Emotion

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BRIEF REPORT

Does Facial Action Modulate Neural Responses of Emotion? An Examination With the Late Positive Potential (LPP)

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The facial feedback hypothesis suggests that emotional facial action causally modulates the subjective experience of emotion. Notably, some proposed that facial action modulates emotional experience because it directly modulates neural responses of emotion. At present, the robustness of the facial feedback hypothesis has been debated. Moreover, little evidence exists for the direct modulation of neural responses by facial action. To fill these gaps, we tested whether facial action systematically modulates a well-validated electrocortical signature of emotional arousal, the late positive potential. Fifty-seven young adults rated the pleasantness of 180 pictures from the international affective picture system while holding chopsticks differently in their mouth to mimic either smiling or frowning expression. Their electroencephalogram was monitored. It was found that the frowning expression increased the late positive potential for negative pictures. In contrast, the smiling expression had no significant effect. Pleasantness ratings were also consistent with the facial feedback hypothesis. We concluded that the facial feedback effect is weak but robust. Critically, we presented the first evidence that facial action modulates an emotion-related neural response.

Keywords: facial feedback hypothesis, electroencephalogram, late positive potential

Supplemental materials: http://dx.doi.org/10.1037/emo0000717.supp

The facial feedback hypothesis suggests that facial action can modulate emotional experience (Izard, 1971; Strack, Martin, & Stepper, 1988; Tomkins, 1962). Theoretically, it is typically assumed that the effect of facial action on emotional experience is direct, unmediated by cognitive processes (but see Laird, 1974 for an alternative account). For instance, Tomkins (1962) and Izard (1971) argued that facial musculature gives direct feedback on subcortical and limbic structures, which are thought to affect the experience of emotion. Zajonc, Murphy, and Inglehart (1989) similarly argued that facial actions modulate the temperature of the blood flowing into the brain, which in turn changes hedonic experience. Empirically, a recent meta-analysis concluded that the effect is small, but reliable (Coles, Larsen, & Lench, 2019), consistent with a few recent studies showing such an effect under different conditions (Marsh, Rhoads, & Ryan, 2018; Noah, Schul, & Mayo, 2018). Thus, despite a recent large-scale replication effort that failed (Wagenmakers et al., 2016), the weight of positive evidence offers some credibility to the facial feedback effect. At present, however, it remains uncertain whether the effect is direct and thus unmediated by cognitive processes.

One reason for this uncertainty comes from the fact that nearly all evidence for the facial feedback hypothesis is based solely on self-report. Moreover, when neuroscience methods are used, the results have so far been inconclusive. In one study, intentional mimicry of angry faces increased the amygdala activation, which was eliminated by the botox treatment administered to the frowning muscle (Hennenlotter et al., 2009). Although the botox treatment might have effectively blocked the interoceptive signals from the face, it might have also made it apparent to the subjects that they were not able to frown. This cognitive appraisal could be responsible for the lack of increased amygdala activation. Another study using electroencephalogram (EEG) showed that when smile was blocked (with chopsticks held in the mouth), there was increased N400 in response to sentences with a positive ending (Davis, Winkielman, & Coulson, 2015). N400 is an electrocortical marker of perceived semantic incongruity (Kutas & Hillyard, 1980). It thus appears that blocking smile is associated with a reduced expectation for positive semantic information. Although consistent with the facial feedback hypothesis, this study focused on semantic processing. Thus, it is unclear whether the manipulation of facial action can affect noncognitive emotional processing.

To address the theoretical uncertainty, we assessed a well-validated electrocortical indicator of emotional arousal, the late positive potential (LPP). LPP is elicited by both positively and negatively arousing pictures (Cuthbert, Schupp, Bradley, Birbaumer,

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Data availability: https://osf.io/tjrs6/.

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& Lang, 2000; Schupp et al., 2000). Moreover, LPP amplitude correlates strongly with the activation of subcortical and corticolimbic regions in response to arousing stimuli (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012; Sabatinelli, Keil, Frank, & Lang, 2013). Of importance, an early component of LPP (before 1,000 ms poststimulus onset) is thought to reflect automatic emotional reactivity that is relatively free from conscious processing such as suppression and reappraisal (Foti, Hajcak, & Dien, 2009; Murata, Moser, & Kitayama, 2013). Following the pen procedure of Strack et al. (1988), we had participants hold a pair of chopsticks with their teeth (simulating a smile), with their lips (simulating a frown), or not hold the chopsticks (serving as control) as they were exposed to a series of emotional pictures of different valence. The goal was to see whether the experimentally manipulated facial actions modulate the LPP to the emotional pictures. We expected that the smile would amplify the LPP to positive pictures while inhibiting the LPP to negative pictures. Conversely, the frown was expected to increase the LPP to negative pictures while inhibiting the LPP to positive pictures. We also tested whether the facial actions affect the subjective rating of the pictures. Of note, we adopted a within-subject design with a large number of trials to increase the power of our design.

Method

Participants

Recent replication attempts of the facial feedback hypothesis used a between-subjects design and set the target of $N = 50$ per condition (Noah et al., 2018; Wagenmakers et al., 2016). Our work used a within-subject design and thus likely had far higher power. We thus considered the same N to be adequate. We recruited 57 undergraduate students by the end of the semester. Fifteen of them were excluded from the analysis because of a failure to meet a priori eligibility criteria for EEG study ($N = 4$), EEG system malfunctioning ($N = 2$), failure to follow instructions ($N = 1$) or complete the whole study ($N = 2$), or excessive artifacts in EEG recording ($N = 6$) (see below). Data, raw EEG files, and stimuli used in the present study are available at the Open Science Framework website: https://osf.io/tjrs6/. All participants provided informed consent, and the study was approved by the institutional review board of the university.

Procedure

Upon arrival at the laboratory, participants learned that the purpose of the study was to calibrate an EEG machine in the laboratory, and to help with the procedure, they would be asked to view a series of emotional pictures while generating different muscle noises on their face. A sheet demonstrating six different facial actions that allegedly would produce six unique patterns of muscle noise was then shown (see Figure 1). The participants were told that they would be randomly assigned to two of the six noise conditions. Unbeknownst to them, however, all participants were assigned to the two facial actions of interest in the present study—holding the chopsticks with their teeth (simulating a smile) and holding the chopsticks with their lips (simulating a frown). The experimenter guided them to hold the chopsticks in an appropriate fashion. Participants then were to go through 12 blocks, four during which they would hold one or the other facial action. The remaining four involved no chopsticks manipulation (control). At this point, they were seated approximately 60 cm from a color computer display on which the task would be delivered, and EEG electrodes were applied.

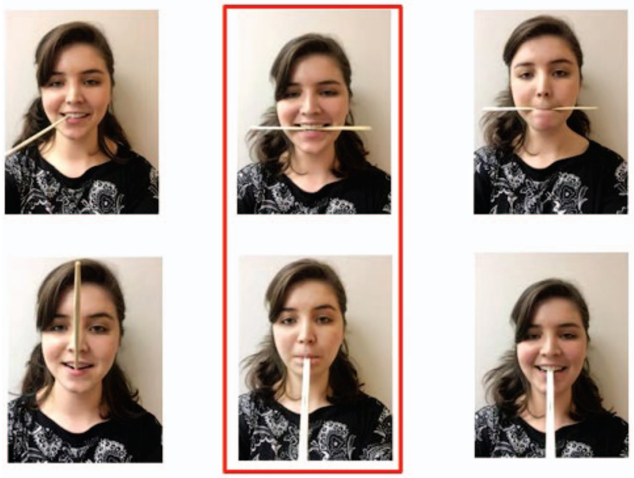

Figure 1. The graphical illustration of the six patterns of facial expressions used in the cover story. The critical ones (that participants were asked to imitate) are highlighted. Permission to include the faces in the publication has been granted by the person in the picture. See the online article for the color version of this figure.

Each trial started with a fixation cross (2,000 ms), followed by a blank screen (500 ms). A picture was then presented for 4,000 ms, after which a question appeared on the screen asking participants to report their subjective feeling toward the picture on a 9-point Likert scale (1, *extremely negative*, 9, *extremely positive*). They responded by pressing one of the number keys on the keyboard. The next trial started after the response. The task was preceded by 15 practice trials. They were asked to avoid eyeblink when the picture is on the screen and to view and focus on the picture the entire time it is on the screen. A Logitech web camera was used to monitor the participants during the entire task to ensure that they follow the instructions correctly.

Emotional Pictures

From the international affective picture system (Bradley & Lang, 2007), we selected 60 positive pictures ($M_{\text{valence}} = 7.27$, $M_{\text{arousal}} = 4.87$), 60 neutral pictures ($M_{\text{valence}} = 5.07$, $M_{\text{arousal}} = 2.90$), and 60 negative pictures ($M_{\text{valence}} = 3.05$, $M_{\text{arousal}} = 4.91$) such that the valence varied systematically, whereas arousal was set higher for both positive and negative pictures than for neutral ones. The total of 180 pictures was divided into three sets of 60 (with 20 in each valence condition), and each set was paired with one of the three facial action conditions (smile, frown, and control). The pairing was counterbalanced across participants. Within each facial action condition, the 60 pictures were divided into four blocks—two blocks of 10 positive pictures plus five neutral pictures, and two blocks of 10 negative pictures plus five neutral pictures. The presenting order of the 12 blocks in total (four smile blocks, four frown blocks, four control blocks) was pseudorandom, such that for every three blocks, participants were guaranteed to encounter one smile block, one frown block, and one control block in a random order. The pictures were presented randomly within each block.

EEG Data Recording and Processing

The EEG was recorded with a 32-channel BioSemi Active Two system (http://www.biosemi.com). An additional of six external electrodes were used for ocular correction and rereferencing. Impedances during data collection were kept under ±20 kΩ. The EEG data were recorded at 512 Hz and resampled at 256 Hz during data processing, and scalp electrodes were rereferenced to the average mastoids. An offline bandpass filter was applied with a lowpass of 20 Hz and a highpass of 0.1 Hz. Electrodes that did not have good recording over the entire task were interpolated using spherical interpolation. The data were then segmented into epochs of 200 ms before stimulus baseline and 2,000 ms after stimulus onset. Each trial was then baseline corrected. Ocular artifacts were corrected based on a commonly used algorithm (Gratton, Coles, & Donchin, 1983). Individual trials were rejected if for any scalp electrodes the peak-to-peak voltage exceeded 200 μV as determined by a 400-ms moving window with a 100-ms step, the fluctuation was greater than 30 μV between two sampling points, or there was little to no activity (±1 μV) over the entire epoch (Luck, 2014). Participants who had 50% or more trials rejected in any of the nine conditions (three facial actions × three valences of the pictures) were excluded from the data analysis. The LPP was quantified for each trial by averaging the amplitude at the Pz electrode with a time window of 600- to 1,000-ms poststimulus onset, and the LPP amplitude for each condition was calculated by averaging across trials.

Analytic Plan

LPP in response to positive versus negative pictures was assessed as a function of the two facial action conditions (smile vs. frown) in a 2 × 2 repeated-measure ANOVA. The control facial action condition and neutral picture condition were subsequently tested with paired-sample *t* test to sharpen the interpretation and verify manipulation. A similar set of analysis was performed on the subjective rating of pictures. We then tested whether there was an association between the LPP and the subjective rating of pictures, calculated at the trial level rather than subject level (see online supplemental materials for details). We also included in the online supplemental materials the full 3 × 3 repeated-measure ANOVA on both LPP and subjective rating.

Results

LPP Amplitude

The EEG waveforms at Pz site are shown in Figure 2A. A 2 (smile vs. frown) × 2 (positive vs. negative pictures) ANOVA on the LPP amplitude showed a significant two-way interaction between facial actions and valence of pictures, $F(1, 41) = 4.698$, $p = .036$, 95% confidence interval [CI: .146, 4.122], $\eta_p^2 = .103$. As shown in Figure 2B, when frowning, negative pictures elicited greater LPP than positive pictures, $t(41) = 2.105$, $p = .041$, 95% CI [.058, 2.835]. When smiling, however, the LPP amplitude was no different between positive and negative pictures, $t(41) = -.992$, $p = .327$, 95% CI [−2.086, .712]. The difference in LPP between positive and negative pictures in the control condition was negligible, $t(41) = -.506$, $p = .616$, 95% CI [−1.773, 1.063]. The LPP was substantially lower in response to neutral pictures than to positive or negative pictures, $t(41) = -4.601$, $p < .001$, 95% CI [−2.682, −1.046]; $t(41) = -5.350$, $p < .001$, 95% CI [−3.079, −1.391], respectively, collapsed across facial action conditions.

Self-Reported Ratings of Pictures

A 2 (smile vs. frown) × 2 (positive vs. negative pictures) ANOVA revealed a significant main effect of the valence of pictures on subjective rating of the pictures, $F(1, 41) = 688.259$, $p < .001$, 95% CI [4.350, 5.075], $\eta_p^2 = .944$, because positive pictures were rated higher in pleasantness than negative picture (*M*s = 7.130 and 2.418). There was also a marginal significant main effect of facial action on the subjective rating, $F(1, 41) = 4.030$, $p = .051$, 95% CI [–.0005, .154], $\eta_p^2 = .089$, suggesting that participants perceived the pictures to be more pleasant when smiling compared with when frowning (*M*s = 4.812 and 4.736). We also found a significant interaction between facial actions and valence of pictures on the ratings, $F(1, 41) = 7.904$, $p = .008$, 95% CI [.053, .321], $\eta_p^2 = .162$. Although participants perceived positive pictures to be more pleasant when smiling than when frowning (*M*s = 7.215 and 7.045, $t(41) = 3.349$, $p = .002$, 95% CI [.068, .273]), they did not perceive negative pictures to be less unpleasant when smiling than when frowning (*M*s = 2.410 and 2.426, $t(41) = -.330$, $p = .743$, 95% CI [–.119, .085]). The mean of the rating of positive and negative pictures in the control facial action condition falls in between the smile and frown condition ($M = 4.802$). Rating of the neutral pictures ($M = 5.096$) falls in between the positive ($M = 7.120$) and negative pictures ($M = 2.447$), collapsed across facial action conditions.

Correlation Between Subjective Rating of Pictures and LPP Amplitude

As expected, we found a significant curvilinear relationship between subjective rating and the magnitude of LPP at the trial level ($b = .110$, 95% CI [.042, .178], $t(573.4) = 3.182$, $p = .002$). As the rating became more extreme (i.e., more positive for the positive pictures and more negative for the negative pictures), the LPP increased significantly.

Discussion

Our work provides the first evidence that emotional facial actions are capable of directly modulating neural responses of emotion. We showed that the frowning expression increased the LPP for negative pictures relative to positive pictures. Although the smiling expression did not have a significant effect, the effect was in an opposite direction. Also, participants' rating of the pleasantness of the pictures revealed that the frowning expression resulted in lower ratings, relative to the smiling expression. Altogether, the observed pattern is consistent with the facial feedback hypothesis.

In the current procedure, holding chopsticks with lips (the frowning expression) effectively blocks smiles. However, holding them with teeth does not prevent one from contracting the corrugator supercilii muscle, the muscle used to frown, when facing negative stimuli. This

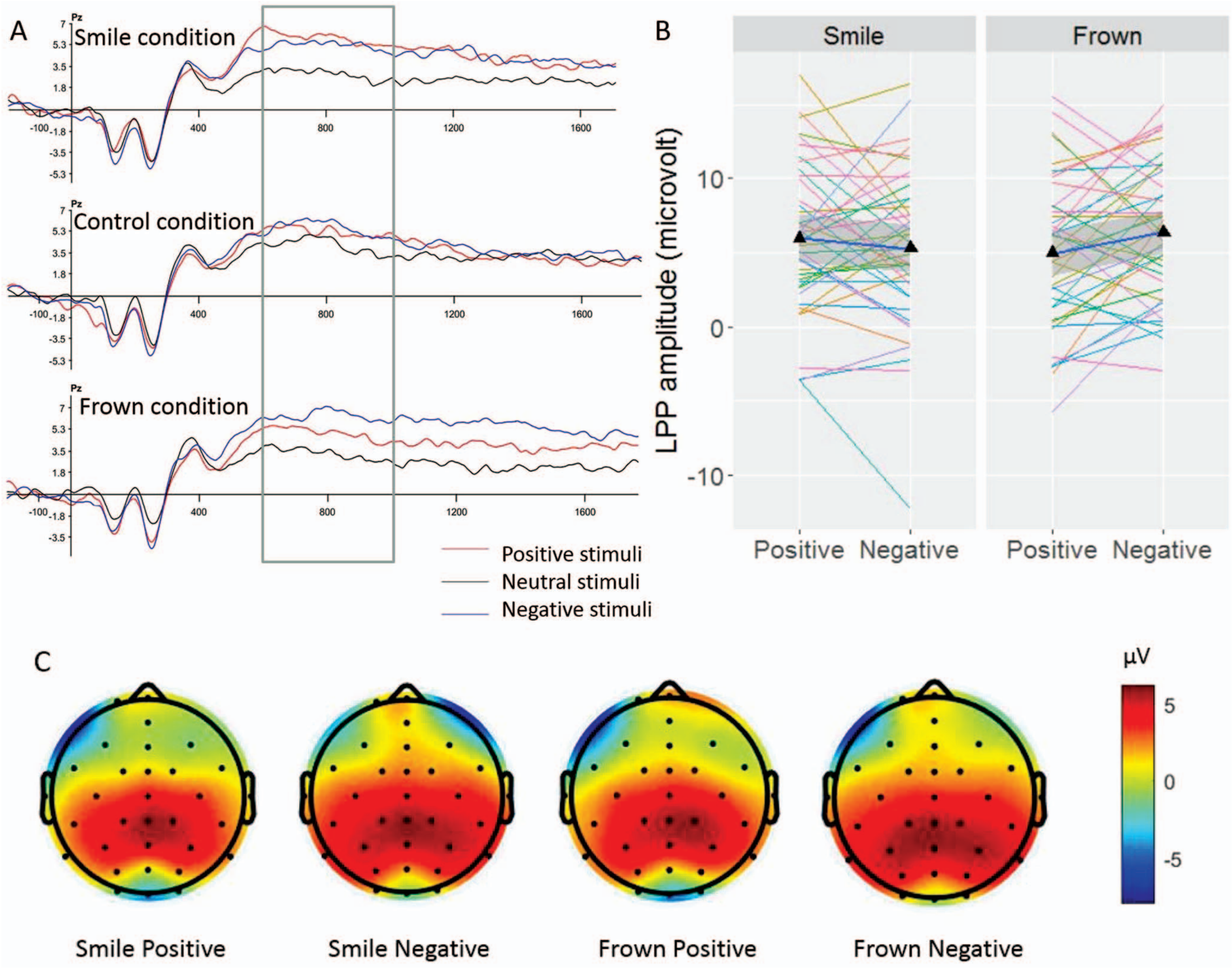

Figure 2. The effect of the facial action manipulation on the magnitude of early late positive potential (LPP). Waveforms in the three facial action conditions at Pz. The box indicates the time window analyzed (A). The LPP amplitude as a function of the four critical conditions defined by the facial actions (smile vs. frown) and the valence of the pictures shown (positive vs. negative). Each colored line indicates the LPP amplitude of a participant in response to positive versus negative pictures, under the smile and the frown condition. The black triangle represents the mean of the LPP amplitude in each condition. The shading represents standard error of the mean (B). Topographical distribution of the early LPP (600–1,000 ms) as a function of the four critical conditions defined by the facial actions and the valence of the pictures (C). See the online article for the color version of this figure.

might explain why the effect of facial action was clearer in the frowning expression condition than in the smiling expression condition.

We want to note a few limitations of the present work. First, the specific neural pathways underlying the current findings are unclear. For example, signals from the face may be relayed to brain stem nucleuses, which may in turn regulate emotional responses in the amygdala and prefrontal regions (Finzi & Rosenthal, 2016; Matsuo, Ban, Hama, & Yuzuriha, 2015). But more work is needed. Second, participants in the present study were aware that they were being observed by video camera throughout the study. The facial feedback effect might have been attenuated by this manipulation (Noah et al., 2018). Future work should test whether the facial feedback effect will be stronger when using a more covert recording procedure.

These limitations notwithstanding, the current study provides additional evidence for the facial feedback hypothesis. More importantly, the current evidence is the first to show that facial action modulates early neural responses of emotional arousal. We thus conclude that the facial feedback effect is alive, and plausibly noncognitive.

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