The Late Positive Potential and explicit versus implicit processing of facial valence

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Running title: Implicit and explicit emotional face processing

Character count: about 18,000 characters

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Abstract

The Late Positive Potential (LPP) depicts brain electrical activity during both automatic and controlled sustained attentional processing of emotional stimuli. We investigated in a sample of 18 healthy women how the LPP is modulated by facial expression during an explicit valence rating task and an implicit gender classification task. Midline LPP amplitudes were significantly larger for valence rating than for gender classification. During valence rating, faces with a positive valence resulted in larger LPP amplitudes at centrofrontal electrodes than faces with a negative valence. During gender classification, a similar valence effect was observed at midline parietal electrodes. This implicit LPP valence effect appears to depend on higher visual processing, as during an additional gender classification task with blurred faces no such implicit valence effect was found.

Key Words: Event-related brain potentials; valence, emotion, faces, directed attention, motivated attention

Introduction

Facial expressions play an important role in human social interaction. Numerous Event-Related Potential (ERP) studies have investigated the processing of facial emotional information in the human brain. Notably, the modulation of early (< 200 ms after stimulus onset) ERP deflections, such as the face-specific N170, by the processing of facial expression has been studied [1]. Here we investigated the modulation of the late (>300 ms) positive ERP deflection, which we call the Late Positive Potential (LPP, cf. [2]). In contrast to the early ERP deflections, the LPP is not much studied in the context of facial expression.

The LPP is larger (i.e., more positive-going) when people watch arousing, motivationally significant stimuli, such as affective pictures, than when they watch neutral stimuli. The larger LPP deflections may last for hundreds of milliseconds or, depending on the duration of the emotional stimulus, even seconds [3]. As these stimuli automatically draw attention and are preferentially processed by the human brain, the LPP is thought to reflect motivated attention [4,5].

The LPP is not only sensitive to automatic, bottom-up attention but also to controlled, top-down attention to emotional information. For instance, when people knowingly attend to the non-affective features of emotional stimuli (e.g., [6,7]) or lower the emotional impact of such stimuli by reappraisal [8], the LPP is less positive-going than when they spontaneously watch emotional stimuli.

In addition, the LPP is modulated by the affective valence of emotional stimuli. Cutberth et al. [3], in their seminal research on brain potentials in affective picture processing, found larger LPP deflections for pleasant than for unpleasant pictures in the 300-700 ms time window. Delplanque et al. [9] found a similar result in the 439-630 ms time window. It should be noted however, that LPP valence effects are less consistently reported than arousal effects [see for review, 10].

As both automatic and controlled attentional processes modulate the LPP, the question arises to what extent LPP amplitudes in response to emotional faces are attenuated when facial expression is to be ignored. Evidence for the existence of implicit processing of facial valence has been found in a PET study of Morris et al. [11] in which participants had to perform a gender classification task with happy and fearful male and female faces. Although their participants paid no attention to the facial expressions, neural structures responded differentially to happy and fearful expressions.

In the present study, participants rated the emotional valence or the gender identity (male or female) of the same set of faces in separate tasks. During the valence rating task, participants rated neutral and emotional faces as either ‘positive’ or ‘negative’. Such a two-alternative forced choice paradigm has been used successfully in previous behavioral studies [e.g., 12,13] and elicits more top-down affective processing than for instance the passive viewing of facial expressions. During the gender rating task, participants classified the gender identity of the faces and could ignore the affective information. To examine implicit processing of facial valence, the individual’s valence ratings from the explicit valence rating task were used to divide the ERP epochs of the gender classification task into “positive” and “negative”.

Fast detection of facial expression may entail coarse processing, but sustained processing of facial expression most probably involves detailed visual analysis. [14]. To examine whether implicit sustained processing is based on such detailed analysis, we had our participants also classify the gender of the same faces when these were blurred. Since blurring removes featural information, detailed facial expressions will be harder to observe in later processing stages (see [15]).

Given the differences in emotional salience between the three tasks, we expected the largest LPP amplitude for the explicit emotional rating task, and the smallest amplitude for the blurred gender classification task. Further, we expected the largest LPP valence effects (‘positive’ vs. ‘negative’ faces) for explicit valence rating, smaller valence effects for nonblurred gender classification, and smallest or no valence effects for blurred gender classification.

Method

Participants

Eighteen healthy female university students volunteered for the experiment and were paid for their participation. They ranged in age from 18 to 29 years, with a mean age of 23.0 years. All participants had normal or corrected-to-normal vision and were right-handers by self-report. The study was carried out in accordance with the guidelines of the local psychology ethics committee.

Stimuli

Stimuli were 20 pictures of male and female faces taken from the Amsterdam Neuropsychological Tasks battery [16,17]. Figure 1 shows examples of the stimuli. The color pictures were taken from 4 different persons (2 men, 2 women) posing 5 different emotions (happiness, surprise, neutral, fear, disgust). One woman and one man had long hair, the other woman and other man had short hair. In addition, the same 20 faces were blurred by means of Gaussian blur (radius 7 pixels, each picture was 240 x 272 pixels). There were 60 trials in each of the three task conditions described below. In each trial, one of the faces was presented (12.8 x 14.5 cm) in the middle of a 17-in. CRT screen on a grey background. In the present experiment, we employed recurring facial stimuli. Repetition might modulate the emotional impact of the stimuli, but previous studies have demonstrated that for later ERP components stimulus repetition and affective category do not interact [18,19].

*** Fig 1 about here***

Procedure

The ERPs were recorded during three blocked conditions: (1) the explicit valence rating condition, in which participants had to rate the emotional valence of non-blurred faces, (2) the blurred gender classification condition, in which participants had to identify the gender of blurred faces, and (3) the non-blurred gender classification condition in which participants had to identify the gender of non-blurred faces. Half of the participants received the three blocks in this order, the other participants received the blocks in reversed order. Note that all participants started with a non-blurred condition. In this -not strictly counter balanced- design the explicit valence rating task equally often preceded as followed the gender classification task in non-blurred conditions, while the blurred condition equally often preceded as followed the nonblurred condition within the gender classification tasks. In the explicit valence rating condition, the participants were asked to rate the faces as either positive or negative. We employed this two-alternative forced choice paradigm to emphasize top-down evaluative processing (see above) and to have the same response type (dichotomous button press) as for the gender classification tasks.

The sequence for each trial was: (1) the presentation of a 500 ms visual warning signal -! ! !- in the center of the screen, followed by (2) a 500 ms blank screen, (3) the presentation of a white fixation cross in the center of the screen with a variable duration of 900 to 1100 ms, (4) the 150 ms presentation of a face in the center of the screen, (5) the 1250 ms presentation of the fixation cross, and finally (5) a response-selection screen that prompted participants to make a (nonspeeded) male/female or positive/negative decision which terminated the trial. The interval between the end of one trial and the beginning of the next trial lasted 1500 ms.

Participants were seated in an electrically-shielded, sound attenuated, and dimly-lit chamber at a distance of approximately 150 cm in front of a monitor. They were told that for each trial, they had to indicate whether the face was male vs. female or positive vs. negative by pressing response buttons bimanually with the index or middle fingers, respectively. To minimize eye movement artifacts, the participants were instructed to avoid eye blinks during stimulus presentations (fixation crosses and faces). Preceding the experimental run, the participants received 12 practice trials for each condition with faces that were not used in the experimental run.

EEG recording

EEG activity was recorded from 30 Ag/AgCl electrodes positioned according to the International 10-20 System at Fz, FCz, Cz, CPz, Pz, Oz, FP1/2, F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P3/4, P7/8, and O1/2. The electrodes were embedded in an elastic cap (Quick-Cap, NeuroMedical Supplies). The EEG was referenced to the linked mastoids. Impedances of the EEG electrodes were kept below 5 kOhm. Electro-oculogram (EOG) activity was recorded from electrodes placed above and beneath the left eye, and from electrodes at the outer canthus of each eye. The EEG and EOG signals were amplified with a band pass of 0.15 to 70 Hz and digitized with a 500 Hz sampling rate (SynAmps amplifier, Neurosoft Inc.). Responses were recorded online along with the EEG data. The off-line processing of the EEG signals consisted of the correction for vertical ocular artifacts employing the regression approach of Semlitsch et al. [20] and the offline low pass filtering at 30 Hz (24 dB roll-off).

Data analyses

ERP epochs with a 1000 ms duration were extracted, beginning 200 ms prior to stimulus onset. The ERP signals were defined relative to the mean of this 200 ms prestimulus baseline period. Average ERPs were computed for each participant and for each task and valence condition. Faces rated as “positive” by a participant during the explicit valence rating condition made up the positive valence condition for that particular participant, not only for the explicit rating tasks but also for the blurred and nonblurred gender classification tasks. Faces rated as “negative” by a participant made up the negative valence condition for that participant. Epochs with incorrect responses and epochs with a baseline-to-peak amplitude larger than 100 µV on any channel (e.g., muscle artifacts) were excluded from averaging. For positive ratings, the mean numbers of valid epochs per condition were 20.4 (SD = 5.16) for explicit valence rating, 21.5 (SD= 6.40) for non-blurred gender classification, and 20.8 (SD = 5.85) for blurred gender classification. For negative ratings, the mean numbers of valid epochs per condition were 33.8 (SD = 6.73) for explicit valence rating, 33.7 (SD= 7.26) for non-blurred gender classification, and 33.2 (SD = 6.55) for blurred gender classification.

Comparable to previous ERP studies [e.g., 2], the LPP was quantified by mean amplitude measures for the 350-800 ms time window. Mean amplitude measures allow the comparison of ERP waveforms based on different numbers of trials [21].

Statistical analyses

The mean amplitude measures were analyzed using repeated measures ANOVAs with task (three levels: valence rating, nonblurred gender classification, blurred gender classification), valence (positive, negative), and topography (5 midline electrode sites) as factors within subjects. Where appropriate, F-ratios were tested with Greenhouse-Geisser corrected degrees of freedom.

Results

Behavioral data.

The mean accuracy for the gender classification task was 99.6% with normal faces and 99.5%. with blurred faces. With the two-alternative forced choice paradigm, the proportion of positive ratings across participants was .99 for happy faces, .49 for surprised faces, .36 for neutral faces, .04 for fearful faces, and .04 for disgust faces. The overall proportion of positive ratings equaled .39.

*** Fig 2 about here***

LPP

The upper part of Fig. 2 shows the grand-average ERPs at Fz, Cz, and Pz for “positive” and “negative” faces during the various task conditions. For the LPP area measure, there was a main task effect, F(2,34)= 18.11, *P*<.001, with the LPP being more positive during explicit valence rating than during both gender classification tasks (both *P* values = .001, Bonferroni adjusted). No LPP amplitude difference was found between blurred and non-blurred gender classification (*P*=.332, Bonferroni adjusted). In addition to further main effects for topography (*P*<.001) and valence

(*P*=.015) - which were less relevant for the present study – we found significant interactions of task and valence, F(2,34) = 4.34, *P* = .042, epsilon =.987, and of topography, task, and valence, F(8,136) = 3.43, *P* = .025, epsilon = .367 (see lower part of Fig. 2). Single electrode valence comparisons for each task revealed significant larger LPP amplitudes in response to positive versus negative faces at Pz (*P*=.032), CPz (*P*=.042), Cz (*P*=.001), FCz (*P*=.001), and Fz (*P*= .001) for the explicit rating condition and at Pz (*P*=.014), and CPz (*P*=.055, borderline significant) for the non-blurred gender identification task. For the blurred gender classification task, no significant valence effects were found at single electrodes (all *P* values >.367).

Discussion

During the explicit valence rating condition, participants rated the faces according to the emotion involved, with the proportion of positive ratings being highest for happy faces and lowest for fearful and disgust faces. This is in concurrence with a previous behavioral study, which also employed the two-alternative forced choice paradigm [12].

The LPP was significantly larger in the explicit valence rating condition than in the non-blurred and blurred gender identification conditions. This most probably reflects the participants' conscious and sustained attention to their emotional responses to the face pictures during the valence rating task. It could be argued that the larger LPP is a consequence of a possibly higher task difficulty for valence rating than for gender classification. In the present research however, participants made nonspeeded responses, starting 1250 ms after stimulus off-set, and in the explicit valence rating condition all responses were correct by definition. Therefore, we consider the augmented LPP amplitude as a consequence of increased emotional processing rather than greater task difficulty.

In the explicit valence rating condition, faces that were rated “positive” resulted in larger LPP amplitudes at midline electrodes than faces that were rated “negative”. This explicit valence affect had a centrofrontal maximum. ERP studies using non-facial emotional pictures, have also demonstrated centrofrontal [9] or more widely distributed [3] LPP valence effects, with positive valence resulting in larger amplitudes when compared to negative valence. Studies with facial stimuli however, have reported that angry expressions elicit larger LPP amplitudes compared to happy and neutral expressions (e.g., [22,23]). It should be noted that in the present study no angry faces were used. Differences in emotional expressions that were employed and differences in task characteristics (e.g., active valence categorizing vs. passive viewing) may account for the inconsistencies in valence effects between previous studies with facial stimuli and the present one.

During the gender classification of non-blurred faces, an implicit valence effect was observed at Pz and to a lesser extent at CPz. The shift in topographic voltage distribution of the valence effect (positive minus negative faces) with a centrofrontal maximum in the valence rating condition and a parietal maximum in the non-blurred gender classification condition suggests task-related differences in brain electrical activity with more frontal LPP modulation during explicit valence rating and more posterior LPP modulation during implicit emotional processing.

During the gender classification of blurred faces no valence effects were found. It therefore seems likely that the modulation of the LPP amplitude by implicit valence effects depends on detailed visual analysis. This makes sense within a framework in which both limbic and frontal structures are engaged in top-down modulation of extrastriate processing. For instance, the amygdalae may mediate early and obligatory neural responses to facial expressions (cf. [11]) and consequently influence later –more elaborate- visual processing by feeding back to the extrastriate cortex.

The two-alternative forced choice paradigm resulted in rating proportions of .39 for positive ratings versus .61 for negative ratings. Especially neutral faces were rated more frequently as “negative” than as “positive”. Hence, the LPP amplitude for negative trials might have been smaller because these trials more often contained neutral (i.e., less arousing) faces. However, further inspection of the data revealed that the modulation of the LPP was associated with the positive and negative valence ratings rather than with the facial expressions per se[1].

Here we found evidence of modulation of the LPP by both implicit and explicit emotional face processing. The outcome is consistent with previous ERP studies suggesting that the LPP reflects both automatic and directed attention to emotional visual stimuli [24]. The present results are consistent with the PET study

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[1] When we analyzed the LLP amplitudes in response to the facial expressions, irrespective of actual valence rating, we found the following mean LPP amplitudes (across midline electrodes and across conditions) for each expression. Neutral: 5.5 µV, surprise: 5.2 µV, fear: 5.3 µV, disgust: 6.4 µV, and happy: 6.3 µV. There were no significant interactions of task, topography, and/or expression. None of the mean amplitudes to emotional expressions was significantly different from neutral.

of Morris et al. [11] but inconsistent with the EEG study of Krolak-Salmon et al. [25], who found emotional modulation of late-latency ERPs (between 250-550 ms and 550-750 ms) only during explicit discrimination of facial expression, but not during gender classification. Krolak-Salmon et al. had ten participants make discriminations between five different facial expressions rather than give forced choice valence ratings. This procedural difference and the small sample size of the Krolak-Salmon et al. study may account for the discrepancy with the present study.

Conclusion

The present study demonstrated that the LPP is sensitive to both explicit and implicit processing of facial valence. The implicit LPP valence effect appears to depend on detailed visual processing, as during implicit emotional processing of blurred faces no differences in LPP amplitudes to positive and negative facial valence were found.

Figure Captions

Fig. 1. Examples of neutral, emotional, and blurred faces. The faces were taken from the Amsterdam Neuropsychological Tasks battery [16,17].

Fig. 2. Upper part: Grand-average ERPs (n = 18) from Cz and Pz for faces rated as “positive” or “negative” during the explicit valence rating task, and during nonblurred and blurred gender classification tasks. Negativity is plotted upwards. Lower part: Topographic distribution of the LPP (350-800 ms) valence effects. Dark medial regions indicate larger LPP amplitude for positive vs. negative faces. During explicit valence rating, valence effects were largest at midline frontal and central electrodes (Fz, FCz, Cz). During gender classification of nonblurred faces, implicit valence effects were largest across midline (centro)parietal electrodes (CPz, Pz). With blurred faces, no implicit valence effects were found.

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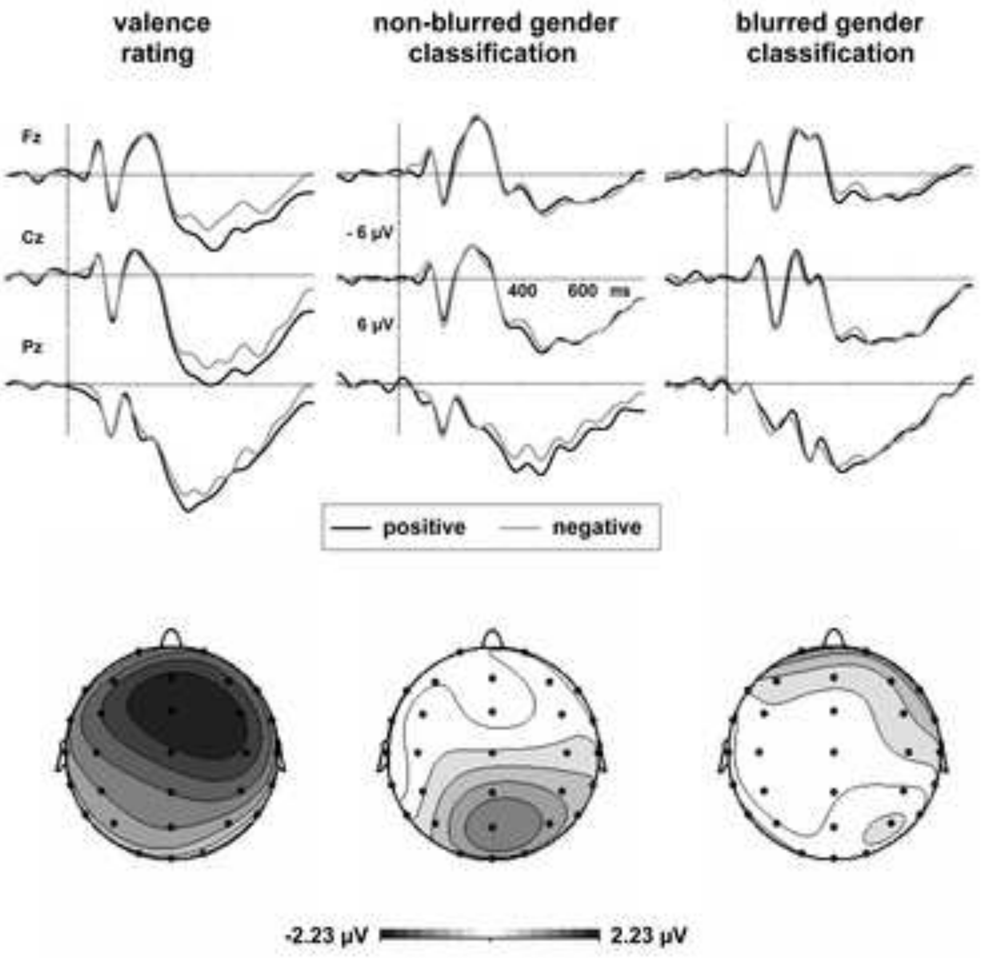
Figure 1

Figure 2


valence rating
non-blurred gender classification
blurred gender classification
Fz
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Pz
- 6 µV
6 µV
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ms
positive
negative
-2.23 µV
2.23 µV