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Gender moderates valence effects on the late positive potential to emotional distracters

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HIGHLIGHTS

- Attention to emotional pictures was measured with ERPs (LPP).
- Valence and habituation were varied.
- Gender moderated valence effects on LPP (men showed a positivity bias).
- Habituation in LPP was slower for negative than positive pictures.

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ABSTRACT

Attention is captured more strongly by emotional pictures than by neutral pictures. This allocation of attention to emotional pictures is commonly indexed by the late positive potential (LPP). This event-related potential (ERP) is larger for negative and positive pictures than for neutral pictures. However, findings are mixed in regards to valence effects, that is, whether the LPP is larger for negative pictures than for positive pictures (negativity bias) or vice versa (positivity bias). Additionally, previous ERP studies have not explicitly considered a moderating effect of gender. In the present study, positive, negative, and neutral pictures were shown at fixation but were always task-irrelevant. Results showed that LPP amplitudes for the positive and negative distracters were moderated by gender. Men showed a positivity bias on the LPP (i.e., larger amplitudes for positive pictures than for negative pictures). Women did not show a clear valence bias on the LPP, but they showed a negativity bias on picture ratings. These gender differences for the LPP did not habituate, as they were obtained even for pictures that were repeated 20 times. Because previous studies with other measures suggest a positivity bias for men and a negativity bias for women, the present findings extend these studies suggesting that attention allocation for emotional pictures of different valence is similarly moderated by gender.

Although the human perceptual system has a limited capacity [20], selective attention helps in directing perceptual resources to task-relevant information at the expense of task-irrelevant information [19]. Some stimulus features, however, may be relevant to survival even though they are irrelevant to the ongoing task. Emotional stimuli are inherently survival-relevant and should capture attention regardless of whether the emotional stimuli are relevant to the task. In support of this, many behavioral studies have shown robust effects of emotion on attention [39]. The notion that effects on perceptual processing may be similar for emotion as for voluntary, directed attention has been referred to as motivated attention [16,17] or emotional attention [23].

Event-related potentials are a common method to examine motivated attention. Research indicates that when participants view emotional (i.e., pleasant or unpleasant) pictures and neutral pictures, they show a late positive potential (LPP) for emotional versus neutral pictures regardless of task relevance [26,27,37]. These findings are consistent with the view that the LPP indexes motivational significance or the degree to which selective attention is allocated incidentally or naturally to emotional pictures [2,22].

The *motivational model of emotion* [16,17] postulates that picture ratings of arousal reflect the degree to which attention is captured by negative pictures (mediated by a defense system) and positive pictures (mediated by an appetitive system). The defense system handles threatening stimuli (e.g., predators and conspecifics), whereas the appetitive system handles preserving stimuli (e.g., related to nurturing, ingestion, copulation) [16,17],

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and the amygdala plays a major role in both systems [23]. Notably, with increases in rated arousal, the defense system is believed to increase activation more strongly than the appetitive system, resulting in a negativity bias [4,6,14].

However, evidence for such a negativity bias for the LPP and other ERP measures is mixed. Whereas some studies found support for a negativity bias [9,14,15,31], many other studies found a positivity bias in which positive pictures elicited larger LPPs than negative pictures did [11,28–30]. Still other studies found no valence differences in ERPs [1,12,13,25,34]. A comparison of these studies does not show a clear pattern except that experiments with passive viewing, larger samples, and balanced gender groups resulted in a positivity bias or no bias at all [11–13,25,28–30,34].

Importantly, these studies did not explicitly consider gender differences with one exception [1]. The reported gender differences for LPP, however, are inconclusive because effects were obtained only for a nonstandard electrode (F7) and in opposite direction than expected (i.e., for women, amplitudes were apparently lower for positive than neutral pictures) [1]. However, consistent gender differences to emotional pictures have been found on self-reported ratings, and also on peripheral and central measures [3,4,33]. In reported arousal and valence ratings, women rated negative pictures as more arousing and unpleasant than men did, whereas men rated positive pictures as more arousing and pleasant than women did [4]. Also, women showed greater facial EMG activity, bradycardia, startle eye blink magnitude, and electrodermal reactivity to negative pictures, whereas men showed greater electrodermal reactivity to erotic pictures [3]. Furthermore, a large meta-analysis of fMRI studies ($n = 88$) found that women were more reactive to negative pictures whereas men were more reactive to positive pictures [33]. Taken together, research suggests that women tend to show a negativity bias whereas men tend to show a positivity bias.

Although clear gender differences have been observed on many measures, previous ERP studies on valence effects (i.e., negativity or positivity bias) have not explicitly considered effects of gender. To address this question, the present study recorded the LPP to positive, negative, and neutral pictures in a gender-balanced sample to examine the moderating role of gender on valence effects on the LPP. Pictures were shown at fixation, but they were always task-irrelevant to minimize confounding effects of gender differences in voluntary attention to the emotional pictures [21]. Habituation was also manipulated by showing the pictures either 20 times or 5 times [24]. Research suggests that emotional pictures do not easily lose their motivational significance. Specifically, LPP amplitudes are reduced by picture repetition but remain larger for emotional pictures than for neutral pictures despite substantial repetition [7,8,10]. Thus, the present design tested if gender differences in valence effects for the LPP would be observed even after extensive picture repetitions.

To conclude, we predicted that gender would moderate valence effects for the LPP and for the self-reported arousal ratings to emotional distracters, with men showing a positivity bias and women showing a negativity bias. We hypothesized that these effects would not habituate and thus, be apparent even after 20 picture repetitions.

Methods

Participants

Participants were recruited from the Psychology Department at Stockholm University. The final sample consisted of 34 students (17 men) with a mean age of 24.5 (SD = 5.5). Mean trait anxiety was 44.1 (SD = 9.6) and mean state anxiety was 35.0 (SD = 6.5) with no gender differences ($p > .50$) [32]. The study was approved by the regional ethics board and was conducted in accordance with the Helsinki declaration. Participants gave informed consent and received either course credit or two movie vouchers for participating.

Apparatus

Pictures were shown in color and were taken from the International Affective Picture Set (IAPS) [18]. From this set, 150 pictures were chosen to target one of three valence categories (50 pictures per category): neutral, positive, and negative. The pictures are further described in the supplementary methods section.

Pictures were shown on a 21″ View Sonic p227f CRT-screen with a refresh rate of 100 Hz and a resolution of 1280 × 1024 pixels. Picture size was 15.5 cm (11.1°) wide and 11 cm (7.9°) high. The background was dark gray. Viewing distance was 80 cm and was maintained with a chin rest, and the experimental software was Presentation 14.8 (Neurobehavioral Systems, Albany, CA).

The EEG apparatus was an Active Two Biosemi system (Biosemi, Amsterdam, Netherlands) with 128 electrodes. Data were sampled at 512 Hz and filtered with a hardware low-pass filter at 104 Hz and an offline notch filter at 50 Hz.

Procedure

Each trial consisted of a 200-ms IAPS picture presented in the middle of the screen followed by a fixation cross for 1500–1800 ms. Participants were instructed that on some trials, two identical letters would be shown (to the left and right of fixation). Their task was to push the left control button for N and the right control button for M. In one task, the letters were superimposed on the pictures, and in the other task, the letters were shown to the left and right of the pictures. Each task consisted of two picture conditions: *repeated* (i.e., pictures were repeated 20 times) and *new* (i.e., pictures were repeated 5 times). Order of task and condition was counterbalanced (Latin square) across subjects. For each subject, the picture set of 50 pictures per emotion (neutral, positive, and negative) was randomly divided into two sets of 25 pictures, one for each task. Within each task, the 25 pictures from each category were further divided randomly into a set of 5 pictures for the repeated condition and a set of 20 pictures for the new condition.

Each picture condition consisted of four blocks. In the repeated condition, the same 5 pictures in each category were used in each of 4 blocks so that each block consisted of 75 trials: 3 emotions, 5 pictures per category, and 5 repetitions. The new condition differed from the repeated condition only in that 5 different pictures from each category were used in each block (i.e., 5 repetitions vs. 20 repetitions in the repeated condition). Within each block, trial order was randomized for each subject. Letters were shown together with the picture on 20% of the trials (in each task), and no letter was shown in the remaining 80% of trials. After the four blocks, participants rated each IAPS picture (200 ms) on valence and arousal [5].

Data analysis

BESA software (version 5.3.7, Besa Software GmbH, Gräfelfing, Germany) was used for offline processing, and the EEG data were processed as in previous studies [36–38]. ERP epochs were extracted (only for trials without letters and without button presses) from 100 ms before to 850 ms after picture onset (−100 to 0 ms was used for baseline correction). Data were re-referenced to the arithmetic average of all electrodes. Grand mean difference waves between emotional (positive and negative combined) and neutral pictures across conditions showed that the LPP was maximal in the 400–600 ms range after stimulus onset on centroparietal electrodes (A01-A05, A19, A32, B01, B02, C01, D01, D15 and D16, which cover the area from Cz to CP1/CP2 to P1/P2)[36–38].

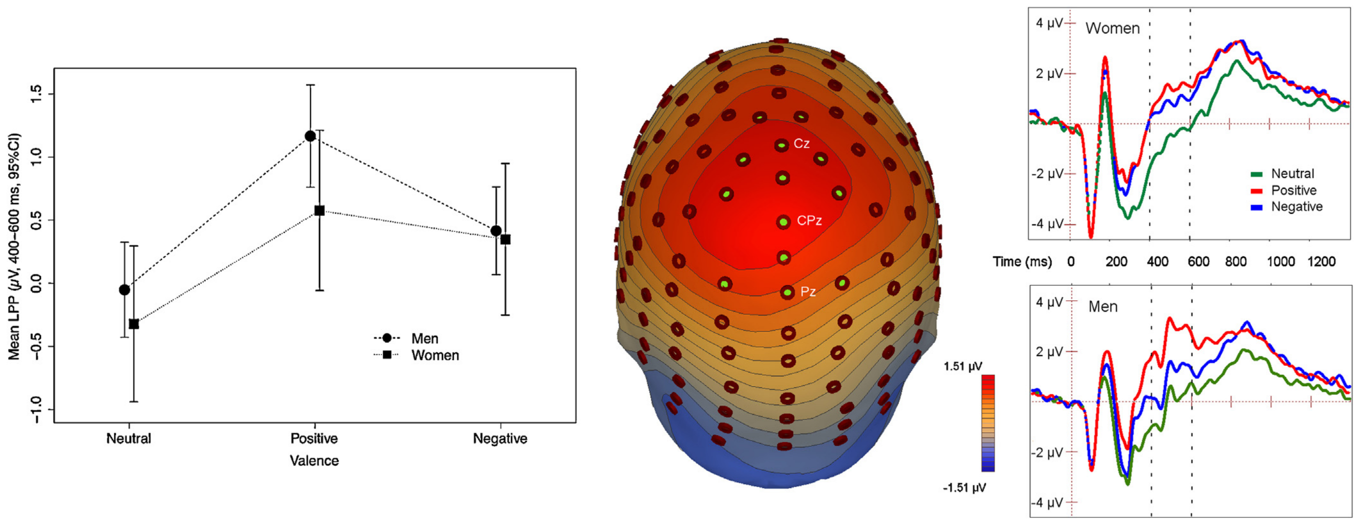

Fig. 1. The left panel shows mean late positive potential (LPP) amplitudes (400–600 ms, ±95% CI) for neutral, positive, and negative pictures by gender. The middle panel shows the topography of the mean amplitude difference between 400 and 600 ms for emotional pictures versus neutral pictures across tasks and conditions. The green dots show the LPP-relevant electrodes that were combined to compute mean LPP amplitudes in the left and right panels. The right panel shows the mean ERP waves for neutral, positive, and negative pictures across the LPP-relevant electrodes, separately for women (top) and men (bottom) across tasks and conditions.

Mean amplitudes were extracted across these electrodes for this interval.

The emotion ratings and LPP amplitudes were analyzed separately in a mixed-design ANOVA with the between-subjects variable gender and the within-subjects variables: task (letters on picture or outside picture), emotion (neutral, positive, negative), repetition (repeated, new), and block (1–4). Additional ANOVAs showed that state or trait anxiety as covariates did not change the results. We also extracted P1 and EPN amplitudes and performed similar analyses as for the LPP [38]. Because effects of emotion did not interact with either gender, or repetition, or both, these results are not reported. Further, preliminary analyses showed that task performance was near ceiling in both tasks ($d' > 4.04$). Because the ANOVAs showed that neither task nor block interacted with any variable of interest, their effects are not reported below. ANOVA results were Greenhouse–Geisser corrected, but uncorrected *df*s are shown. Significance level was alpha < .05, two-tailed.

Results

Results for LPP amplitudes and emotion ratings are shown in Figs. 1–3. Note that for each subject, the IAPS pictures from each valence category were assigned randomly to different conditions (of task and repetition). Therefore, LPP amplitudes and emotion ratings refer to identical pictures within a subject but to different pictures across subjects.

Late positive potential

The left panel in Fig. 1 shows LPP-relevant mean amplitudes for the three emotions, for women and men separately. The mixed-design ANOVA of these amplitudes showed an interaction of gender and emotion (neutral, positive, negative), $F(2, 64) = 5.04$, $p = .013$, $\eta_P^2 = .14$. This effect was mainly driven by an interaction between gender and valence (positive, negative), $F(1, 32) = 7.26$, $p = .011$, $\eta_P^2 = .19$. For men, amplitudes were larger for positive pictures than for negative pictures, $F(1, 16) = 30.25$, $p < .001$, $\eta_P^2 = .65$. For women, amplitudes did not differ between positive and negative pictures, $F(1, 16) = 2.74$, $p = .117$, $\eta_P^2 = .15$. Note that an analysis of only the data from the repeated conditions (i.e., 20 picture repetitions) yielded similar findings. In this condition, the interaction between gender and valence (negative, positive) was significant, $F(1, 32) = 6.29$, $p = .017$, $\eta_P^2 = .16$. For men, amplitudes were larger for positive than for negative pictures ($p = .002$), whereas for women, amplitudes did not differ between positive and negative pictures ($p = .74$).

The ANOVA also showed an interaction between emotion and repetition, $F(2, 64) = 6.21$, $p = .004$, $\eta_P^2 = .16$. Importantly, this interaction was not qualified by a higher-order interaction with gender, $F(2, 64) < 1$, $p = .82$, $\eta_P^2 = .01$. The emotion by repetition interaction is illustrated in Fig. 2. Mean amplitudes decreased from the new condition to the repeated condition more strongly for positive pictures than negative pictures, $F(1, 32) = 4.45$, $p = .043$, $\eta_P^2 = .12$, and more strongly for positive pictures than neutral pictures, $F(1, 32) = 14.89$, $p = .001$, $\eta_P^2 = .32$. Effects of repetition did not differ between negative and neutral pictures, $F(1, 32) = 1.30$, $p = .262$, $\eta_P^2 = .04$.

Arousal and valence ratings

The left panel of Fig. 3 shows arousal ratings for the three valence categories, for women and men separately. The mixed-design ANOVA of arousal ratings showed an interaction of gender

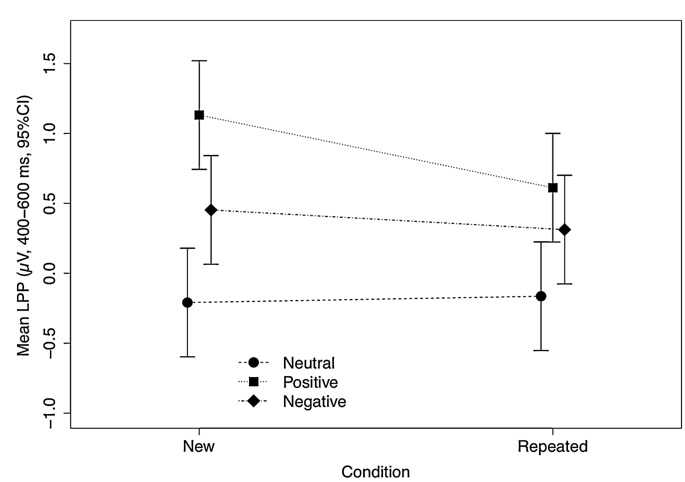

Fig. 2. Mean LPP amplitudes for neutral, positive, and negative pictures, separately for new and repeated pictures.

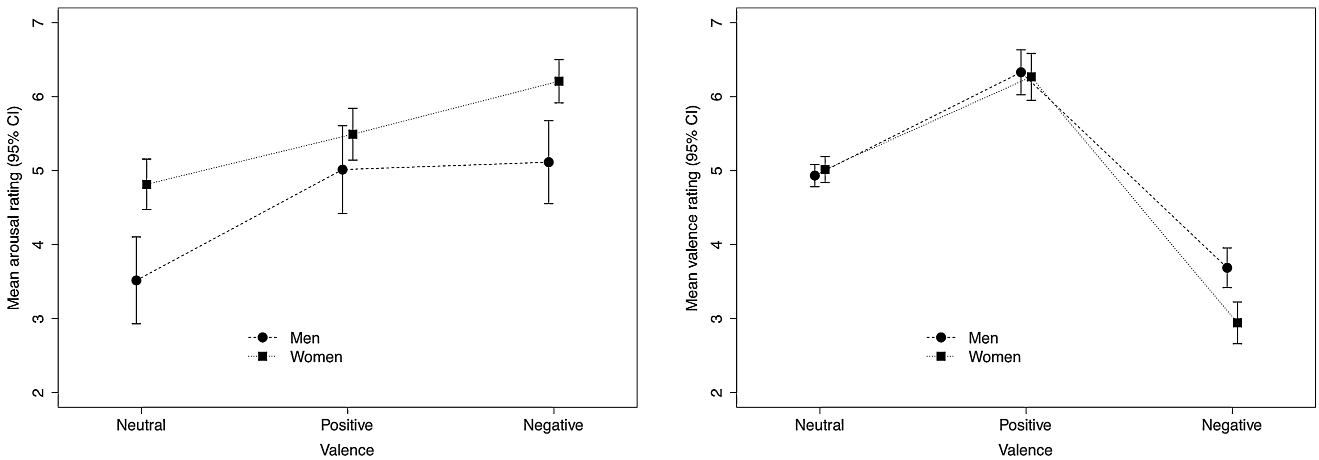

Fig. 3. The left panel shows mean observed arousal ratings (±95% CI) for neutral, positive, and negative pictures by gender. The right panel shows mean observed valence ratings.

and emotion (neutral, positive, negative), $F(2, 64) = 4.07$, $p = .028$, $\eta_p^2 = .11$. The interaction between gender and emotion (negative, positive) was also significant, $F(1, 32) = 5.71$, $p = .023$, $\eta_p^2 = .15$. For men, arousal ratings did not differ between negative and positive pictures, $F(1, 16) < 1$, $p = .61$, $\eta_p^2 = .02$. For women, arousal ratings were larger for negative pictures than positive pictures, $F(1, 16) = 17.85$, $p = .001$, $\eta_p^2 = .53$. The ANOVA showed that the gender by emotion by repetition interaction was not significant, $F(2, 64) = 2.18$, $p = .12$, $\eta_p^2 = .06$, but that the emotion by repetition interaction was significant, $F(1, 32) = 3.37$, $p = .041$, $\eta_p^2 = .09$. This suggests that emotional pictures were rated as less arousing if they were repeated rather than new.

The right panel of Fig. 3 shows valence ratings for the three valence categories, for women and men separately. The mixed-design ANOVA of valence ratings showed an interaction of gender and emotion, $F(2, 64) = 4.93$, $p = .024$, $\eta_p^2 = .13$. Women rated negative pictures as more unpleasant than men did ($p < .001$, $\eta_p^2 = .32$) but gave similar ratings for neutral and for positive pictures ($p > .48$). The ANOVA showed that the gender by emotion by repetition interaction was not significant, $F(2, 64) < 1$, $p = .45$, $\eta_p^2 = .03$, but that the gender by repetition interaction was significant, $F(1, 32) = 4.75$, $p = .037$, $\eta_p^2 = .13$. This suggests that women tended to rate pictures as less pleasant if they were repeated rather than new, whereas men tended to show the opposite pattern.

Discussion

The main finding of this study was that valence effects on LPP amplitudes and on emotion ratings were moderated by gender. Men showed larger LPP amplitudes for positive pictures than for negative pictures (i.e., positivity bias), whereas women did not show differences in LPP amplitudes for positive and negative pictures. However, women showed a negativity bias on arousal ratings in that they rated negative pictures as more arousing than positive pictures. Notably, the gender differences for the LPP showed no evidence of habituation even when the pictures were repeated 20 times.

Our findings of gender effects extend previous ERP studies on valence effects for emotional pictures [9,11–15,25,28–31,34]. Specifically, our findings demonstrate that attention allocation to emotional pictures of different valence is moderated by gender, similar to other processes that have shown gender differences [3,4,33]. Thus, any study on emotion needs to consider whether gender may have a potentially confounding effect if this variable is uncontrolled. Further, research needs to resolve the actual mechanism for effects of gender. On one hand, gender per se may not cause these differences but may be a marker for other individual differences (e.g., in emotion regulation and personality) [35]. On the other hand, the ultimate causes of these gender differences may be biological influences (e.g., genetic, hormonal) and environmental influences (e.g., social, cultural) or a combination of both, but their different contributions have not yet been isolated [33].

As an additional finding, the general habituation effects on the emotional LPP varied with valence, but this effect was not moderated by gender. As in previous studies, LPP amplitudes were larger for both positive and negative pictures than for neutral pictures, and this emotional modulation habituated with picture repetition but remained significant even after 20 repetitions [7,8,10]. However, the present results suggest that this habituation effect varies with valence, as LPP amplitudes decreased more strongly for positive pictures than for negative pictures. These differences were not moderated by gender. These findings support the notion of a negativity bias [4,6,14] but in terms of habituation: Although overall LPP amplitudes may not show a negativity bias, LPP amplitudes may resist habituation more strongly for negative pictures than for positive pictures. If so, motivational significance may be maintained longer for negative pictures than for positive pictures, presumably because of the greater survival relevance of negative stimuli than positive stimuli [16].

To conclude, valence effects on the LPP for emotional pictures were moderated by gender. Men showed a positivity bias for the LPP, and although women did not show a clear valence bias for the LPP, they showed a negativity bias on picture ratings. Notably, the gender differences for the LPP were obtained even for pictures that were repeated 20 times. Because previous studies with other measures suggest a positivity bias for men and a negativity bias for women, the present findings extend these studies suggesting that attention allocation for emotional pictures of different valence is similarly moderated by gender. Furthermore, because the LPP habituated more strongly for positive pictures than for negative pictures, a negativity bias may be present during habituation.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.neulet.2013.07.018.

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