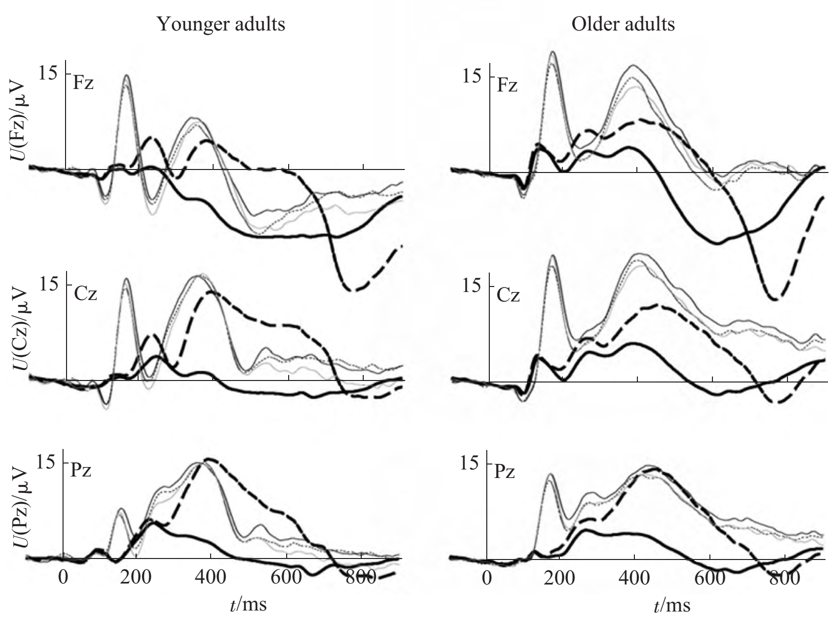

Fig. 2 Grand average ERPs time-locked to the onset of the critical stimuli from 3 scalp sites in the midline for all three conditions (i.e. the standard, the target and the three differently-valenced deviant stimuli) in both groups

– –: Target; ——: Standard; ——: Deviant happy; ----: Deviant neutral; ——: Deviant sad.

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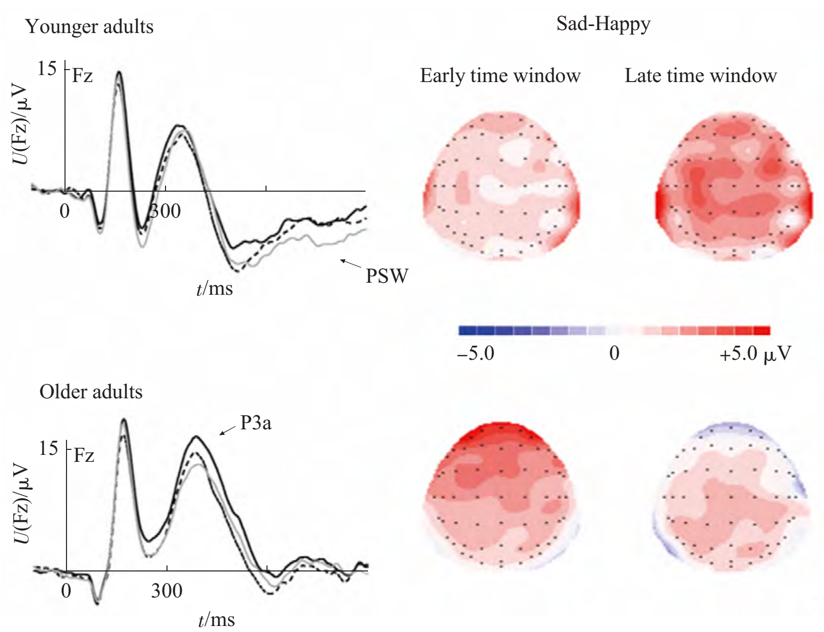

Fig. 3 Grand average ERPs elicited by deviant stimuli of happy, neutral, and sad pictures at electrode Fz

The topographies of the emotion effect, separately for the younger and older adults, were showed for the relatively early and late time windows. —— : Happy; ---- : Neutral; —— : Sad.

pictures elicited a larger positive slow wave (PSW) than the other two in younger adults. These observations were statistically verified by ANOVAs performed on the mean amplitudes in the P3a and PSW time windows, respectively.

A global ANOVA revealed a main effect of valence (F (2, 60) = 5.69, $P < 0.010$), and a marginally significant age × time window × valence interaction at lateral electrodes (F (2, 60) = 2.80, P = 0.069). At the midline electrodes, a global ANOVA (valence ×time window×electrode×age group) revealed a main effect of valence (F(2, 60)=4.90, $P < 0.050$), and a significant age ×valence × time window interaction (F(2, 60) = 4.59, $P < 0.050$). Therefore, additional analyses were performed at midline sites per time window and group for the research question separately.

2.2.1 P3a amplitude

Separate analyses limited to each age group over all the three electrode sites in the relatively early time window revealed a main effect of valence in older adults (F (2, 30) = 3.65, $P < 0.050$), but no valence difference was found in younger adults (F(2, 30)=0.56, P = 0.577). Post-hoc Newman-Keuls comparisons revealed that in older adults the sad picture elicited a larger P3a than the happy and neutral pictures ($P <$ 0.050), while the happy and neutral faces did not significantly differ. In sum, in the early time window, the amplitude was not modulated by the valence of stimuli in the younger group, yet the sad stimuli elicited a larger P3a than both happy and neutral stimuli in older adults, which indicated that negative stimuli attracted more attention at the early stage of emotional processing in older adults.

2.2.2 Positive Slow wave (PSW) amplitude

In the late time window, separate analyses limited to each age group revealed a significant main effect of valence in younger adults (F(2, 30) = 4.05, $P < 0.050$), but no significant effect in older adults (F(2, 30) = 1.70, P=0.201). Post-hoc Newman-Keuls comparisons revealed that in younger adults sad pictures elicited a larger PSW compared with the happy one ($P < 0.050$), but neutral pictures did not significantly differ from the others.

Interestingly, compared with the P3a time window, the pattern of the valence effect was reversed in the two age groups at the late time window. The sad stimuli elicited a larger PSW in younger adults. Contrarily, the amplitudes were not modulated by the valence in older adults, which implied implementation of emotional-regulation goals that came to predominate over general negative-valence biases. Figure 3 shows the topographic scalp distributions for

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the difference waves between sad and happy stimuli in the early and late time windows separately; younger adults had larger emotional effects in the late time window, but older adults had larger effects in the early time window.

3 Discussion

The present study aimed to use ERP measures associated with task-irrelevant emotional stimuli to explore age-related differences in the time course of emotional processing and regulation. In the relatively early time window, the amplitude was not modulated by valence in younger adults, but sad stimuli elicited a larger P3a than the happy and neutral ones in older adults. In the late time window, the sad stimuli elicited a larger PSW than the happy ones in younger adults; contrarily, older adults showed no amplitude differences among the three valences. The between-group time-course effect of emotional stimulus processing was more supportive of the socioemotional selectivity theory.

3.1 The time course of age-related emotional processing

Our ERP-based approach addresses past concerns about the temporal resolution of this time-sensitive phenomenon and can control for possible age-related eye movement slowing confounds present in eye-tracking studies.

The P3a originating from stimulus-driven attention mechanisms associates with detections of rare or physically-alerting stimuli[21]. The sad stimuli elicited a larger P3a than the other two in older adults, which implies that sad information may be perceived as more novel than both happy and neutral information, and it was salient for older adults in the short term. This finding is consistent with previous studies reporting that when people are distracted, relatively automatic processes may focus on goal-inconsistent information[6,9] similar to the sad faces for older adults in the present study. Younger adults, with better cognitive function than older adults, appear to focus more on the ongoing target detection task and be less distracted by differently-valenced emotional stimuli. Hence, no valence effect is observed in the early time window. In the late time window, after the "press or not" decision has been made and participants passively view the emotional picture, valence effects in younger adults manifested; sad stimuli elicited a larger PSW than the happy stimuli, and no controlled processing was intentionally activated to suppress emotional preference tendencies once the valence information had been detected. This finding does not surprise us given that negativity preferences in younger adults have been observed in many domains of research[10]. In contrast, with enough time to access the necessary cognitive resources, older adults were able to conduct emotional regulation to override the negativity tendency, which resulted in no valence difference in brain activation.

The current results were most consistent with socioemotional selectivity theory suggesting that positivity preferences are "top-down," selectively-processed phenomena and the cognitive control hypothesis stating that older adults need enough time to prepare adequate cognitive resources to display positive preferences. In the present study, for task-irrelevant emotional processing, automatic negativity preferences set in immediately, and are later followed by a controlled emotional-regulation that is inexorably activated in older adults' emotional processing. In contrast to cognitive control models, simplified processing models consider the positivity preference in older adults to be a tool compensating for worsened cognitive function; to avoid affective complexity, a focus on positive information emerges. However, in the current study we found different valence patterns along the time course, and the larger P3a elicited by the sad stimuli in the early time window illustrated that negatively-biased processing was not absent in older adults, which is inconsistent with the premise of simplified processing models.

3.2 Task-relevant/irrelevant emotional processing

Older adults' positivity effects in emotional information processing have most consistently been found in the memory domain whereas reports from the attention literature have been strikingly heterogeneous. A recently-conducted meta-analysis[22] investigated the magnitude of older and younger adults' preferences for emotional stimuli in studies of memory and attention and suggested that older adults showed a smaller negativity preference than the young in memory recognition measurement, but that age-related emotional effects were not significant in the attention domain.

As noted by some researchers[4, 23], the positivity effect is strongest on tasks that require controlled processing. The fact that the attention domain relies more on automatic emotional processes, especially in

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the early processing stages, may explain the differences between the memory and attention literature. The heterogeneity of findings in the attention literature may also result from broad differences in attention measures (RT, ERP, fMRI, eye-tracking), task (categorization, passive viewing, dot-probe, visual search, rapid serial visual presentation), stimuli (words, synthetic faces, faces, actual objects), valence (happy, sad, angry, fear, neutral), and the like. We believe that, being that the cognitive control account asserts that cognitive resources involved in emotional processing influence age-related valence preferences, whether the attention probe was task-relevant or task-irrelevant may explain some of the mixed results.

Older adults' positivity effects were consistently found in task-relevant emotional processing, like categorizing the valence of stimuli or naturally viewing emotional pairs [5, 9, 24-26]. Contrary to task-relevant emotional processing, researchers have generally not observed age-related emotional preferences under task-irrelevant conditions where the emotional stimuli were involuntarily processed (e.g. dual task, visual search, dot-probe, etc.)[9, 26-28]. However, in the present study, in spite of the task-irrelevant design, we didn't find age-related positivity effects in early processing, but we did observe elimination of negativity preferences in older adults in the late time window. We present separate possible explanations for this divergence from previous studies. First, the reaction time (RT) measure adopted in most of the previous task-irrelevant studies may not be as sensitive as ERP measurement; such sensitivity differences could have masked the difference between age groups in prior studies. Second, our use of the modified oddball paradigm for which target detection was fairly easy such that the elderly could perform as well as the young, may have caused less drastic between-group mood disturbances than other, more-challenging paradigms such as the dual task [9]. Third, we may conclude from our results that in our modified oddball task emotional information processing had both automatic (i.e. target identification) and controlled (i.e. passive viewing) stages, which provided an opportunity for us to investigative age-related emotional preferences in both voluntary and involuntary context. Fourth, compared to emotional pair viewing tasks designed as slides with both emotional and neutral stimuli simultaneously presented, the deviant emotional stimuli in the oddball task (one face at a time) seem more similar to natural emotional processing than strictly binary presentation. Future research should determine the different mechanisms underlying age-related, goal-directed regulation and passive regulation, and how they are reflected both behaviorally and neurologically.

4 Conclusions

In general, we found time course differences in how older and younger adults reacted to emotional stimuli in a task-irrelevant emotional processing condition, and age-related positivity effects manifested uniquely in the later time window as the contrast between no valence preferences in older adults and negativity preference in younger adults. In the absence of emotionally-relevant task information, novel goal-inconsistent negative information attracted older adults' attention at the early stage, but emotional-regulation gradually eliminated the negative bias over time. These findings provide neural evidence reflected in ERPs supporting socioemotional selectivity theory and Mather and Knight's cognitive control model, rather than the simplified processing model.

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年龄相关的情绪偏向效应的时间进程 *

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摘要 来自记忆、注意和决策等领域的大量研究发现，在加工情绪刺激时老年人具有正性情绪偏向或负性情绪规避的特点．本研究采用 oddball 变式，将情绪面孔图片作为分心刺激呈现．实验过程中记录被试脑电，考察不同情绪效价对脑电波的影响，同时考察老年人在非任务相关条件下情绪加工和情绪调节的时间进程．研究发现，在相对早期时间窗口(270～460 ms)，年轻组脑电不受情绪效价影响，而老年组中悲伤情绪面孔较之快乐和中性情绪面孔引发了一个更大的正成分(P3a)．在晚期时间窗口(500～850 ms)，年轻组中悲伤情绪面孔吸引了被试更多注意并引发了一个更大的正性慢波．相反，老年组在晚期加工阶段，情绪效价效应消失．研究揭示了老年人和年轻人在加工非任务相关的情绪刺激时存在的时间进程差异，年龄相关的正性情绪效应发生在晚期时间窗口，表现为年轻组的负性情绪偏向和老年组的无情绪偏向．研究结果为社会情绪选择理论提供了来自脑电数据的支持．

关键词 正性情绪偏向，老化，事件相关电位，oddball 范式，时间窗口

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