

Self-enhancement Influences Medial Frontal Cortex Alpha Power to Social Rejection Feedback

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Abstract

■ Although previous research has demonstrated that individuals are motivated to self-enhance, the neurocognitive mechanisms and temporal dynamics of self-enhancement are poorly understood. The current research examined whether self-enhancing motivations affect the perceptual processing of social feedback. Participants who varied in self-enhancement motivations received accept and reject feedback while EEG was recorded. Following this task, we measured perceptions of feedback by asking participants to estimate the number of

times they were rejected. Source localization and time–frequency analyses revealed that alpha power in the medial frontal cortex (MFC) completely mediated the relationship between self-enhancement motivations and rejection estimates. Specifically, greater self-enhancement motivations predicted decreased MFC alpha power to reject compared to accept feedback, which predicted decreased rejection estimates. These findings suggest that self-enhancement motivations decrease perception of social rejection by influencing how the MFC processes social feedback. ■

INTRODUCTION

Previous research has revealed that individuals across domains are motivated to see themselves in a positive light. For instance, 94% of college professors reported doing above-average work (Cross, 1977), most individuals considered themselves above-average drivers (Svenson, 1981), and surgeons overestimated the accuracy of their diagnoses (Oskam, Kingma, & Klasen, 2000). However, little is known about the neurocognitive mechanisms or temporal dynamics of these self-enhancing biases. For instance, it is unclear whether self-enhancing motivations influence ongoing perception of evaluative feedback or first emerge after consolidation of feedback. To better understand how self-enhancing motivations shape a person's conscious experience of the social world, the current research examined whether self-enhancement influences the perceptual processing of social feedback.

Self-enhancement and Perception

Self-enhancement refers to strategies that either diminish perceptions of negative attributes (i.e., self-protection) or augment perceptions of positive attributes (i.e., self-advancement; Sedikides & Gregg, 2008). Although both self-protection and self-advancement contribute to viewing the self positively, self-protection may be especially critical during perception, as negative feedback compared with positive feedback evokes stronger affective re-

sponses (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) and can quickly diminish self-esteem (Williams, Cheung, & Choi, 2000). Furthermore, individuals show strong motivation to protect self-esteem from decline but are not motivated to advance self-esteem beyond a satisfactory baseline (Tesser, Crepez, Collins, Cornell, & Beach, 2000).

Although previous work has conceptualized self-protection as emerging after the consolidation of negative feedback, an alternative and unexamined possibility is that this motivation alters ongoing perception of feedback. Indeed, perception and encoding are substantially influenced by top–down motivational factors (Engel, Fries, & Singer, 2001), and the motivation to maintain a positive self-image influences a variety of cognitive processes (Sedikides & Gregg, 2008). Furthermore, top–down attentional control is evident in electrocortical activity 100 msec following stimulus presentation (Rutman, Clapp, Chadick, & Gazzaley, 2009; Di Russo, Martínez, & Hillyard, 2003; Hillyard, Vogel, & Luck, 1998; Gomez-Gonzalez, Clark, Fan, Luck, & Hillyard, 1994).

One self-protective motivation that might influence ongoing perceptual processes is adaptive disengagement. Self-esteem hinges on feedback in different domains (Crocker, Luhtanen, Cooper, & Bouvrette, 2003; Crocker & Wolfe, 2001), and adaptive disengagement is the motivation to remove negative feedback as a basis of self-esteem. Indeed, previous work has shown that disengagement buffers self-esteem from negative feedback (Leitner, Jones, & Hehman, 2013). Additionally, Leitner, Hehman, Jones, and Deegan (under review) developed a questionnaire

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that captures the degree to which a person typically disengages from negative feedback and found that (a) adaptive disengagement tendencies are stable over time; (b) adaptive disengagement tendencies are associated with greater emotion regulation, self-esteem, and psychological well-being; and (c) individuals who reported high adaptive disengagement tendencies subsequently disengaged from negative social feedback. Notably, this relationship between adaptive disengagement tendencies and disengaging from negative feedback remained significant when self-esteem was modeled as a control variable, suggesting that adaptive disengagement has unique predictive validity.

Thus, adaptive disengagement may be part of a broad self-regulatory system that maintains positive mental states, and recent work suggests that a measure that captures adaptive disengagement tendencies is reliable and valid. As adaptive disengagement decreases the self-relevance of negative feedback and decreased self-relevance corresponds with diminished encoding (Kuiper & Rogers, 1979; Rogers, Kuiper, & Kirker, 1977), we anticipate that adaptive disengagement motivations affect the perceptual processing of negative feedback.

Neural Mediators of Self-enhancement

Previous reviews suggest that several neural regions within the medial frontal cortex (MFC) might support the link between self-enhancing motivations and self-knowledge (Beer, 2012; Amodio & Frith, 2006). For example, research using fMRI has identified regions within the MFC associated with monitoring the valence of self-relevant information (Hughes & Beer, 2013; Beer & Hughes, 2010; Masten et al., 2009; Moran, Macrae, Heatherton, Wyland, & Kelley, 2006; Somerville, Heatherton, & Kelley, 2006), and some have theorized that areas of the MFC shape perceptions of relative social standing (Somerville, Kelly, & Heatherton, 2010).

However, a number of conflicting results have been reported regarding the relationship between hemodynamic responses in the MFC and self-enhancing perceptions. For instance, some research found a negative relationship between MFC activity and self-serving evaluations (Beer & Hughes, 2010; Somerville et al., 2010; Beer, John, Scabini, & Knight, 2006), whereas other research found a positive relationship (Hughes & Beer, 2013). Additionally, these studies have exclusively used fMRI, a methodology with high spatial but poor temporal resolution, and therefore the temporal dynamics of self-enhancement remain unknown. Thus, it remains unclear whether (a) self-enhancement is positively or negatively related to neural activity in the MFC and (b) self-enhancement emerges during perceptual processing or only after the feedback has been fully consolidated. Answering these questions is critical to understanding how self-enhancement motivations influence a person's conscious experience, and the current research thus examined electrocortical activity with high temporal resolution.

Gaining Insight from Neural Oscillations

Examining electrocortical indicators of attention in response to feedback is one way to better understand the neural and temporal dynamics of self-enhancement. The magnitude of the ERP P100, for example, is regarded as indicative of early attentional processes (Di Russo et al., 2003; Gomez-Gonzalez et al., 1994; Luck & Hillyard, 1994). However, ERPs are the global products of power bursts and phase resetting in multiple brain regions (Trujillo & Allen, 2007; Buzsaki, 2006), and two limitations of traditional ERP processing are that it does not localize the neural generators of the potential and it filters large swaths of potentially informative neural oscillatory data. These limitations can be circumvented by employing source localization and time–frequency analyses. Source localization is a data-driven approach that identifies the unique neural generators driving a given ERP component, and time–frequency analyses can index power, the degree to which collections of neurons oscillate in a given region at specific frequencies.

Importantly, oscillatory activity is thought to facilitate the activation of functional neural networks and thus top–down motivational influences on perceptual processes (Engel et al., 2001). For instance, power within the theta frequency band (4–8 Hz) in prefrontal regions has been associated with more efficacious attentional and encoding processing (Sauseng et al., 2004; Gevins, Smith, McEvoy, & Yu, 1997). Traditionally, alpha oscillations (8–12 Hz) have been interpreted as an indicator of “cortical idling,” as alpha activity has been shown to increase when individuals relax (Pfurtscheller, Stancak, & Neuper, 1996), and combined EEG/fMRI studies found that alpha activity was inversely related to BOLD signal (Feige et al., 2005; Laufs et al., 2003). However, recent work has refined this “idling” hypothesis, suggesting that alpha power corresponds with the inhibition of goal-irrelevant processing to facilitate processing of goal-relevant information (Klimesch, Fellinger, & Freunberger, 2011; Jensen & Mazaheri, 2010; Cooper, Croft, Dominey, Burgess, & Gruzelier, 2003). Thus, when a person is motivated to attend to a stimulus, greater alpha power may reflect mechanisms involved in diverting attentional resources away from unimportant stimuli and toward target stimuli. Supportive of this idea, some studies have found that alpha power during encoding is greater for subsequently remembered stimuli (Meeuwissen, Takashima, Fernández, & Jensen, 2011; Khader, Jost, Ranganath, & Rösler, 2010).

Taken together, previous research suggests that self-enhancing motivations may bias ongoing perceptions by modulating MFC alpha and theta power in response to negative social feedback.

Current Research

To test whether self-enhancing motivations influence oscillatory power when receiving social feedback, participants

who varied in adaptive disengagement reported to the laboratory and received equal amounts of positive and negative social feedback while we recorded EEG. Following the task, participants made retrospective estimates of the amount of reject and accept feedback they received. We hypothesized that greater adaptive disengagement would decrease the power of MFC theta/alpha during negative feedback encoding, which in turn would predict fewer rejection estimates.

METHODS

Participants

Forty-three white introductory psychology students (22 men) participated in exchange for partial course credit. All participants were right-handed, raised in the United States, and had no disabilities that would impair task performance. Three participants (1 man) were omitted from analyses because of an insufficient number (<10) of valid trials.

Procedures

Self-enhancement Motivation

During pretesting, participants completed the Adaptive Disengagement Scale (Leitner et al., under review) using a 1 (*strongly disagree*) to 7 (*strongly agree*) response scale. This measure assesses a person's proclivity to self-enhance by dismissing negative feedback as a basis for self-worth. Items included "I am good at shaking off failures and keeping a positive attitude," "when I perform poorly at something, I do my best to keep a positive sense of self-esteem," "I can adapt to almost any situation to maintain my self-esteem," and "when bad things happen to me, I try to not feel bad about myself," $\alpha = .86$.

Social Feedback

Several weeks later, participants reported to the lab. Similar to the procedures of Somerville et al. (2010), a cover story indicated that we were investigating facial features that promote social interactions and that each participant would receive social feedback from individuals who viewed the participant's photo. Accordingly, we photographed participants and indicated that we would upload their photo to be viewed by other individuals in the study. After fitting the participant with an EEG cap, the main task began.

Participants were led to believe that other individuals (heretofore "confederates") were viewing their photo and deciding whether to accept or reject a profile that the participant would ostensibly create later in the session. Additionally, participants viewed grayscale photos of confederates who were ostensibly deciding whether to accept or reject the participant's profile. In reality, participants were interacting with a computer, and confederate photos were derived from the Eberhardt Face Database, Center for Vital Longevity Database (Miner & Park, 2004), MORPH Longitudinal database (Ricanek & Tesafaye, 2006), and faces collected by our lab used in previous research (Hehman, Leitner, Deegan, & Gaertner, 2013). Trials began with a fixation cross, which was followed by a confederate face, a black screen, and "ACCEPT" or "REJECT," ostensibly indicating the decision of the confederate (Figure 1). Finally, participants indicated whether they were accepted or rejected by pressing the corresponding key on a keypad. Participants received equal amounts of accept and reject feedback: 50 face/accept and 50 face/reject pairs. Feedback was randomly paired with each face and presented in random order, ensuring that idiosyncrasies of specific faces (e.g., attractiveness) randomly varied across feedback type. To control for potential cross-race and -gender effects, confederate race and gender were matched to participant race and gender (e.g., White male participants saw all White male confederate faces).

Reject and Accept Estimates

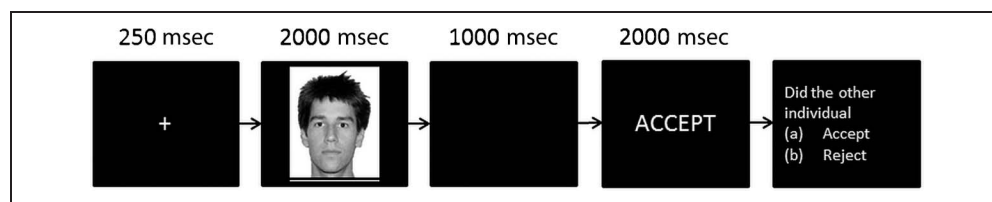
After the feedback task, participants estimated the number of times they received reject and accept feedback.

Finally, we used a funneled debriefing procedure to assess participant suspicion, after which we fully debriefed and thanked participants. No participant expressed certainty that the feedback was fake, and thus, all participants were included in analyses.

EEG Recording

Continuous EEG activity was recorded using an ActiveTwo head cap and the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands). Recordings were collected from 64 Ag-AgCl scalp electrodes and two electrodes located on the right and left mastoids. Two additional electrodes were placed 1 cm below and to the left of the left eye to record vertical and horizontal ocular movements, respectively. A

Figure 1. Presentation of social feedback stimuli.



ground electrode was formed by BioSemi's Common Mode Sense active electrode and the Driven Right Leg passive electrode. EEG activity was digitized with ActiView software (BioSemi) and was sampled and analyzed at 2048 Hz.

Offline analyses were conducted with Brain Electromagnetic Source Analysis (BESA) 5.3 software (MEGIS Software GmbH, Grafelfing, Germany). EEG data were transformed to the original average reference for all analyses. EEG signals were band-pass filtered from 0.3 to 75 Hz and epoched and stimulus-locked to accept and reject feedback extending from 500 msec prefeedback to 1000 msec postfeedback. Epochs containing artifacts (amplitude > 120 μ V, gradients > 75 μ V, low signal < 0.01) were identified and rejected using BESA's artifact scanning tool. Ocular artifacts were corrected via the adaptive algorithm implemented in BESA. Epochs were baseline corrected by subtracting the average value of EEG 100 msec prefeedback from the entire epoch. All participants had at least 10 accept and reject feedback epochs.

Analytic Approach

To understand the oscillatory activity that might mediate the relationship between self-enhancement motivations and feedback estimates, we took the following analytic approach. First, we examined ERP components to detect the earliest component that was modulated by feedback valence. Specifically, we analyzed the P1, N1, and P300 as these components are influenced by selective attention (Luck & Kappenmann, 2012) and feedback-related negativity (FRN), which is modulated by negative feedback (Gehring & Willoughby, 2002) and prediction violation (Moser & Simons, 2009). Second, we conducted source localization analyses to reveal the neural generators of the earliest component that showed sensitivity to feedback valence. Third, we conducted time–frequency analyses to examine whether feedback valence influenced theta and alpha power in the identified sources. Finally, we assessed whether adaptive disengagement predicted differential oscillatory power in response to reject and accept feedback and whether this differential oscillatory power predicted feedback estimates.

ERP Analysis

For ERP analyses, EEG data were band-pass filtered between 1 and 30 Hz, consistent with previous work (e.g., Simanova, van Gerven, Oostenveld, & Hagoort, 2010).

N1/P1

Early N1/P1 components typically evoke occipitoparietal distributions measured at bilateral occipital and parietal electrodes (Darriba, Pazo-Álvarez, Capilla, & Amenedo, 2012; David et al., 2011). Consistent with past research,

grand-averaged waveforms and topographical voltage distributions indicated that the P1 was maximal in the bilateral occipitoparietal channels around 130 msec. We thus operationalized P1 magnitude as the mean evoked EEG activity between 100 and 150 msec for channels Oz, O1/2, POz, PO3/P4, PO7/8, Pz, P3/4, P5/6, P7/8, and P9/10 (Figure 2). A negative-going component was maximal at bilateral occipitoparietal channels at 180 msec. Thus, N1 magnitude was operationalized as the mean evoked activity between 160 and 200 msec across these same channels.

FRN

Consistent with previous research (Moser & Simons, 2009), the FRN was evaluated by comparing the difference between frontocentral electrocortical responses to negative and positive feedback in the 250–350 msec time window after feedback. Specifically, we analyzed whether mean amplitudes at Fz and FCz between 250 and 350 msec were different in response to reject and accept feedback.

P300

Consistent with previous research (Finke et al., 2011; Stadelmann et al., 2011), we operationalized the P300 as the mean amplitude in the 300–500 msec time window at channels Fz, Cz, and Pz. Greenhouse–Geisser correction was applied to all ANOVAs.

Source Localization

To identify the neural sources involved in perception of reject and accept feedback, source localization analyses were performed in BESA, consistent with procedures in Hanslmayr et al. (2008). BESA transforms electrode space into source space to fit the location and orientation of dipole sources that explain the greatest variance of ERP scalp topography. This allows ongoing EEG activity to be represented by source activity. To avoid distorting source localization and time–frequency analyses, EEG activity for these analyses were only high-pass filtered at 0.3 Hz and were not corrected for ocular artifacts. To avoid biasing the results toward any one condition, source localization analyses were conducted on a grand-averaged waveform comprised of both reject and accept feedback epochs. We conducted source localization on the base-to-peak time window of the P100 component, as this was the only component to be significantly influenced by feedback valence (see below).

To construct an adequate dipole model, we combined a sequential fitting strategy (Hochstetter et al., 2004) with iterative 3-D source imaging. First, we accounted for eye activity by placing sources in the left and right eyes. Next, bilateral and symmetrical sources were placed in the left and right occipital cortex, as these regions are

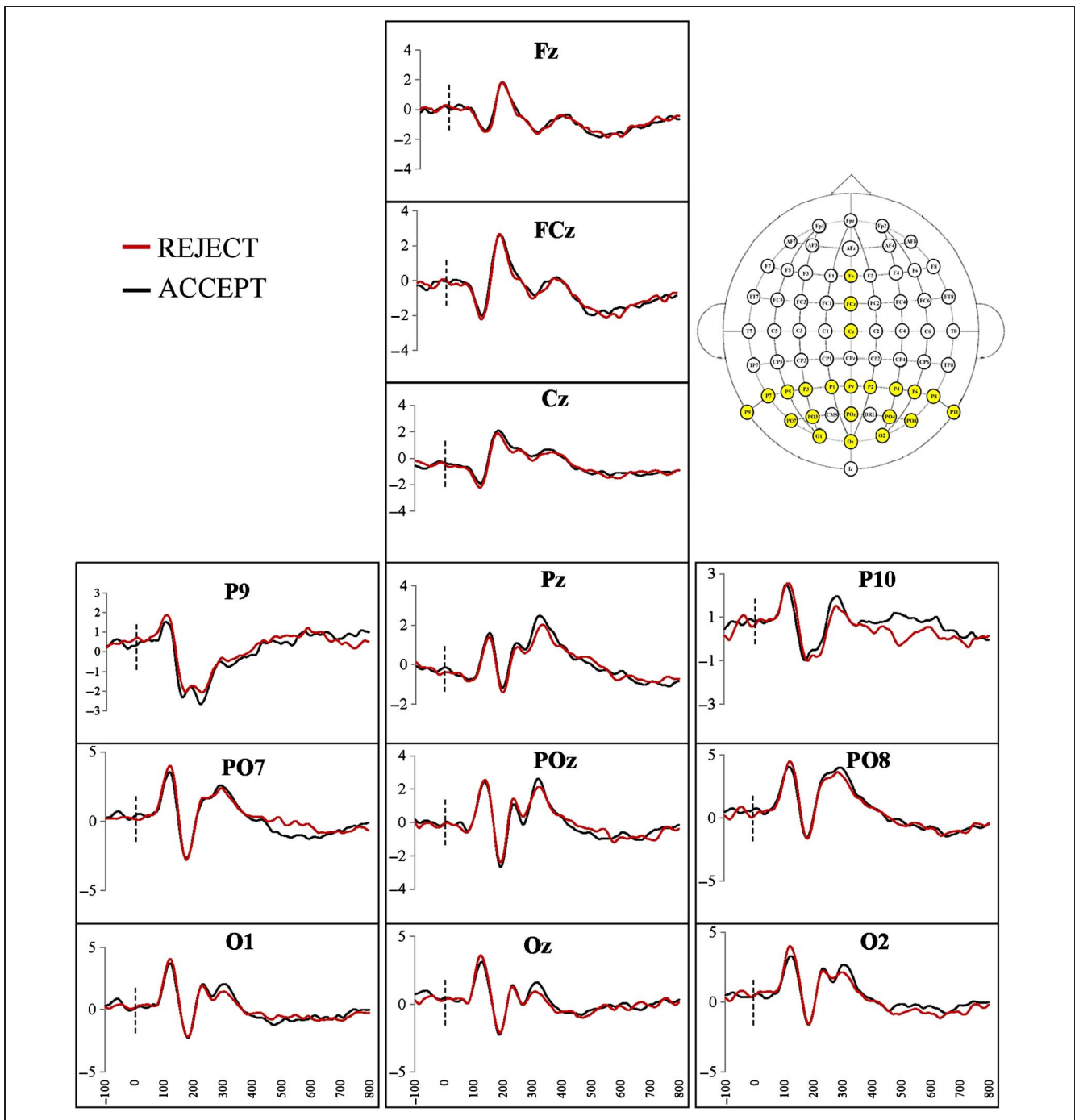


Figure 2. Grand-averaged waveforms from in response to accept and reject feedback. Highlighted channels were used to calculate ERPs.

typically reactive during early visual processing (Hanslmayr et al., 2008). We then identified additional sources using Classical LORETA Analysis Recursively Applied (CLARA; Hoehstetter, Berg, & Scherg, 2010), an iterative application of weighted LORETA images that reduces source space with each iteration. As compared to LORETA (Pascual-Marqui, Michel, & Lehmann, 1994), CLARA increases the spatial resolution of estimated sources. CLARA source analyses were conducted with a two iteration scheme, using the default voxel dimension of 7 mm^3 , and a singular value

decomposition cutoff of 0.01%. In addition to the eye and occipital sources, CLARA identified sources in the left cerebellum, right cerebellum, insula, and MFC. The locations of these eight sources are plotted in Figure 3A, and the corresponding Talairach coordinates are shown in Table 1. To best model current density in each location, dipoles were converted to regional sources with three orientations, and each orientation was analyzed as a separate dipole. Because our focus was on location rather than orientation of sources, we report analyses regarding only

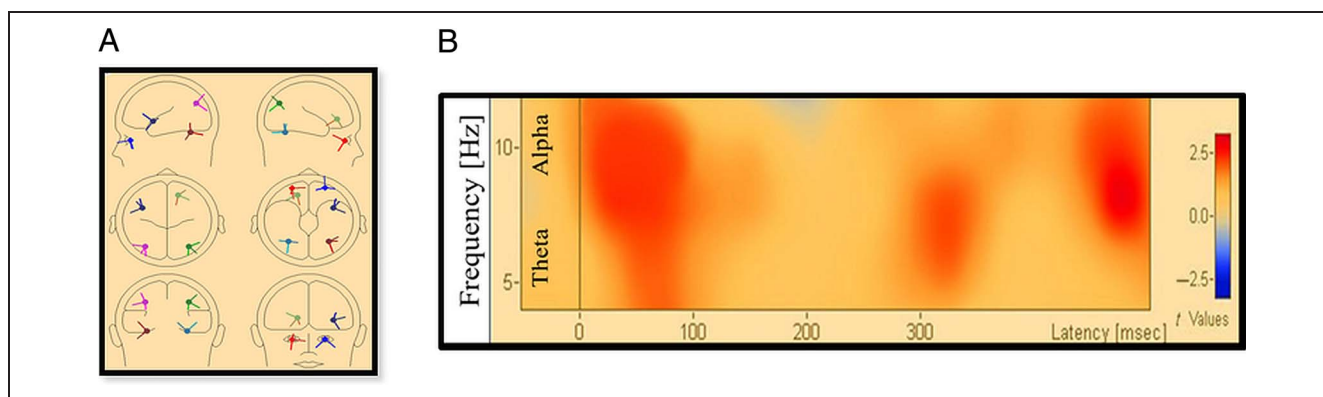


Figure 3. (A) Dipole sources solution. (B) Pairwise comparison for power in the MFC source in response to reject minus accept feedback. Warmer colors depict time and frequency periods where power was greater in response to reject than accept feedback. The largest difference between reject and accept feedback was in the alpha and theta frequency bands around 0–500 msec postfeedback.

the source location. This source model explained 99% of total variance.

Consistent with previous research (Hanslmayr et al., 2008; Sehatpour, Molholm, Javitt, & Foxe, 2006), we validated the current source model with a multiple source probe scan (MSPS) as implemented by BESA. Should the current model adequately represent all active brain regions, the MSPS algorithm would show only activity around the present sources.

Time–Frequency Analyses

Using the aforementioned source model, we transformed single-trial source waveforms into time–frequency space, after which we calculated the instantaneous envelope amplitude of each source as a function of frequency and latency, following established procedures (Hoechstetter et al., 2004). The absolute power in each source with respect to the baseline was averaged over trials and displayed as a function of frequency and latency in event-related synchronization/desynchronization plots (Pfurtscheller & Lopes da Silva, 1999). Frequencies were sampled between 4 and 12 Hz in 2-Hz steps and in sampling steps of 25 msec between –500 msec and +1000 msec relative to feedback onset. Consistent with Sauseng and Klimesch (2008), we operationalized theta as 4–8 Hz and alpha as 8–12 Hz. We analyzed this time–frequency data between 0 and 500 msec poststimulus because (a) we were interested in perceptual and encoding processes, (b) ERPs can reflect neural events that extend for hundreds of milliseconds around its peak (Luck, 2012), and (c) it is recommended to analyze oscillatory activity in a time period that allows for at least two periods of the oscillation (e.g., 500 msec for a 4-Hz oscillation), because smaller time windows are heavily influenced by outliers, muscle artifacts, and non-brain interference (Bastiaansen, Mazaheri, & Jensen, 2012).

To most rigorously model within-participant variance separately from between-participant variance, best accounting for the interdependence of the data, power

analyses were conducted using hierarchical linear modeling (Raudenbush, Bryk, & Congdon, 2004).

RESULTS

Behavioral Data

Overall, participants made greater estimates of rejection ($M = 36.70$, $SD = 12.67$) than acceptance ($M = 28.95$, $SD = 10.97$) feedback, $t(47) = 4.73$, $p < .001$. Supporting our hypotheses, adaptive disengagement ($M = 4.89$, $SD = 1.13$) mitigated perceptions of rejection, as higher adaptive disengagement corresponded with fewer rejection estimates, $r = -.35$, $p = .026$, and regression analyses demonstrated that higher adaptive disengagement predicted fewer rejection estimates even when controlling for acceptance estimates, $\beta = -.34$, $SE = 1.29$, $p = .006$. Adaptive disengagement was unrelated to acceptance estimates, $p > .10$. Thus, although all participants received equal amounts of accept and reject feedback, participants who self-enhanced through adaptive disengagement estimated fewer instances of rejection.

Table 1. Talairach Coordinates of the Sources

Source Region (Abbreviation)	<i>x</i>	<i>y</i>	<i>z</i>
Left eye	–26	60	–29
Right eye	26	60	–29
Left occipital cortex (LOC)	–34	–78	28
Right occipital cortex (ROC)	34	–78	28
Insula	–39	11	3
Left cerebellum (LC)	–32	–59	–25
Right cerebellum (RC)	32	–59	–25
Medial frontal cortex (MFC)	18	39	10

ERP

Before conducting source localization and time–frequency analyses, we examined ERPs to determine the time period in which feedback valence first modulated global electrocortical activity. Grand-averaged waveforms for frontal, central, parietal, and occipital channels are shown in Figure 2. Mean evoked activity for components of interest are shown in Table 2.

A 2 (Feedback) \times 17 (Channel) repeated-measures ANOVA revealed a main effect for Channel, $F(5, 184) = 12.46, p < .001, \eta^2 = .24$, such that P1 magnitude was greater among more central than lateral channels. More importantly, a main effect emerged for Feedback such that the P1 was greater to reject than accept feedback, $F(1, 39) = 4.75, p = .035, \eta^2 = .11$. No other effects were significant, $ps > .4$, and neither adaptive disengagement nor rejection estimates predicted P1, $ps > .10$.

Feedback \times Channel repeated-measures ANOVAs on the N1, FRN, and P300 found no significant effects of Feedback or interactions (see Supplementary Materials). In summary, we found that the P1 was exclusively sensitive to feedback valence. Accordingly, we sought to localize the source of this electrocortical activity and to more deeply explore the effect using time–frequency analyses.

Source Localization and Power Analyses

To reveal the neural generators of the P100 component, we conducted source localization analyses on the 81–126 msec time window. The dipole source solution is plotted in Figure 3A. Because all activity detected by the MSPS surrounded the sources of the current model, the MSPS indicated that the current source model fit the data adequately (see Supplementary Materials).

To understand whether oscillatory power in these sources was related to adaptive disengagement and rejection estimates, we conducted multilevel analyses predicting power in the eight sources in Figure 3A. In all analyses, power at each source was modeled as an outcome variable, and feedback (0 = *reject*, 1 = *accept*) was entered as a Level 1 predictor. Additionally, in separate analyses, adaptive disengagement and rejection estimates (controlling for acceptance estimates) were

Table 2. Means and Standard Deviations of Evoked EEG Activity in Each ERP Component

Component	Reject Mean (SD)	Accept Mean (SD)
P1	2.06 (1.18)	1.81 (0.95)
N1	–1.19 (1.02)	–1.24 (0.95)
FRN	–0.86 (1.56)	–0.74 (1.43)
P300	–0.04 (0.99)	0.02 (.84)

Bold values indicate that reject and accept means significantly differed from each other ($p < .05$).

entered as mean-centered Level 2 predictors. Interactions between Level 2 predictors and feedback were examined to determine whether the link between feedback and oscillatory power differed as a function of adaptive disengagement or rejection estimates.

Power Analyses

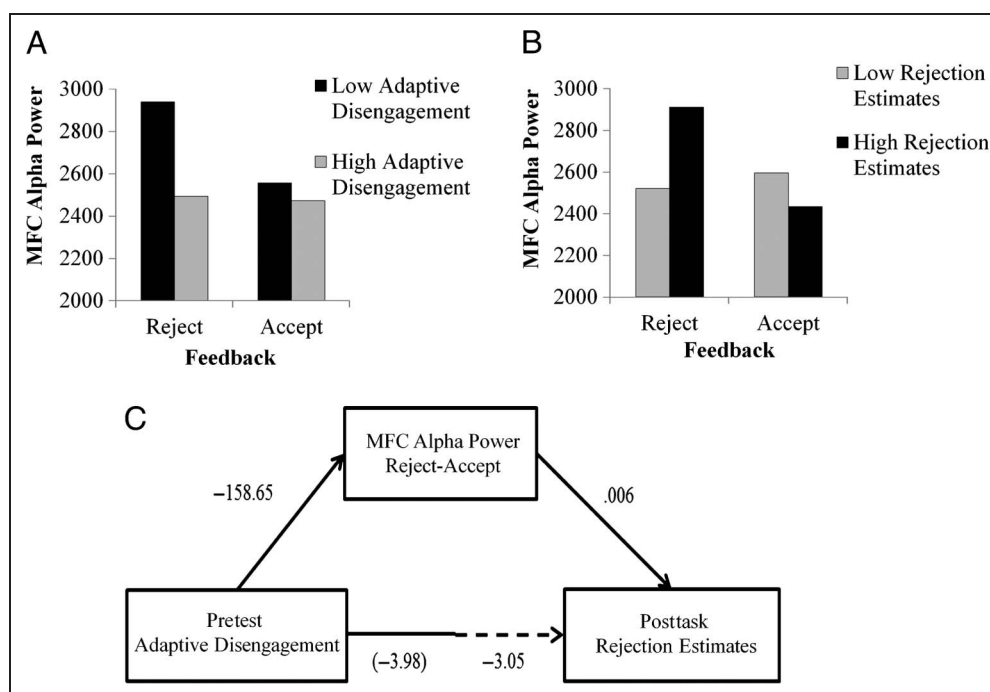
Consistent with previous research showing robust neural responses to negative feedback (Cavanagh, Cohen, & Allen, 2009) and the P1 ERP effects reported above, MFC power was greater in response to reject than accept feedback (Figure 3B). Greater MFC power to reject than accept emerged in both the theta band, $\pi_{10} = -238.75, SE = 120.02, p = .054$, and alpha band, $\pi_{10} = -201.18, SE = 76.87, p = .025$. Importantly, however, a significant Feedback \times Adaptive disengagement interaction indicated that adaptive disengagement moderated the relationship between feedback and MFC alpha power, $\pi_{11} = 158.65, SE = 78.87, p = .046$ (Figure 4A). Simple slopes (Shacham, 2009) revealed that participants higher in adaptive disengagement (+1 *SD*) showed equivalent MFC alpha power in response to reject and accept feedback, $p = .87$, whereas participants lower in adaptive disengagement (–1 *SD*) showed significantly greater MFC alpha power in response to reject than accept feedback, $\pi = -382.03, SE = 122.88, p = .004$. Thus, individuals who were less likely to disengage showed greater MFC alpha power to negative feedback.

Next, we examined whether increased MFC alpha power to negative feedback corresponded with greater rejection estimates. Indeed, when MFC power was modeled as an outcome and rejection and acceptance estimates were simultaneously entered as Level 2 predictors, a significant Feedback \times Rejection estimates interaction emerged, $\pi_{12} = -21.74, SE = 8.68, p = .017$ (Figure 4B). Simple slope analyses indicated that participants who estimated fewer rejection trials (–1 *SD*) showed equivalent MFC alpha power to reject and accept feedback, $p = .60$. Conversely, participants who estimated a high number of rejection trials (+1 *SD*) showed significantly greater MFC alpha power to reject than accept feedback $b = -476.76, SE = 139.04, p = .002$. No other effects at other sources or frequency bands were significant, $ps > .10$.

Mediation

The aforementioned analyses revealed that (a) lower adaptive disengagement corresponded with increased rejection estimates, (b) lower adaptive disengagement corresponded with increased MFC alpha power to reject (relative to accept) feedback, and (c) increased MFC alpha power to reject (relative to accept) feedback corresponded with greater rejection estimates. Bringing these elements together, we examined whether MFC alpha power mediated the relationship between adaptive disengagement and rejection estimates. To this end, we

Figure 4. (A) Interactive effect of feedback and adaptive disengagement on MFC power. (B) Interactive effect of feedback and rejection estimates (controlling for acceptance estimates) on MFC power. (C) Mediation model showing simple paths of MFC alpha power to reject–accept mediating the relationship between pretest adaptive disengagement and posttask rejection estimates (controlling for acceptance estimates). Values represent unstandardized regression coefficient. Solid lines are significant. Dashed line represents the nonsignificant direct path when the mediator is entered in the model.



averaged participants' MFC alpha power to reject and accept feedback 0–500 msec poststimulus and computed a difference score (reject – accept). Next, we tested for mediation by deriving 95% bias-corrected confidence intervals (CIs) from 1000 bootstrap estimates (Edwards & Lambert, 2007). As illustrated in Figure 4C, lower adaptive disengagement predicted greater MFC alpha power to reject (relative to accept) feedback, which in turn predicted greater rejection estimates. Supportive of mediation, the indirect path was significant, $b = -0.96$, 95% CI [-2.66, -0.16], and the direct path between adaptive disengagement and rejection estimates became nonsignificant when the mediator was entered in the model, $b = -3.05$ [-6.70, 0.32], indicating that MFC alpha power to reject (relative to accept) completely mediated the relationship between adaptive disengagement and rejection estimates (MacKinnon, Fairchild, & Fritz, 2007). Further demonstrating the robustness of this mediation effect, the indirect pathway remained significant when we tested for CIs using the percentile method, 95% CI [-2.34, -0.05], a method that yields fewer Type I errors than bias correction (Fritz, Taylor, & MacKinnon, 2012). These findings indicate that the relationship between adaptive disengagement and rejection estimates was fully explained by MFC alpha power to feedback. Participants lower in adaptive disengagement estimated that they received more rejection feedback, and this was due to increased MFC alpha power to reject (relative to accept) feedback.

DISCUSSION

Recent reviews have urged researchers to gain a better understanding of the temporal and neural dynamics of

self-enhancement (Beer, 2012). Heeding this call, the current research harnessed advances in electrocortical source localization and time–frequency analyses to demonstrate that individual differences in self-enhancement altered neural oscillatory patterns elicited in response to social feedback. Participants low in adaptive disengagement showed greater MFC alpha power to reject than accept feedback, whereas participants high in adaptive disengagement showed equivalent MFC alpha power to reject and accept feedback. Consistent with the interpretation that MFC alpha power contributed to perceptual processing, greater alpha power to reject than accept feedback predicted greater retrospective estimates of rejection feedback.

This is the first study to reveal the neural activity that completely mediates the relationship between a self-enhancing disposition and a perceptual bias in a specific situation. Although previous work has found correlations between neural activity and self-serving evaluations (Beer & Hughes, 2010), motivated social cognition (Hughes & Beer, 2012), and self-esteem (Somerville et al., 2010), the neural signatures underlying motivation–perception relationships have remained relatively unexamined. Notably, adaptive disengagement was measured several weeks before the experiment, suggesting that the chronic motivational orientation that underlies adaptive disengagement influenced the perception of social feedback during the experiment. Thus, our finding that MFC alpha power completely mediated the relationship between pretest adaptive disengagement and posttask rejection estimates suggests that MFC alpha power plays an important role in top–down and bottom–up perceptual processing of self-relevant feedback.

These findings extend social psychological research on self-enhancement by revealing the time period in which self-enhancement processes first emerge. Although extant research has found that following negative social feedback individuals are motivated to restore self-esteem (DeWall et al., 2011; Aydin, Fischer, & Frey, 2010; DeWall, Maner, & Rouby, 2009; Tesser et al., 2000), these previous studies have not demonstrated whether self-enhancement affects ongoing processing of self-relevant information or first emerges after complete consolidation of this information. In contrast, the current results indicate that self-enhancement emerges during the first few hundred milliseconds of processing social feedback. These results are consistent with previous frameworks suggesting that self-enhancing motivations pervade all stages of social cognition (Sedikides & Gregg, 2008) but extend previous work by highlighting the time window in which self-enhancement effects emerge. Notably, the current work suggests that interventions designed to improve self-esteem, such as training associations between the self and positive concepts (Baccus, Baldwin, & Packer, 2004), might influence the first few hundred milliseconds of feedback processing.

These findings also extend social neuroscience research on self-enhancement (e.g., Hughes & Beer, 2013; Beer & Hughes, 2010; Somerville et al., 2010; Beer et al., 2006) by directly indexing the neural oscillations that likely support motivational influence on perception (Engel et al., 2001). Importantly, alpha oscillations are thought to inhibit the processing of goal-irrelevant information to facilitate processing of target information (Klimesch et al., 2011). Accordingly, to the extent that rejection feedback was “target” information, increased MFC alpha power to rejection feedback may have been associated with the inhibition of processing of peripheral information, thereby facilitating processing of rejection feedback. Another interpretation is that increased MFC alpha power to rejection feedback inhibited self-enhancing strategies that could be employed in response to social rejection information. Specifically, increased MFC alpha power to rejection feedback may have inhibited the neural activity that supports adaptive disengagement, whereas decreased alpha power facilitated the neural activity that supports adaptive disengagement. Both interpretations are plausible, and future research will need to examine whether alpha power in the current paradigm reflects inhibition of attention to irrelevant information, or inhibition of self-regulatory strategies.

Notably, self-serving biases in rejection estimates were related to neural responses to reject, rather than accept, feedback. Additionally, adaptive disengagement did not predict neural responses to accept feedback. These findings are consistent with research showing that self-enhancement may be driven more by self-protection than self-advancement motivations. For instance, negative compared to positive feedback elicits larger changes in self-esteem (Nezlek & Gable, 2001), and individuals are more motivated to avoid a negative self-definition than pursue a

positive one (Baumeister et al., 2001). Furthermore, there is an upper limit to the self-esteem a person is motivated to attain (Tesser et al., 2000). Thus, self-enhancing processes in the current study may have influenced alpha power to reject feedback, rather than accept feedback, as reject feedback presented the greatest threat to self-worth.

We tested our hypotheses in a social context, as social inclusion plays a powerful role in a person’s overall well-being (Cacioppo, Hughes, Waite, Hawkley, & Thisted, 2006), and some brain regions may monitor the environment for social cues regarding inclusionary status (Mitchell & Heatherton, 2009; Eisenberger & Lieberman, 2004). However, we anticipate that these effects extend to situations in which feedback does not explicitly convey inclusionary status. For instance, the valence of test feedback has been shown to evoke robust neural responses during encoding, especially when individuals feel threatened (Forbes & Leitner, under review), and self-enhancing strategies might moderate these neural responses. Additionally, as individuals self-enhance through a variety of strategies (Tesser et al., 2000), future studies might investigate the neural dynamics of self-enhancement in non-social contexts.

Related to this point, the current research indexed self-enhancing motivations by measuring adaptive disengagement, a domain-independent construct. Specifically, the Adaptive Disengagement Scale concerns a person’s response to negative feedback in general, rather than feedback in a specific domain, and thus should have implications for feedback processing in a variety of contexts. However, adaptive disengagement is positively related to several other indices of well-being, including emotion regulation and self-esteem (Leitner et al., under review). As such, it is possible that these interrelated variables all reflect a common motivation to maintain positive mental states or that a covariate of adaptive disengagement was the driver of the current findings. Future research might thus examine several self-enhancement and self-regulation variables in concert to gain greater insight into the motivations and strategies that influence neural activity during feedback processing.

As participants tended to underestimate the number of times they were rejected, greater adaptive disengagement corresponded with less accurate rejection estimates. These findings suggest that self-enhancement motivations correspond with decreased encoding of negative feedback. However, it is important to note that our measure of rejection estimates did not directly measure encoding. Rather, rejection estimates may have been influenced by a number of factors, including the salience of feedback during the task and subsequent availability heuristics. To determine whether self-enhancement directly modulates encoding, we would need to assess episodic memory of specific instances of feedback. Future research might thus develop paradigms that index recall for isolated social events and examine the relationships between self-enhancing motivations, neural oscillations, and encoding.

Although the current research used a high-density electrode array for data collection and the source of greatest interest (i.e., MFC) was modeled in the cortex, we interpret the location of our effects cautiously. The MFC source in the current research was near the vACC, which is fairly deep in the cortex, and volume conduction limitations make precise localization of this source more difficult. Additionally, our source model identified the insula as generating activity to both accept and reject feedback, but feedback valence did not affect oscillations within this source. This finding is in contrast to previous fMRI findings that the insula is sensitive to feedback valence (Eisenberger, Inagaki, Muscatell, Haltom, & Leary, 2011), but substantial methodological differences might explain this discrepancy. Thus, the high temporal resolution and oscillatory examination in the current work should be viewed as complimenting research that uses methodologies with greater spatial resolution. Future research should continue to investigate both the spatial and temporal dynamics of self-regulating processes.

In the current study, we posit that alpha power reflected early-stage perceptual processing, as alpha oscillations are linked to early-stage encoding of visual information (Klimesch et al., 2011) and P1 magnitude (Fellinger, Klimesch, Gruber, Freunberger, & Doppelmayr, 2011; Klimesch, 2011; Freunberger et al., 2008). Additionally, our power analyses were based on neural sources that generated P1. However, the possibility remains that alpha reflected postperceptual processing, as we averaged alpha power 0–500 msec poststimulus (to reliably index the oscillation), and P1 was unrelated to both adaptive disengagement and rejection estimates. One explanation for the null relationship between P1 and self-enhancement is that P1 was influenced by activity within several brain areas (i.e., occipital cortex, insula, cerebellum, and MFC) and thus might reflect some perceptual processes that are orthogonal to self-enhancement. In contrast, oscillatory activity in dissociable brain regions that underlie the P1 may provide a clearer picture of the link between brain activity and cognition. Indeed, compared to an ERP analysis, our analytic approach provided more information regarding neural generators, as well as oscillatory activity within these generators, that predicted self-enhancement. Nevertheless, future work will need to examine precisely when self-enhancing biases in attentional processing emerge.

Finally, feedback valence only influenced the P1, and not the N1, FRN, or P300 components. As the P1 is the first component to reflect top-down attentional control (e.g., Gomez-Gonzalez et al., 1994), these finding highlight the speed with which individuals respond to rejection feedback. Although Gehring and Willoughby (2002) found the FRN to be larger to negative feedback, we did not find that effect. This discrepancy may be because of the meaning of the negative feedback in each experimental context. Negative feedback in Gehring and Willoughby's (2002) research conveyed economic loss, whereas negative

feedback in our study conveyed social rejection. Thus, future research is needed to determine how situational factors influence ERPs and the cognitive processes they reflect.

In summary, the current research demonstrated that self-enhancement motivations influence perceptual processing of social feedback. This research adds to a recent wave of studies examining the neural underpinnings of self-enhancement and is the first to reveal that self-enhancing motivations affect the neural oscillations involved in feedback processing. It is increasingly clear that self-enhancing motivations shape a person's ongoing experience with the social world, and continuing to elucidate relationships between these motivations and neural processes will provide a more complete understanding of social cognition.

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