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Negativity bias of the self across time: An event-related potentials study

Yangmei Luo[a,b], Xiting Huang[a,b,*], Youguo Chen[a,b], Todd Jackson[c], Dongtao Wei[a,b]

[a] Key Laboratory of Cognition and Personality (SWU), Ministry of Education, Chongqing 400715, China
[b] School of Psychology, Southwest University, Chongqing 400715, China
[c] School of Psychology, James Cook University, Townsville, Australia

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ABSTRACT

To investigate the neural basis of self-evaluation across time as a function of emotional valence, event-related potentials were recorded among participants instructed to make self-reference judgments when evaluating their past, present and future selves. Results showed that, when evaluating present and past selves, negative words elicited a more positive ERP deflection in the time window between 650 ms and 800 ms (LPC) relative to positive words. However, when evaluating the future selves, there was no significant difference on the amplitude of the LPC evoked by negative versus positive words. Findings provided evidence for the effect of emotional valence on the self across time at a neurophysiological level and identified the time course of negative bias in the temporal self. More specifically, people were inclined to be relatively less negative and optimistic about their future self but had mixed emotions about past and present selves.

A fundamental feature of human conscious experience is the sense of a self that persists across time [15]. That is, the self is an entity that exists not only in the present moment, but also from the past and into the future. However, evaluations of the self are not necessarily constant and may change when significant experiences occur. For example, when we enter new schools, begin a new job, or get married, perceptions of one's past, present and future selves may also change in response to the new circumstance. Considerable research has examined people's past memories, current self-assessments or forecasts regarding their futures, but fewer studies have compared and contrasted views of the self in relation to each of these time periods. As a result, it is not entirely clear whether appraisals of the self are homogeneously positive or negative across time or the extent to which both strengths and weaknesses in views of the self are endorsed in these temporal phases. Furthermore, even less is known about continuities and discontinuities in neural responses that accompany evaluations of one's past, present, and future selves. Exploration of these issues may have utility because the processing of personal changes across time and the ability to distinguish one's self from different time periods may have a critical role in the formation and consolidation of a stable identity during late adolescence and beyond [4,14]. On a related note, identification of normative patterns of subjective evaluations and neural activation related to self-assessments over time may also provide a foundation for future work designed to identify possible deviations in populations such as those who experience depression, anxiety disorders or schizophrenia.

Regarding the literature on these issues, behavioral studies have found that emotional valence have important effects on representations of the temporally extended self. Separate studies have found that people often devalue their past selves in order to maintain favorable self regard [23] and more readily access feelings or emotion information regarding their present [19], yet they also have overwhelmingly positive representations of their future selves [17,13]. However, findings from recent neuroscience studies investigating the neural basis of the self across time have been inconsistent. Sharot et al. collected fMRI data while participants thought of autobiographical events related to a description of a life episode (for example, 'winning an award' or 'the end of a romantic relationship'). The results revealed that enhanced activation in the amygdala and in the rostral anterior cingulate cortex was found when imagining positive future events relative to negative ones, providing evidence that the emotional valence have effects on the future self [21]. D'Argembeau et al. investigated the neural bases of temporal self adopting a self-reference paradigm, wherein participants were asked to make judgments about whether trait adjectives (e.g., kind) describe the self or those of an intimate other, for both the present time period (i.e., at college) and a past time period (i.e., high school years). They found that cortical midline structures (CMS) were more activated when reflecting on the present self than when reflecting on the past self or others [4]. Another study employing the same paradigm reported higher CMS activity when participants reflected on the current self compared to past or

* Corresponding author at: School of Psychology, Southwest University, Beibei, Chongqing 400715, China. Tel.: +86 23 6825 3624.
E-mail address: xthuang@swu.edu.cn (X. Huang).

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future selves [5]. Inconsistent with Sharot et al.'s study, however, both of D'Argembeau et al.'s studies failed to detect an effect for emotional valence on neural correlates of the temporally extended self.

In the current study, event-related potentials (ERPs) to investigate neural basis of self-evaluation across time as a function of emotional valence. Compared with fMRI, ERP can provide an excellent means to evaluate the time course of cognitive processes with high time resolution on the order of milliseconds. Specifically, the processing of the emotional valences may occur within hundreds of milliseconds when making judgments about trait adjectives in response to past, present and future selves. Thus, it might be helpful to use ERPs techniques to investigate the processing of positive versus negative emotional valences of the self-extended in time. Furthermore, because neuronal activities are measured directly by ERPs techniques, ERPs can provide time-locked neuronal response, while fMRI requires mass neuronal activation to obtain a response, associated recordings of brain activation may result from overlap of several mental processes.

Considerable research has found people are more sensitive to negative than positive information, a phenomenon that has been coined the "negativity bias" [22]. For example, the distress felt when one loses \$100.00 typically exceeds the happiness experienced when one finds \$100.00. This negativity bias has been documented in both behavioral and ERP studies [18,11,10]. ERP studies have found a negativity bias occurs in both the earlier attention allocation stage and the late evaluation or reaction readiness stages. Thus, negativity biases may involve both automatic and controlled processes [10]. For example, in one study, P2, late positive components (LPC) and lateralized readiness potential (LRP) were measured while participants were required to evaluate positive, neural negative pictures. Results showed the amplitude of P2 in the negative picture block was larger than in the positive picture block, a result indicative of an early attentional negativity bias. The LPC amplitude in the negative picture block was also larger than that of the positive or neutral blocks, indicating a negativity bias in later cognitive evaluations. The emotional negativity bias may also occur in reaction readiness [10]. Cacioppo and Berntson have contended that positive and negative information is processed by different motivation systems [2]. Several studies have demonstrated that depressed and anxious samples show increased strength of negativity biases relative to controls [3,16].

As mentioned above, research suggests people are typically optimistic about their futures but have mixed emotions about their past and present. The negative information processing may be different from different life periods and the negativity bias may change across the past, present and future. In previous studies on the negativity bias, according to our knowledge, no research has investigated the time course of negativity bias across different temporal selves. Therefore, according to the findings of the previous behavioral research in temporal self, it can be hypothesized that the strength of the negativity bias will increase when evaluating the past and present selves, compared with evaluating the future selves, which occur at both the behavioral and electrophysiological level.

To test this hypothesis, the ERPs technique was used to investigate the neural basis of the temporally extended self as a function of emotional valence. In the experiment, participants were asked to make self-judgments in response to positive traits and negative traits according to their present, past, and future selves. The past self was operationalized as the self 5 years ago, the present self was defined as the self in college and the future self was operationalized as the self 5 years in the future.

The sample was comprised of 17 sophomore or junior undergraduates (nine women, eight men) aged 19–22 years (mean age, 20.4 years) from Southwest University in Chongqing, China. All participants engaged in the experiment as paid volunteers. The selection of sophomore or junior undergraduates ensured the sample had undergone the important transition [4], from high school 5 years ago and would typically experience a transition into the workforce during the next 5 years. All participants provided written informed consent, were right-handed, had no history of current or past neurological or psychiatric illness, and had normal or corrected-to-normal vision.

Stimuli were 80 trait adjectives [40 positive and 40 negative] selected from Anderson's word list [1], and translated into Chinese. In light of possible cultural differences, word stimuli were selected to correspond to those found in a published Chinese word database, wherein Huang and Zhang provided ratings of the familiarity, meaningfulness and valence of positive and negative trait adjectives [9]. Independent-samples *t*-tests showed the positive and negative traits did not differ with regard to familiarity ($M_{\text{positive traits}} = 3.45$, s.d. = 0.35; $M_{\text{negative traits}} = 3.38$, s.d. = 0.09; $t = 1.25$, $p = 0.216$), meaningfulness ($M_{\text{positive traits}} = 3.13$, s.d. = 0.23; $M_{\text{negative traits}} = 3.11$, s.d. = 0.09; $t = 0.55$, $p = 0.588$) or strokes in writing the Chinese character ($M_{\text{positive traits}} = 25.33$, s.d. = 5.03; $M_{\text{negative traits}} = 25.53$, S.E. = 4.56; $t = -0.19$, $p = 0.853$). However, as expected, there was a significant difference in emotional valence of adjectives ($M_{\text{positive traits}} = 5.61$, s.d. = 0.24; $M_{\text{negative traits}} = 2.72$, s.d. = 0.46; $t = 35.64$, $p < 0.001$).

Participants made self-judgments on the same set of adjectives in three conditions. Specifically, they were asked to decide whether or not the 80 adjectives described their characteristics 5 years ago (past self), their current characteristics (present self) and their characteristics 5 years into the future (future self) two times within each condition (i.e., 160 trials per condition). Within each condition, there were four blocks of 40 trials each. The interval between trials was 1000–1500 ms. Conditions and blocks were presented in random order.

A self-reference paradigm was employed in our study. Before initiating each condition, participants were asked to describe the corresponding temporal self for 2 min to evoke that temporal self. For example, in the "past self" condition, participants were instructed to describe in writing their image of the self from 5 years earlier. Subsequently, each trial of the self-reference task followed. First, a fixation point appeared for 800–1000 ms in the center of the screen and was followed by a temporal self for 250 ms, including "the self 5 years ago", "the self at college" and "the self 5 years from now". Next, after a 400–800 ms interval, a trait adjective was presented for 3000 ms. Participants were asked to make respond as accurately and quickly as possible regarding the extent to which each adjective described their past, present or future self on a 3-point rating scale (0, not suitable; 1, uncertain; 2, suitable).

Brain electrical activity was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (Brain Product, Munchen, Germany), with the reference on left and right mastoids. The vertical electro-oculogram was recorded with electrodes placed above and below the left eye. All interelectrode impedance was maintained below 5 kΩ. The electroencephalogram (EEG) and electro-oculogram were amplified using a DC—100 Hz bandpass and continuously sampled at 500 Hz/channel for off-line analysis. Eye movement artifacts (blinks and eye movements) were rejected off-line.

EEG of positive and negative past, present, and future selves were overlapped. The averaged epoch for ERPs was 1200 ms including a 200 ms pre-response baseline. As shown by ERPs grand averaged waveforms and topographical map (see Fig. 1), negative traits elicited more positive deflections than did positive traits in the past and present self conditions. Moreover, these differences were largest at central-parietal sites. Thus, the following 9 electrode points were chosen for three-way repeated-measures analyses of variance (ANOVAs). The ANOVA factors were temporal self (past versus present versus future), valence (positive versus negative) and electrode site (Cz, C3, C4, CPz, CP3, CP4, Pz, P3, P4). For all analyses, p values were corrected for deviations according to the Greenhouse–Geisser method.

Two-way repeated-measures analysis of variance (ANOVA) with temporal self (past versus present versus future) and valence (positive versus negative) as within-participant factors was performed on response time and ratings separately.

Two-way repeated-measures ANOVA on adjective ratings yielded a main effect of valence, $F(1, 16) = 201.56$, $p < 0.001$; and an interaction between temporal self and valence, $F(2, 32) = 8.31$, $p = 0.01$. All other comparisons were not significant ($ps > 0.05$). A simple effects analysis of this interaction revealed the ratings of positive trait adjectives in the future self condition ($M = 140.94$, s.d. = 12.63) were significantly higher than those related to the past self condition ($M = 127.47$, s.d. = 19.72) ($p = 0.003$) or present self condition ($M = 130.47$, s.d. = 17.90) ($p = 0.006$), but there was a null effect for ratings of the past versus present self ($p = 0.403$). In addition, ratings of negative traits in the future self condition ($M = 24.35$, s.d. = 19.15) were lower than those regarding either the past self ($M = 40.94$, s.d. = 23.74) ($p = 0.01$) or present self ($M = 37.18$, s.d. = 23.13) ($p = 0.012$).

Two-way repeated-measures ANOVA on response time yielded main effects for valence, $F(1, 16) = 31.63$, $p < 0.001$; temporal self, $F(2, 32) = 4.96$, $p = 0.014$; and their interaction, $F(2, 32) = 4.40$, $p = 0.032$. None of the other comparisons was significant ($ps > 0.05$). A simple effects analysis on the interaction showed that for positive traits, RTs in the future self condition ($M = 825.65$ ms, s.d. = 125.58) were faster than those for past ($M = 961.25$ ms, s.d. = 214.03) ($p = 0.004$) or present ($M = 919.55$ ms, s.d. = 116.76) ($p = 0.042$) selves, which did not differ from one another ($p = 0.327$). RTs for negative traits paired with the future self ($M = 918.225$ ms, s.d. = 148.89) were also faster than those paired with the past self ($M = 1024.53$, s.d. = 212.32) ($p = 0.014$) or present self ($M = 1035.83$, s.d. = 192.56) ($p = 0.030$).

As shown in Fig. 1, the N1 (50–150 ms), P2 (150–300 ms), N2 (300–400 ms) and late positive component (LPC) were elicited by all three temporal self conditions (past, present, future).

Main effects for trait valence and temporal self were not significant for N1, P2 and N2. From ERP waveforms, we found that, relative to positive traits, negative traits for present and past selves elicited a more positive ERP deflection than for future self in the interval between 650 ms and 800 ms (LPC). Three-factor repeated-measures ANOVA on the amplitude of LPC yielded main effects for temporal self, $F(2, 32) = 13.61$, $p = 0.002$ and electrode site, $F(2, 32) = 4.25$, $p = 0.04$, as well as a temporal self $\times$ valence interaction, $F(2, 32) = 4.31$, $p = 0.025$. None of the other comparisons was significant ($ps > 0.05$). A simple effects analysis on this interaction indicated that the mean LPC amplitude elicited by negative trait adjectives was more positive than that elicited for positive adjectives when evaluating the present self ($M_{\text{negative traits}} = 6.34\,\mu V$, s.d. = 0.89; $M_{\text{positive traits}} = 4.16\,\mu V$, s.d. = 0.49, $F(1, 14) = 18.64$, $p = 0.001$) and past self ($M_{\text{negative traits}} = 6.02\,\mu V$, s.d. = 0.85; $M_{\text{positive traits}} = 4.66\,\mu V$, s.d. = 0.53, $F(1, 14) = 8.51$, $p = 0.036$), but there was no such difference in the future self condition ($M_{\text{negative traits}} = 5.43\,\mu V$, s.d. = 0.74; $M_{\text{positive traits}} = 4.92\,\mu V$, s.d. = 0.75, $F(1, 14) = 2.17$, $p = 0.160$). As shown in Fig. 1, regarding difference waves (negative present self minus positive present self), a voltage map of the difference wave highlighted increased activity in the central-parietal cortex. In contrast, neither the main effects nor the interactions for the mean amplitude of the late positive component between 400–650 ms and 800–1000 ms were significant.

The present results provide evidence for neural substrates of the temporally extended self as a function of emotional valence within a self-reference paradigm. Specifically, negative trait adjectives used to describe past and present selves elicited more positive ERP deflections than did positive trait adjectives in the interval between 650 ms and 800 ms (LPC). This pattern may reflect a negativity bias effect [11]. Notably, however, no such bias emerged in the future self condition. Thus, results provided evidence for differences in the processing of emotional valence for different temporal selves at not only behavioral but also electrophysiological levels.

The behavioral findings were in line with those of previous studies. Participants represented their past and present selves more slowly compared to their future selves. Moreover, although participants had consistently less negative and more positive views of themselves regarding each temporal self, these biases were much more prominent for the future self than past and present selves, a pattern observed in other research [17,13,21]. For example, in

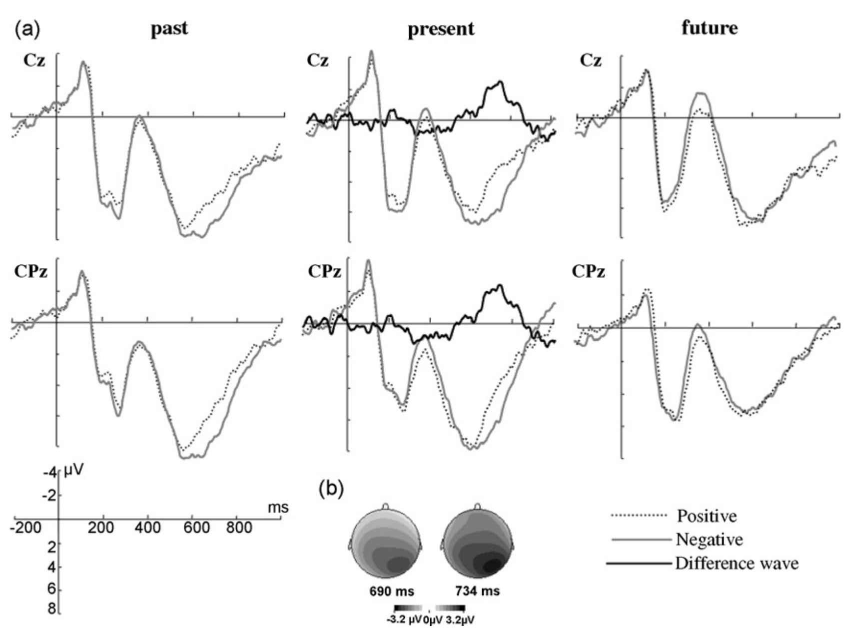

Fig. 1. (a) Grand average event-related brain potentials evoked by positive and negative traits for the past, present and future condition, and the difference wave (negative present condition–positive present condition) at Cz and CPz. (b) Topographical maps of the voltage amplitudes for the difference wave at 690 ms and 734 ms.

a study of autobiographical memory, university students asked to anticipate their future selves, endorsed positive over negative descriptions at an overwhelming rate [13].

In the ERP data, a significant interaction between temporal self and emotional valence was identified. From 650 ms to 800 ms after stimulus onset, amplitudes of LPC over central-parietal scalp locations became more positive for negative traits in the past and present self conditions, relative to ERPs for positive traits. In contrast, there was no such effect in LPC amplitudes elicited by negative versus positive traits for the future self condition.

Previous ERP research indicates LPC can be elicited by a variety of emotional stimuli including words [12], sentence [8], faces [20] and pictures [11,10]. In one such study, wherein participants viewed positive, negative and neutral pictures using an oddball paradigm [11], larger amplitude LPCs emerged during the evaluative categorization of negative stimuli compared to positive stimuli. Thus, emotional LPC is regarded as a later component related to evaluative meaning [10]. It is well known that cognitive evaluation plays an important role the generation and regulation of emotion. In the evaluative stage, information is represented and analyzed more fully, with more past or recent experiences referenced. As outlined above, there appear to be different motivation systems for processing positive versus negative information [2]. Given the implications of negative environmental events for survival and daily life, negative information recruits more physiological and psychological resources [10].

One possible interpretation of this result is that the LPC amplitude LPC reflects the modulation of negative information processing in different temporal conditions. When individuals evaluate their future self, positive expectations may predominate over negative expectations, as evidenced by data from behavioral and neuroimaging studies [17,13,21,6]. In general, people's thoughts about the future are dominated by desirable goals and plans. Negative views of the future may arise in the face of immediate threats but are more transitory and end as the danger passes [17]. Hence, fewer cognitive resources may be directed, typically, to processing negative information regarding the future. This contention is supported by Sharot et al.'s fMRI study wherein imagining positive future events was associated with stronger associations in activity of the rostral of the anterior cingulate (rACC) and the amygdala compared to imagining negative future events [21].

In contrast with the future self, participant evaluations of past and present selves were associated with mixed emotions that included positive and negative descriptions of the self, perhaps because past and present evaluations were rooted more strongly in life experience than speculation or goals related to the future. D'Argembeau et al. provided indirect evidence for this idea. Following an fMRI session, their participants rated the frequency with which specific events came to mind while making judgments about past, present and future. They found frequency of recalling specific events was higher when making judgments regarding present and past selves than when making judgments about the future self; however, there was no recall difference between present and past self conditions [5]. Hence, specific events are more likely to be referenced when judging past and present selves. Revisiting Vaish and Grossmann [22] review may help to explain the salience of negative experiences. These authors concluded that adults display an adaptive, "negativity bias" reflected in their propensity to attend to, learn from, and use negative information far more than positive information. Although speculative, results of present study might suggest that this bias is rooted more strongly in lived experience than a hypothetical future that has yet to occur.

Aside from significant effects for the LPC component, null effects were observed for past, present and future self conditions in ERP components (i.e., P1, N1 and N2) attributed to early stages of visual and semantic processing. These findings may have been expected given that adjective lists were similar to one another in familiarity as well as composition and were constant across the three temporal self conditions.

To the best of our knowledge, this is the first study to employ ERPs to investigate neural substrates of the temporally extended self as a function of emotional valence. Results showed that, when evaluating present and past selves, negative self-descriptors elicited more positive ERP deflections between 650 ms and 800 ms (LPC) compared to positive self-descriptors. However, when evaluating the future self, no difference was found in mean LPC amplitudes evoked by negative versus positive trait descriptors. In sum, the observed behavioral and neurophysiological differences suggest that a negativity bias [11] may apply to past and present self descriptions but not those related to a more hypothetical future self. The time course of this bias may reflect the modulation of negative information processing in different temporal selves. Specifically, people had mixed emotions regarding their past and present self but were inclined to be more optimistic about attributes of their future selves.

In addition to the need for replications, there may be utility in extending future research to samples having clinical depression and/or anxiety-based disorders. The pattern of current results suggested participants showed negativity biases related to past and present selves as well as relatively more optimism and less pessimism about their future selves. Given evidence that the clinically depressed have negative views of the self, current experience and future [7], there may be value in testing the hypotheses that both behavioral responses and patterns of neurophysiological activation in these individuals reflect negativity about past and present selves that extends, in contrast to non-depressed samples, to the future self.

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