Running Title: Brain signatures of emotional prosody and power

Early and Late Brain Signatures of Emotional Prosody among Individuals with High versus Low Power

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Abstract

Using event-related brain potentials (ERPs), we explored the relationship between social power and emotional prosody processing. In particular, we investigated differences at early and late processing stages between individuals primed with high or low power. Comparable to previously published findings from non-primed participants, individuals primed with low power displayed differentially modulated P2 amplitudes in response to different emotional prosodies, whereas participants primed with high power failed to do so. Similarly, participants primed with low power showed differentially modulated amplitudes in response to different emotional prosodies at a later processing stage (late ERP component), whereas participants primed with high power did not. These ERP results suggest that high versus low power leads to emotional prosody processing differences at the early stage associated with emotional salience detection and at a later stage associated with more in-depth processing of emotional stimuli.

Word count: 138

Keywords: emotional prosody; social power; ERP

Introduction

"The most important thing in communication is hearing what isn't said" (Peter Drucker, n.d.). The ability to accurately "read" non-verbal signals conveyed through body language, facial expression, or tone of voice (prosody) is indeed a vital skill for successful communication. How meaningful signals are conveyed and understood through prosody (characterized through complex fluctuations of acoustic parameters such as pitch, loudness, voice quality, and tempo) has received increasing attention over the past few decades. However, while there is an extensive literature devoted to how emotions are conveyed or understood through prosody (see e.g., Paulmann, 2015, for review), far less is known about how emotional prosody processing is influenced by social psychological factors. The exception to this is research exploring differences in emotional prosody processing as a function of sex (e.g., Schirmer, Kotz, & Friederici, 2002; Schirmer & Kotz, 2003), age (e.g., Paulmann, Pell, & Kotz, 2008; Mitchell & Kingston, 2014) or cultural background (e.g., Paulmann & Uskul, 2014; Pell, Monetta, Paulmann, & Kotz, 2009; Scherer, Banse, & Walbott, 2001). Only recently, research has also started to explore how *social power*, typically defined as the ability to control valued resources that comprise of outcomes that are physical (e.g., housing), economic (e.g., promotion), or social (e.g., inclusion) (e.g., Fiske, 1993; Keltner, Gruenfeld, & Anderson, 2003; Magee & Galinsky, 2008), can impact on emotional prosody perception (Uskul, Paulmann, & Weick, 2016). Findings from this research show that both generalized sense of power measured as an individual difference variable as well as temporary feelings of holding high versus low power are associated with accuracy in recognizing emotions from voice. Specifically, individuals who hold a strong sense of power (Study 1) as well as those primed with feelings of powerfulness (Study 2) are less accurate in recognizing emotions from prosody than individuals who hold a weak sense of power or those primed with feelings of powerlessness (Uskul et al., 2016) (see below for further details); however, the underlying cause for this effect is yet unknown. The present investigation aims to fill this gap.

Emotional Prosody

Emotional prosody perception requires the listener to pay close attention to a variety of emotional prosodic cues as they unfold over time. This complex process has been shown to involve several functionally different transient processing stages. Initially, acoustic attributes are extracted during sensory processing. Next, emotional significance is determined. Eventually, in a final step, more cognitively based operations including emotional meaning evaluation take place (for recent models on the time-course underlying these processes see, for example, Schirmer & Kotz, 2006; Kotz & Paulmann, 2011; or Frühholz, Trost, & Kotz, 2016). So far, the role of contextual and individual factors on emotional prosodic processing is still underspecified; however, some models on vocal signal processing (e.g., Schirmer & Kotz, 2006) theorize that these factors can impact on all of the proposed stages. In the present study, we test how and if holding or lacking power can modulate different processing steps. If it does, this would suggest that future models of emotional prosody processing would need to consider the impact of top-down information more closely than it is currently done.

The majority of evidence supporting multi-stage models of emotional prosody processing comes from research using event-related brain potentials (ERPs). Early sensory processing, or the extraction of acoustic cues (e.g. pitch and loudness information), has been linked to a negativity peaking at around 100 ms after stimulus onset. It is debated whether this early sensory ERP is modulated by the emotionality of a stimulus. Some studies presenting audio-visual stimuli suggest that emotionality does modulate the N1 (Jessen & Kotz, 2011; Jessen, Obleser, & Kotz, 2012; Lerner, McPartland, & Morris, 2013), although rare evidence also exists from studies looking at emotional prosody only (see Pinheiro et al., 2013 for N100 emotion effects in schizophrenic patients). Subsequent ERPs have consistently been shown to be modulated by the emotional connotation of an auditory stimulus. For instance, rapid emotional salience detection (i.e., early emotional appraisal) has consistently been tied to the fronto-centrally distributed P2 component (e.g., Paulmann & Kotz, 2008; Paulmann, Bleichner, & Kotz, 2013; Schirmer, Chen, Ching, Tan, & Hong, 2013; Pell, Rothermich, Liu, Paulmann, Sethi, & Rigoulot, 2015). Specifically, this research has shown that so-called basic emotions (anger, disgust, fear, sadness, happiness, surprise) can be distinguished from one another and from neutral sounding stimuli within 200 ms after stimulus onset as reflected in differently modulated P2 amplitudes. It has been argued that this early emotional appraisal is linked to enhanced or preferential processing of emotional attributes of language stimuli; this in turn should enable the listeners to respond adequately and adjust their own behaviour accordingly.

In contrast, more specific and enhanced emotional meaning evaluation has been linked to later, long-lasting negative (Bostanov & Kotchoubey, 2004; Schirmer et al., 2002, 2005; Schirmer & Kotz, 2003; Paulmann & Pell, 2010; Paulmann, Ott, & Kotz, 2011) or positive (Kanske & Kotz, 2007; Paulmann et al., 2013; Schirmer et al., 2013; Pell et al., 2015) ERP components, depending on the type of experimental design or stimuli used. For instance, Schirmer et al. (2013) and Paulmann et al. (2013) presented evidence demonstrating that sentences spoken in different emotional prosodies elicit distinct long-lasting ERP signatures in late time-windows (400 ms post prosody onset) possibly reflecting processes that link emotional sentence meaning to stored emotional memory information, helping to establish an emotional interpretation of the stimulus. In other words, enriched interpretation or assessment of emotional-specific meaning is linked to this later time-window of processing.

Social Power

Power is a fundamental part of everyday social life and has been shown to shape many aspects of our interactions with others (e.g., Keltner et al., 2003; Kipnis, 1972; Maner, Kaschak, Jones, 2010). One definition that is commonly adopted in social psychological research states that power is ‘an individual’s relative capacity to modify others’ states by providing or withholding resources or administering punishments’ (Keltner, Gruenfeld, & Anderson, 2003, p. 265). Another commonly used definition further highlights the interpersonal consequences of social power stating that it is the degree to which an individual can exert control over another (Schmid Mast, Jonas, & Hall, 2009). Social power is considered to be different from other hierarchical concepts such as status (i.e., respect in the eyes of others on the basis of one's relative rank, see e.g., Magee & Galinsky, 2008) or dominance (i.e., actual use of power typically at the expense of other individuals, see e.g., Hirsh, Galinsky, & Zhong, 2011).

Individuals are believed to develop a generalized sense of power, anchored in their past interpersonal experiences (e.g., Anderson, John, & Keltner, 2012; Bugenthal, Blue, & Cruzcosa, 1989; Chen, Lee-Chai, & Bargh, 2001). Researchers have developed several measures to assess individuals' sense of their power either as a generalized psychological property or in specific social relationships and groups (e.g., Anderson et al., 2005; Anderson & Galinsky, 2006). The sense of power can also be activated by cues in one's social environment or recollections of past power-related experiences (e.g., Chen et al., 2001; Galinsky et al., 2003). In most past research that adopted a situational perspective on power, the sense of power was activated by bringing the concept of power to mind through a word-fragment completion task (see Bargh, Raymond, Pryor, & Strack, 1995), by asking participants to imagine themselves in or simulate the role of a manager or a subordinate (e.g., Guinote, 2008; Guinote, Judd, & Brauer, 2002) or via a mind-set priming method which asks participants to recall either a situation in which they possessed power over someone else or a situation in which someone else possessed power over them (Galinsky et al., 2003). Over numerous studies in the past two decades, these priming procedures have been linked to important changes in individuals' cognitive and emotional responses and social behaviors. Among those techniques, the recall priming task by Galinsky et al. (2003) has been shown to have far-reaching effect on a variety of behavioral outcomes, including individuals' tendency to generate creative ideas (Galinsky et al., 2008), ability to recognize facial emotional expressions (Galinsky et al., 2006) and to ignore peripheral information and focus on task relevant details (Guinote, 2007a, 2007b).

In addition to the behavioural evidence demonstrating differences between individuals primed with high or low power, there is also emerging evidence demonstrating differences in the neuro-biological underpinnings of social power. For example, when primed with high power (vs. low power), activation in the left inferior frontal gyrus was reduced during math performance among female participants. These findings were interpreted to suggest that individuals primed with high power demonstrated less cognitive interference (linked to the left inferior frontal gyrus) which led to better performance results (Harada, Bridge, & Chiao, 2013).

Two prominent theories have been drawn on to explain the effects of social power on cognition, affect, and behavior. The Approach-Inhibition Theory proposed by Keltner and colleagues (2003) argues that holding power activates approach-related tendencies (e.g., focusing on rewards, appetitive stimuli, automatic processing), while reduced power activates inhibition-related (e.g., focus on punishment, aversive stimuli) tendencies. In line with this, Van Kleef and colleagues (2008) reported that individuals with a higher sense of power are better at regulating emotional responses, show less distress and compassion than those with a lower sense of power when having interactions in which the conversation partner addressed past suffering. Similarly, it has been reported that individuals holding power experience more positive emotions when compared to those who lack power (e.g., Anderson & Berdahl, 2002; Langner & Keltner, 2008), and that those high in power are less influenced by emotional reactions of others (e.g., Anderson et al., 2003).

The Situated Focus Theory of Power proposed by Guinote (e.g., 2007, 2013) puts forward an alternative approach to explain power-related findings in the literature stating that high-power individuals exhibit more flexible processing characteristics; they tend to focus on what is goal-relevant and what easily comes to mind. This flexibility means that powerholders can rely on a range of factors when making decisions, including subjective feelings, simple heuristics, or – if they want to – exert more effort to form their judgements. In contrast, individuals lacking power are argued to be more detail orientated, vigilant, and to act more deliberately. In line with this approach, Guinote (e.g., Guinote, 2001; Guinote et al., 2002) showed that high-power (vs. low power) individuals use more abstract (rather than concrete) language to describe themselves; demonstrating a lack of focus on detail and instead showing a preference for “gist” descriptions. Similarly, Smith and Trope (2006) demonstrated that powerholders describe actions with more abstract terms than those lacking power. Furthermore, in line with the idea that powerholders are also more flexible in her approach, Guinote (2007b) reported that participants were better at switching between focusing their attention on configurational (i.e., gist) or detailed-oriented information.

Taken together, there is considerable evidence demonstrating that power affects various cognitive and affective processes. Given the lack of knowledge on emotional prosody and social power, we believe these effects warrant further investigation.

Non-verbal communication and Social Power

To the best of our knowledge, there is only one previous attempt to explore the relationship between social power and prosody conveying basic emotions. In a correlational and an experimental study, Uskul et al. (2016) demonstrated that holding power is linked to lower accuracy in emotional prosody recognition. In the experimental part of this study, participants were primed using the above described recall task to prime high vs. low power (Galinsky et al., 2003). Immediately after, they engaged in an emotional prosody recognition task which required participants to identify the emotional tone of voice used by a speaker who uttered so-called pseudo-sentences (i.e., sentences that do not convey emotional meaning through lexical-semantic properties). Results revealed that individuals primed with low power significantly outperform individuals primed with high power in recognizing the majority of emotions conveyed in the task. Together with findings from a correlational study which revealed that having a strong generalized sense of power (assessed as an individual difference variable) was associated with lower accuracy rates in emotional prosody recognition, these findings provide initial evidence that feelings of power (either in the form of a generalized or a temporary feeling) can be linked to reduced interpersonal sensitivity in the domain of emotional prosody (Uskul et al., 2016).

There is additional evidence demonstrating that power affects recognition of basic emotions conveyed through other communication channels (e.g., facial expressions). However, this research has yielded mixed evidence showing that both high *and* low power can increase emotion recognition accuracy. A study conducted by Galinsky and colleagues (2006, Study 3) revealed lower emotional facial recognition rates for individuals primed with high power when compared to unprimed participants (Study 3). Specifically, participants either had to recall an incident where they felt in power (high power prime), or recall how they felt on the day before the experiment (no prime/control condition). They were then asked to identify emotional facial expressions using a forced-choice task (four response alternatives were provided). Non-primed participants significantly outperformed participants primed with high power in accurately identifying emotional facial expressions (1.57 vs. 4.54, respectively, errors in 24 faces). Similarly, Shirako and colleagues reported lower emotional prosody recognition rates for participants primed with high power when compared to those primed to feel low in power (Shirako, Blader, & Chen, 2013 [as cited in Magee & Smith, 2013]). These data suggest that priming the concept of holding power has a detrimental effect on identifying emotions from non-verbal cues.

Other research contradicts these findings. In a meta-analysis, it was outlined that holding power actually correlates positively with non-verbal (emotion) identification (Hall, Halberstadt, & O'Brian, 1997). Hall and Haberstadt (1994) also reported that females in "subordinate" positions are outperformed by females in "higher" positions when engaging in a non-verbal-auditory-decoding task; interestingly, this power difference is only found when the test materials were spoken by a female speaker and not by a male speaker. In addition, it has been reported that individuals primed with high in power displayed higher emotional facial expression recognition rates than individuals primed with low power or not primed at all (no difference between the latter two conditions; see Schmid Mast, Jonas, & Hall, 2009, Study 3).

Taken together, the literature provides ample evidence to suggest that social power, assessed either as an individual difference variable or a temporary state following a prime, shapes interpersonal sensitivity; however, the direction of this effect is not consistent across different studies. Crucially, few studies have explored the role of social power in emotional prosody processing in particular. Moreover, the mechanisms underlying previously observed power differences during emotional prosody recognition are unknown and warrant investigation. We designed the present study to address these points. In addition, we also examined sex differences in emotional prosody processing because previous research has found sex differences in emotion recognition accuracy (c.f. Hall, 1978) and neural processing underlying emotional prosody recognition (Schirmer et al., 2013; Schirmer, Striano, & Friederici, 2005).

The present study

Studies exploring potential brain mechanism differences in interpersonal sensitivity between individuals primed with high versus slow power are rare. One exception is a recent transcranial magnetic stimulation study (Hogeveen, Inzlicht, & Obhi, 2014) investigating human mirror activity as a function of primed social power. In this study, primed (high vs. low power) and unprimed participants were stimulated with a TMS pulse while watching video clips of hand actions. The power priming procedure used was identical to the one used in the present study (Galinsky et al., 2003). The elicited motor evoked potentials were reduced in individuals primed with high power compared to individuals primed with low power. This reduction was argued to reflect lower levels of motor cortex excitability for high power primed participants. In other words, participants primed with high power showed less mirror system activation when observing others' actions and the authors argued that it is this reduced motor cortex excitability leading to lower interpersonal sensitivity in these individuals (Hogeveen et al., 2014).

So far no research has examined ERP-correlates associated with emotional perception as a function of the recipient's social power. Thus, the present investigation was designed to investigate ERP patterns in response to emotional prosody processing in individuals primed with high vs. low power. This endeavor is important given the heterogeneous results on the relationship between social power and non-verbal emotion recognition reported in the literature. In this study, we ask whether and how differences in social power on emotional prosody processing manifest at the neural level. That is, while behavioral studies measuring emotional prosody recognition accuracy are informative, they fail to provide insight into the time-course underlying emotional prosody perception among individuals primed with high versus low power. This, however, is crucial given the different processes (acoustic analysis as reflected in the N1 ERP component, salience detection as reflected in the P2 ERP component, meaning evaluation as reflected in the late potential) postulated in multi-stage models of emotional prosody processing (Schirmer & Kotz, 2006; Kotz & Paulmann, 2011; Frühholz et al., 2016). If previously observed low emotional prosody recognition rates for individuals primed with high power are related to altered acoustic extraction or emotional salience detection processes, differences between high and low power primed individuals should be detected in early emotional prosody processing stages (N1 and P2 components). However, if differences in emotional meaning processes lead to emotional prosody recognition rates between high and low power primed individuals, we expect to find ERP differences between the two groups in later processing stages (the positive potential). Specifically, we would expect less or no modulation of ERP components linked to these processes for high power individuals if they exhibit reduced emotional sensitivity. Crucially, we can use ERPs to investigate the *temporal* unfolding of neural processes underlying emotional prosody recognition among individuals primed with high vs. low power and this permits the examination of three different sub-processes of emotional prosody processing: early sensory processing (linked to the N1 component), early emotional salience detection (linked to the P2 component) and emotional meaning evaluation of the prosodic contour of a stimulus (linked to later long-lasting components). This investigation thus allows clarifying the on-line processing mechanism underlying the observed differences between high and low power primed in emotional prosody recognition accuracy.

Method

Participants and procedure. In a between-subjects design, forty right-handed undergraduate students (22 women, M_{age} = 22.39) were randomly assigned to a low (n = 20; 10 women) or high (n = 20; 12 women) power prime condition. As outlined above, the goal of this investigation was to explore emotional prosody perception in these two participant groups (high vs. low power prime condition). Sample size was determined on the basis of effect sizes observed in previous ERP studies (e.g., Paulmann & Kotz, 2008). The procedures used to prime high vs. low power and the emotion recognition task were identical to those used in our previous study (Uskul et al., 2016) and as introduced by Galinsky and colleagues (2003). This priming method has been shown to effectively induce a feeling of holding or lacking power as indicated in differences of self-reported power scores (i.e., manipulation check). Thus, following this commonly employed procedure, we asked participants to recall and describe a particular incident in which they had power over another individual or individuals (high power prime) or to recall and describe an incident in which someone else had power over them (low power prime). All participants had normal or corrected to normal vision and none reported any hearing impairments or psychiatric/neurological conditions. Participants were also asked to report their daily intake of caffeine, alcohol, and nicotine and no unusual reports were found. Participants were either compensated financially for their participation or received course credit.

After preparation for EEG recordings, participants were seated in a shielded chamber at a distance of approx. 100 cm in front of a monitor. Priming with high or low power occurred after EEG preparation, just before the recognition task started. In the recognition task, participants were asked to indicate which emotional tone of voice the speaker had used by clicking on one of seven response options displayed on screen. Five practice trials were presented before a total of 196 sentences were pseudo-randomly presented over seven blocks. In each block, an approximately equal amount of different emotional prosodies was presented. Each block of 28 sentences was followed by a short break. A trial worked as follows: a fixation cross was presented in the middle of the screen for 250 milliseconds. After the fixation cross disappeared, a sentence was played via speakers, followed by the response screen which stayed until participants made their choice. Response options were labelled as anger, disgust, fear, happy, surprise, sad, neutral. A blank screen (inter-stimulus interval) was presented for 1000 milliseconds before the next trial began. No time limitation was imposed on participants but they were encouraged to respond as quickly and accurately as possible. Run-time of experiment was approximately 30 minutes.

Following the completion of the EEG experiment (i.e., emotion recognition task), participants responded to a 7-item manipulation check that assessed how they *felt* in the described incident they were asked to recall (in-control, powerful, independent, weak, dominant, powerless, and in-charge; 1 = *strongly disagree* to 9 = *strongly agree*). The manipulation check administered after the EEG study confirmed that participants in the high power condition (M = 5.63, SD = .87) perceived themselves as having significantly more power than those in the low power condition (M = 3.85, SD = .83), t (38) = 6.65, p < .001.

Materials. Materials used in the present study were taken from a published inventory (Paulmann & Uskul, 2014). For this inventory, 28 so-called pseudo-sentences (e.g., Flotch deraded the downdary snat) were intoned by a British actress in 6 different emotions (anger, disgust, fear, happiness, surprise, and sadness) or in a neutral tone of voice (see Paulmann & Uskul, 2014 for details). The advantage of using pseudo-sentences is that emotional connotation can only be extracted from prosody and not from content. Table 1 lists main acoustic parameters for the stimuli split by emotional category.

-- Insert Table 1 about here --

ERP recording. The EEG was recorded from 63 Ag–AgCl electrodes mounted on a custom-made cap (waveguard) according to the modified extended 10–20 system using a 72 channel Refa amplifier (ANT). Signals were recorded continuously with a band pass between DC and 102 Hz and digitized at a sampling rate of 512 Hz. Electrode resistance was kept below 7 KΩ. The reference electrode was placed on the left mastoid and data was re-referenced offline to averaged mastoids. Bipolar horizontal (positioned to the left and right side of participants' eyes) and vertical EOGs (placed below and above the right eye) were recorded for artifact rejection purposes using disposable Ambu Blue Sensor N ECG electrodes. CZ served as ground electrode. Data were filtered offline with a cut-off of 30 Hz (using an FIR-Filter provided by EEP) and a baseline correction was applied using the EEProbe cntaverage function. For each ERP channel, the mean of our baseline time-window (-200 to 0 ms) was subtracted from the averaged signal. Additionally, ERPs were filtered offline with a 7 Hz low-pass filter for graphical display, only. Data were inspected visually in order to exclude trials containing extreme artifacts and drifts, and all trials containing EOG-artifacts above 30.00 µV were rejected automatically using the software EEProbe and the cntreject function. In total, approximately 19% of data was rejected (range for emotional categories: 17.6% - 20%). All trials that were not contaminated with artifacts were in an epoch of 800 milliseconds time-locked to the sentence onset, with a 200 milliseconds prestimulus baseline.

Data analysis

Electrodes were grouped according to scalp regions of interests (SROI). Each SROI defined a critical region of scalp site: Left frontal: F5, F3, F1, FC5, FC3, FC1; left central: C5, C3, C1, CP5, CP3, CP1; left posterior: P5, P3, P1, PO7, PO3, O1; right frontal: F6, F4, F2, FC6, FC4, FC2; right central: C6, C4, C2, CP6, CP4, CP2; and right posterior: P6, P4, P2, PO8, PO4, O2. This electrode grouping approach allowed us to keep the number of electrodes in each SROI constant while covering a broad scalp range to explore topographical differences. ERP mean amplitudes measured at frontal, central, and posterior SROIs created the factor region (frontal, central, parietal), and ERPs measured at right and left hemisphere SROIs established the factor hemisphere (right vs. left) in the statistical analysis. Following previous approaches (e.g., Paulmann et al., 2013; Schirmer et al., 2013) as well as ERP guidelines (e.g., Luck, 2005), ERP-time windows were selected based on a combination of the following strategies: visual inspection, previous evidence, and determining peak latency. Based on visual inspection and after determining peak amplitudes (using the avrretrieve function of EEProbe), early time-windows from 130-170 ms (N1) and from 200 to 250 ms (P2) after sentence onset were chosen as the critical time frames for the components of interest. In addition, a later time-window ranging from 450 to 850 ms after sentence onset was analyzed based on previous evidence (Paulmann et al., 2013) and visual inspection. Following our previous approach (Paulmann, Pell, & Kotz, 2008), we report omega-squared (Ω^2) as an effect size estimator. Ω^2 can be described as the coefficient of determination, which represents the proportion of variance in the dependent variable accounted for by the independent variable and is interpreted similar to r^2 (see Olejnik & Algina, 2003).

Results

Behavioral results. Accuracy rates were determined by counting correct responses to prosodic stimuli, dividing them by the total number presented in each category and then multiplying them with 100 (to obtain percentages, rather than proportions). A mixed model ANOVA with emotional prosody recognition as the dependent variable and type of *emotion* as a within-subjects factor and *power prime* and *participants' sex* as between-subjects factors revealed a significant main effect of *participant sex*, F (1, 36) = 4.90, p = .03, Ω^2 = *.09*, showing that female participants were more accurate at recognizing emotions (M = 76.53%, SD = 7.11) than male participants (M = 69.93%, SD = 12.35). Individuals primed with low power (M = 74.29%, SD = 10.01) showed slightly higher emotion recognition rates compared to individuals primed with high power (M = 72.83%, SD = 10.66), but this difference was not significant, F (1, 36) = .67, p = .42, Ω^2 = *.0*. In addition, a significant main effect of *emotion* was found, F (6, 216) = 45.16, p < .001, Ω^2 = *.06*. Anger was recognized best (M = 89.82%, SD = 10.96), followed by neutral (M = 88.66%, SD = 11.32), sadness (M = 80.00%, SD = 14.19), disgust (M = 77.41%, SD = 16.46), surprise (M = 66.87%, SD = 18.26), fear (M = 61.07%, SD = 16.96), and happiness (M = 51.07%, SD = 20.63). No significant interactions between type of *emotion* x *participant sex,* F (1, 36) = .62, p = .71, Ω^2 = *.0,* or *emotion x power prime,* F (1, 36) = .88, p = .51, Ω^2 = *.0*, were found. Table 2 displays behavioural effects.

-- Insert Table 2 about here --

ERP results. We entered the mean ERP amplitudes obtained in each of the processing stages into mixed ANOVAs with *emotion* (anger, disgust, fear, sadness, happiness, pleasant surprise, neutral), *region* (frontal, central, posterior electrode-sites), and *hemisphere* (right vs. left) as within-subjects factors and *power* condition (high vs. low) and *participant sex* (male vs female) as between-subjects factors. For the ease of reading, below we only report significant main effects and interactions involving the critical factors *emotion* and *power*. We also report effects approaching significance ($p < .08$) to inform readers about emerging patterns. To correct for multiple comparisons of posthoc contrasts, we adopted the formula proposed by Keppel (1991) which revealed a modified *p* value of .017 obtained by multiplying *p* of .05 with the degrees of freedom associated with the conditions tested, divided by the number of comparisons. We thus used this value to determine the significance level of the observed effects obtained in our analyses below. A Geisser-Greenhouse correction was applied to all repeated measures with greater than one degree of freedom in the numerator. To confirm that no differences were present between our different conditions and/or groups, we ran an additional analysis for the baseline time-window (-200 to 0 ms time-locked to sentence onset). This analysis revealed no significant main effects (all *F*s < 0.84 and all *p*s > 0.97) or interactions (all *F*s < 2.27 and all *p*s > 0.11) confirming that the groups' amplitudes in response to the different emotional categories did not differ at baseline.

N1. In a time-window between 130-170 ms, a non-significant effect of *emotion* was observed, F (6, 216) = 2.05, $p = .08$, $\Omega^2 = .02$. This was qualified by a non-significant interaction between *emotion* and *participant sex*, F (6, 216) = 2.22, $p = .06$, $\Omega^2 = .02$. No other effects reached significance (all *p*s > .08).

P2. Within the time-window of 200 to 250 ms, the effects of *participant sex*, *power* condition, or *emotion* were not significant (all *p*s > .20); however, there was a significant *emotion* X *region* interaction, F (12, 432) = 2.72, $p = .025$, $\Omega^2 = .03$. Further analyses by *region* showed a significant *emotion* effect at frontal electrode sites, F (6, 216) = 3.02, p = .01, $\Omega^2 = .04$, but not at central or parietal sites (all ps > .23), suggesting that different emotional prosodies elicited differentially modulated P2 amplitudes at frontal electrode sites independent of power prime. Specifically, posthoc contrasts revealed that ERPs in response to angry prosody differed significantly from ERPs in response to disgust, sad, and pleasant surprise prosody (all ps < .017). It also differed marginally significantly from happy (p = .029) prosody. No other contrasts were significant below the adjusted p-value of .017.

Crucially, there was an *emotion* X *power* interaction, F (6, 216) = 3.30, p = .01, $\Omega^2 = .04$. Follow-up analyses by *power* condition revealed a significant *emotion* effect for participants primed with low power, F (6, 114) = 3.05, p = .02, $\Omega^2 = .03$, but not for those primed with high power, F (6, 114) = 1.41, p = .25, $\Omega^2 = .01$. Posthoc contrasts revealed that participants primed with low power showed significantly different ERPs in response to angry compared to disgust, happy, and sad prosody (all Fs > 7.10, all ps < 0.017). The contrasts between angry prosody and fearful prosody (p = .045), between disgust and sad (p = .042) and between neutral and sad (p = .028) prosody approached significance. Finally, there was also a non-significant four-way interaction between *emotion* X *region* X *power* X *sex*, F (12, 432) = 2.22, p = .06, $\Omega^2 = .01$, for which step-down analyses did not reveal any significant effects (ps for all other effects were > .15). These results reveal that early emotional salience detection differs between individuals primed with high vs. low power; only those primed with low power (and not those primed with high power) showed significantly differently modulated P2 amplitudes across the scalp. Figure 1 displays the P2 effects for both power groups separately. In addition, Figures 2-4 show relevant effects in bar graph format.

Later component. An analysis of the later time-window (450 - 850 ms after stimulus onset) showed a significant main effect of *emotion*, F (6, 216) = 3.02, p = .01, $\Omega^2 = .04$, which was qualified by a significant *emotion* X *power* interaction effect, F (6, 216) = 2.68, p = .02, $\Omega^2 = .03$, and a significant *emotion* X *participant sex* interaction, F (6, 216) = 2.24, p = .05, $\Omega^2 = .02$. For the first interaction effect, we conducted a step-down analysis by *power* prime which revealed a significant *emotion* effect for the group primed with low power, F (6, 114) =

4.84, p = .001, Ω^2 = *.05*, but not for the group primed with high power, F (6, 114) = .68, p = .66, Ω^2 = *0*. Posthoc contrasts for the group primed with low power revealed significant ERP differences for the comparisons between anger and happy prosody, anger and neutral prosody, sadness and neutral, and surprise and neutral prosody (all *F*s > 11.10, all *p*s < 0.017). Marginally significant differences were found for the contrasts between anger and disgust prosody (p = .044), happy and surprise (p = .018), anger and fear (p = .054), fear and neutral (p = .045), as well as between happy and sad prosody (p = .031) (see Figure 1 for the direction of differences).

For the *emotion* X *participant sex* interaction, step-down analyses by participant *sex* revealed a significant *emotion* effect for women, F (6, 126) = 2.78, p = .03, Ω^2 = *.03,* but not men, F (6, 102) = 2.31, p = .07 Ω^2 = *.02*. For female participants, posthoc contrasts revealed significant differences between ERPs in response to anger and happy and happy and surprise (all *p*s < .017), and marginal effects for anger vs. neutral (p = .037), fear vs. happy (p = .034), happy vs. sadness (p = .037), and neutral vs. surprise (p = .025). For male participants, posthoc contrasts revealed significant ERP differences between anger and neutral prosody, neutral and fear, and neutral and happy prosody (all *p*s < .017). Contrasts between neutral and disgust (p = .036), neutral and sadness (p = 0.024), and neutral and surprise prosody (p = .023) were marginally significant. Finally, step-down analyses conducted to unfold the marginally significant *hemisphere* X *region* x *power* prime interaction, F (2, 72) = 3.08, p = .06, Ω^2 = *.01*, did not reveal any significant effects. All other effects resulted in *p*s > .10). Late component effects are displayed in Figures 5-7 in bar graph format.

In sum, participants primed with low power showed significantly differently modulated amplitudes in response to the different emotional prosodies at later processing stages, whereas no such amplitude differences in response to the different emotional prosodies were found for those primed with high power. While both male and female participants showed significantly modulated LPP amplitudes, individual emotion contrasts differed depending on participants' sex.

-- Insert Figures 1-7 about here --

General Discussion

The role of social psychological factors in emotional prosody processing has been underexplored despite evidence linking power to differences in interpersonal sensitivity in other domains (e.g., face processing). For the first time, we explored ERP-patterns of individuals primed with feeling either low or high in power, focusing on three different processing stages. The goal of this investigation was to shed light on the underlying mechanisms of previously reported power differences observed in behavioural data (Uskul et al., 2015). Our data did not reveal any differences between low versus high power groups in the N1 component, suggesting that the two groups did not differ in how acoustical attributes were extracted in this initial sensory processing stage. Examining the P2 component, we found that participants primed with low power displayed differentially modulated amplitudes, an effect reported for non-primed populations (e.g., Paulmann & Kotz, 2008; Paulmann et al., 2013; Schirmer et al., 2013); this effect was, however, absent among those primed with high power. Examining the later component, we found that participants primed with low power showed differentially modulated amplitudes in response to different emotional prosodies, again similar to unprimed populations (e.g., Paulmann et al., 2011, 2013; Schirmer et al., 2013), but those primed with high power did not. These findings provide novel evidence for the temporal dynamics underlying emotional prosody perception in high versus low power primed participants.

In the light of studies that have repeatedly linked the P2 to early emotional (salience) detection based on the analysis and integration of emotionally relevant acoustic cues (c.f. Paulmann & Kotz, 2008; Paulmann et al., 2011, 2013; Schirmer et al., 2013), the current findings reveal that only individuals primed with low power engage in initial, rapid evaluation of emotionally relevant acoustic attributes. This difference could be accounted for by at least two explanations. First, it might be due to the tendency of those in low power to focus on detail (e.g., Smith & Trope, 2006; Smith, Wigboldus, & Dijksterhuis, 2008). Attention to detailed acoustic changes is crucial during early (P2) stages of emotional prosody processing as forming an emotional ‘Gestalt’ is only possible if integration of the various relevant acoustic cues remains unhindered. Thus, if high power individuals pay less attention to these complex acoustic fluctuations than low power individuals, then their emotional prosody differentiation as reflected in the P2 would be altered. This explanation is in line with recent work showing that low power increases vigilance in the processing of perceptual cues (Weick, Guinote, & Wilkinson, 2011), whilst the lack of control that accompanies low power motivates individuals to integrate information into a coherent whole (Whitson & Galinsky, 2008).

Alternatively, individuals primed with low power (compared to those primed with high power) may have simply been more motivated to engage with the stimulus materials. It has, for instance, been argued that individuals lacking power have an increased motivation to do well on a task (i.e., to be particularly accurate; c.f. Fiske & Depret, 1996). Moreover, it has been argued that high (primed) power individuals display more of a goal-directed behavior (e.g., Galinsky et al., 2003; Guinote, 2007). In a situation where there is no immediate benefit (as in the current task), individuals primed with high power might choose not to pay attention to subtle differences in acoustic attributes (which is in line with the idea that they prefer to process the “gist” of information; see Guinote, 2013). It is worth noting that (priming) high power is often associated with *increased* performance in cognitive tasks (see Weick et al., 2011, for a discussion of this literature), which would argue against an explanation in terms of task disengagement. That said, this possibility remains to be tested in future studies where individuals primed with high versus low power are asked to carry out the same task as the one used in the current research, this time within a meaningful context (e.g., using a cover story that would encourage them to do particularly well in this task to win a prize at the end).

Finally, the following interpretation of the data should also be considered. Looking at the means of ERP amplitudes suggests that increased amplitudes were observed for the high power prime group when compared to the low power prime group (though note that this difference was not supported statistically). If increased amplitudes are a sign of increased processing efforts, it could be speculated that individuals primed with high power focused too much on acoustic details (rather than not enough). If true, getting “caught up” in emotionally relevant details, or absorbing too much information, could then lead to a lack of differentiation between emotions. How this over-attentive processing approach could result in reduced emotional recognition rates for individuals primed with high power (as observed previously) remains to be tested in future studies; however, one speculation is that over-vigilant processing actually leads to a reduced ability to identify *relevant patterns* (e.g., acoustic cue combinations) needed for successful emotional prosody recognition. In other words, too much focus might be put on individual cues, rather than their appropriate combination.

In addition to early processing differences, we also found differences in the subsequent processing stage as a function of power prime. Again, similar to unprimed participants (e.g., Paulmann et al., 2013; Schirmer et al., 2013), only the low power group showed differently modulated late components in response to different emotional expressions. Previous reports (e.g., Paulmann et al., 2011, 2013; Schirmer et al., 2013) have functionally linked these later long-lasting components to an enhanced, continuous analysis of stimuli that carry potentially relevant affective information (i.e., an in-depth analysis of emotionally relevant stimuli to ensure appropriate social behavior, for example fight vs. flight). Building on these findings, the current data point to the possibility that the group primed with high power failed to consistently exhibit such an in-depth analysis. This is perhaps not surprising given that their differentiation of emotional prosodies at an early stage was also not significant (see Schirmer et al., 2013 who suggest that different processing stages are not independent of each other). We have argued that the later, more thorough analysis of emotional prosodic attributes relies on processes that emphasize a “continuous combinatorial analysis of emotional features” (Paulmann et al., 2011, pg. 10). If true that people primed with high power do not generally steadily scan for manifold variations in the acoustic signal, then the lack of emotional differentiation at a late processing stage is not surprising. Alternatively, the lack of late differentiation between emotions might indicate that participants primed with high power disengaged with the process of explicit evaluative judgements (i.e. linguistic labelling, or categorizing) of specific emotions. Schirmer and Kotz (2006) proposed that this evaluative judgement is one of the last stages of emotional prosody processing. Future studies will have to try and tease apart the two alternative interpretations (failure of in-depth processing vs. failure to engage with labelling emotions).

Finally, (primed) power has also been linked with a disregard for other individuals and with a decline in the motivation to affiliate with others (e.g., Case, Conlon, & Maner, 2015; Keltner, Gruenfeld, & Anderson, 2003). These behavioral tendencies could also explain the lack of engagement with emotional stimuli. Specifically, it could be argued that powerholders were less likely to engage with the speakers' emotional states (that is they did not want to take their perspective, or felt less inclined to show "compassion" in response to their emotional utterances), similar to how they have been shown to disengage with language of others that expressed distress (Van Kleef et al., 2008).

In our previous studies (Uskul et al., 2016), results suggested that priming individuals with high power reduced emotional prosody accuracy rates rather than low power prime leading to enhanced emotional prosody recognition rates. Although visual inspection of the behavioural recognition rates suggest that those primed with low power perform better than those primed with high power, this comparison failed to reach significance. In our previous studies (i.e. those that aimed to explore behavioural differences), we tested more than 200 participants all together. Here, given that the focus was on ERP differences, sample size was limited to 40 participants. It can thus be speculated that the failure to replicate the behavioural significance is related to sample size. Nevertheless, the previous observation that those primed with low power perform similarly to those without power (Uskul et al., 2016) was mirrored in the current ERP results where ERP components linked to emotional prosody processing observed in those primed with low power are comparable to components previously observed in non-primed populations (e.g., Paulmann et al., 2013;

Schirmer et al., 2013). It can thus be speculated that priming high power leads to changes in brain processing mechanisms (e.g., processing mechanisms underlying emotional prosody perception). This speculation fits well with recent evidence demonstrating that priming power can impact on neural responses in other domains (e.g., mirroring other people's actions), such as reduced motor-evoked potentials observed in those primed with high power when compared to individuals primed with low power (Hogeveen et al., 2014).

The present study also allows for commenting on the relationship between social power and individual emotions as expressed through prosody. It has been suggested that low power individuals will engage more with negative affect, while high power individuals might engage more with positive affect (c.f. Keltner et al., 2003). Specifically, it has been argued that negative affect is experienced more strongly by low power individuals, while the experience of positive emotions is heightened in high power individuals. Moreover, it has been suggested that high power links to approach-related emotions, while lower power links to avoidance-related emotions (e.g., Keltner et al., 2003). The present findings are, however, difficult to reconcile with valence-based or approach/inhibition-based accounts. In particular, we found that high power dampened individuals' responses to both positive emotions (e.g., happiness) and negative emotions (e.g., fear) in the ERP data. A similar pattern was observed for approach-related emotions (e.g., anger) and for inhibition-related emotions (e.g., disgust, surprise). Thus, the differential processing of prosodies documented in the present research appears to be indicative of a more general phenomenon that occurs across a range of emotions.

Overall, perhaps the most consistent and strongest differentiation between low and high power primed individuals was observed for acoustic signals of anger. Relative to other emotions, angry prosodies elicited strong amplitudes and a distinct pattern of cortical activity in low power, but not in high power individuals. Anger is a dominance-signaling cue, and as such the finding that power reduces the processing of acoustic anger signals is particularly intriguing, albeit consistent with recent evidence that suggests high power can act as a buffer and reduce individuals' sensitivity to hostile behaviors (Strelan, Weick, & Vasiljevic, 2014).

Taken together, these data, for the first time, suggest that individuals primed with high or low power listen to emotional language stimuli in a non-identical fashion. Future studies are needed to clarify the extent to which individual emotion effects as observed here can be replicated and extended with different stimuli containing different emotional acoustic variables. In the current study, only a moderate amount of prosody items was presented to participants, to ensure that experimental run time stays within norms reported for emotional prosody studies (e.g., 45 minutes maximum). To help increase the signal-to-noise ratio, future studies could minimize the amount of emotional tones tested and increase participant numbers in each priming group.

Finally, it is noteworthy that our data also revealed differences between women and men when recognizing emotions from the voice. Specifically, sex differences were found in the early N1 component; the data showed that females' N1 response differed between neutral and negative (anger and sadness) and neutral and positive (happiness) prosody, while the same differentiation was not found for male participants. However, this early sensory processing difference did not lead to differences in early salience detection as the P2 component did not vary as a function of participant sex. Lastly, the later ERP effect previously linked to more enhanced processing of emotional prosodies, only differed slightly between female and male participants as reflected in differences in a subset of individual emotion contrasts. Our findings thus add to the body of evidence which suggests that women and men can (but do not always do) differ in their evaluation of emotional (prosodic) characteristics (e.g., Schirmer & Kotz, 2003; Schirmer et al., 2002).

Limitations

In contrast to some previous reports (e.g., Paulmann et al., 2013; Schirmer et al., 2013), the current study presented fewer than 30 trials per emotional category condition as we followed the same experimental design applied in Uskul et al. (2016). This number was further reduced after removing EEG artefacts, leading to a lower signal-to-noise ratio of our data in comparison to the majority of previous studies. Although the lack of emotion differentiation effects observed in the group primed with high power are unlikely directly linked to this limitation, given that significant emotion effects were reported in studies testing fewer participants (e.g. < 15) with similar number of trials presented (e.g., Paulmann, Seifert, Kotz, 2010; Paulmann, Ott, Kotz, 2011), future studies should examine power effects by increasing trial numbers. Similarly, the convention in ERP studies is to analyze correctly and incorrectly answered trials separately; this sensible approach is particularly important when one is interested in the routine applied during a specific process. However, in the present study, we were particularly interested in studying the processes associated with participants' performance in an emotional prosody recognition task (i.e. processes that sometimes lead to accurate and sometimes to inaccurate identification of a stimulus). Thus, both correctly and incorrectly answered trials were included in the analysis. To overcome the problem of analyzing trials in a combined way (as was done here), we suggest that future studies should reduce the number of emotions tested (and thereby increase trial numbers for the remaining categories) and to provide task instructions that might lead to higher error rates in participants (e.g., manipulate motivation to do well/not well in the task). This should permit analyzing the data separately, leading to the possibility to compare performance across groups for processes associated with correct and incorrect identification separately.

Conclusion

The current study set out to explore ERP-patterns underlying previously observed emotional prosody processing differences between individuals primed with high and low power. Specifically, we examined power differences using ERPs to investigate online processing differences in early and later stages which have been shown to provide information about salience detection versus deeper processing, respectively (e.g., Paulmann & Kotz, 2008; Paulmann et al., 2013; Schirmer et al., 2013). This allows commenting on the time-course of emotional prosody perception and helps explain the underlying mechanisms for the observed power differences. In particular, the current results suggest that high power affects both early and later processing of emotional prosody. This way, the current findings contribute to the emerging literature on the role of power in neural processes related to interpersonal sensitivity (Hogeveen et al., 2014) and point to a need to take into consideration the role that social psychological variables can play in the neural underpinnings of emotional prosody processing.

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Tables

Table 1

Fundamental Frequency (f_0) and Intensity (dB) Values from Acoustical Analyses Carried Out for Stimulus Materials

Emotion	Mean *F0 (Hz)*	Range *F0 (Hz)*	Mean dB	Range dB	Duration (seconds)
Anger	258.0	241.6	53.7	78.0	2.2
Disgust	242.1	319.8	54.1	43.8	2.7
Fear	299.3	211.3	53.1	55.8	2.2
Happiness	256.7	199.4	54.8	43.1	2.1
Neutral	211.3	167.8	51.6	41.8	2.4
Surprise	311.5	378.8	55.8	45.5	2.0
Sadness	256.0	166.5	48.6	67.4	2.3

Note: Range refers to the difference between the highest and lowest F0 value in an utterance.

Table 2

Mean Recognition Rate for Each Emotion by Power Prime

	Emotion						
power prime	anger	disgust	fear	happiness	neutral	sad	surprise
Low	91.79	80.18	62.14	48.57	90.71	79.29	67.32
	(8.76)	(16.03)	(18.08)	(19.88)	(9.01)	(14.41)	(19.78)
High	87.86	74.64	60.00	53.57	86.61	80.71	66.43
	(12.71)	(16.83)	(16.16)	(21.58)	(13.15)	(14.30)	(17.12)

Note: Standard deviations are provided in brackets.

Figure Captions

Figure 1. Early and late ERP effects as a function of power prime (high vs. low) at selected electrode-sites. Waveforms show the average for neutral (green), happy (red), and angry (blue) sentences from 100 ms before stimulus onset up to 800 ms after stimulus onset.

Figure 2. The illustration shows P200 mean amplitudes (in Microvolt) for each emotional category for the High Power Primed Group.

Figure 3. The illustration shows P200 mean amplitudes (in Micro Volt) for each emotional category for the Low Power Primed Group.

Figure 4. The illustration shows P200 mean amplitudes (in Micro Volt) for each emotional category at frontal electrode sites.

Figure 5. The illustration shows mean amplitudes (in Micro Volt) for the late component for each emotional category.

Figure 6. The illustration shows mean amplitudes (in Micro Volt) for the late component for each emotional category for participants primed with high power.

Figure 7. The illustration shows mean amplitudes (in Micro Volt) for the late component for each emotional category for participants primed with high power.

Authors' Note

We would like to thank Sarah Harris, Alexandra Dylman and Desire Furnes for their help with stimulus preparation and data collection. This work was supported by the Department of Psychology (University of Essex) Research Promotion Fund awarded to Silke Paulmann.

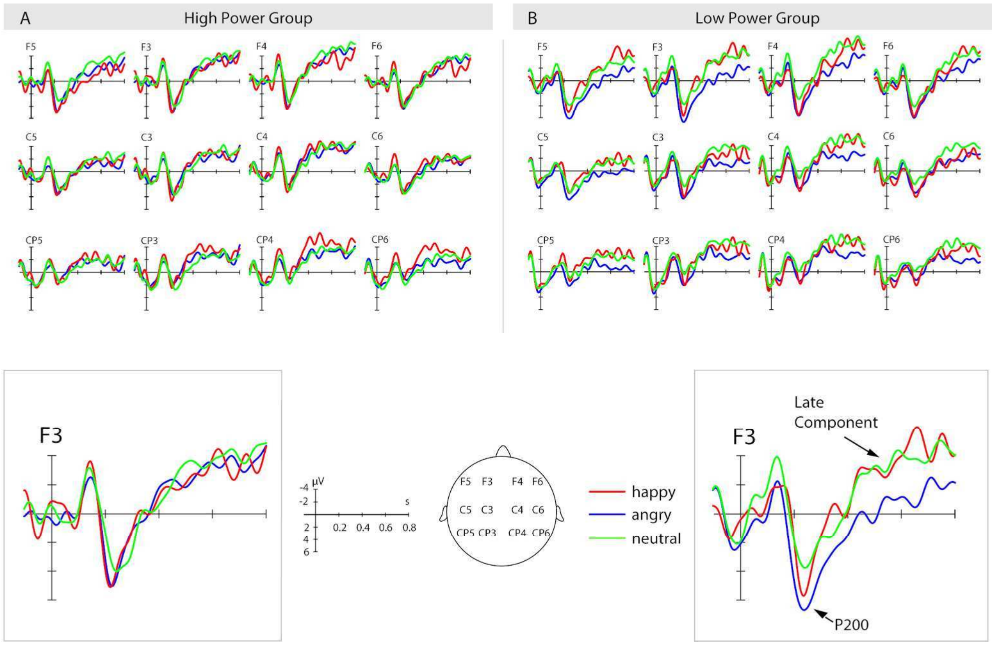

Figure 1: Early and late ERP effects as a function of power prime (high vs. low) at selected electrode-sites. Waveforms show the average for neutral (green), happy (red), and angry (blue) sentences from 100 ms before stimulus onset up to 800 ms after stimulus onset.

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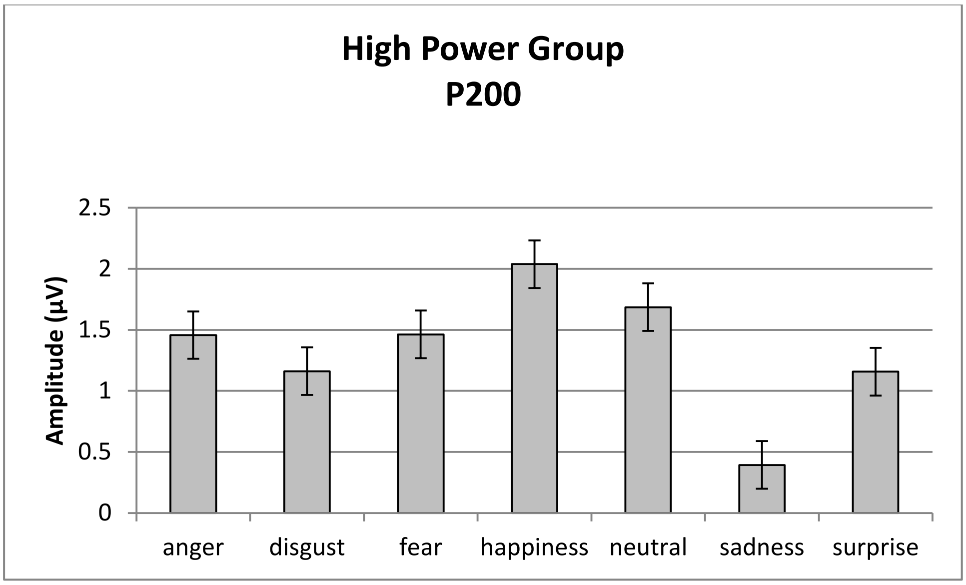
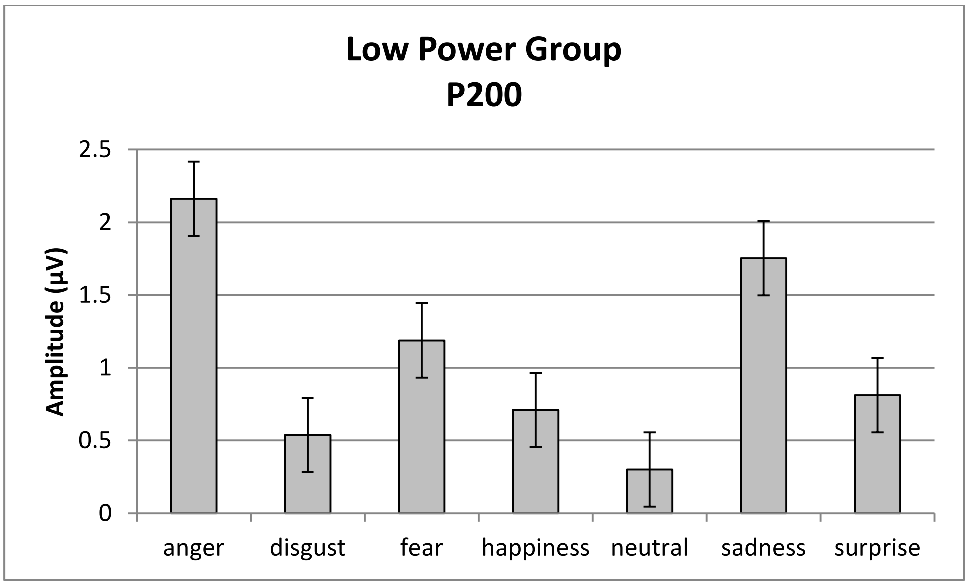
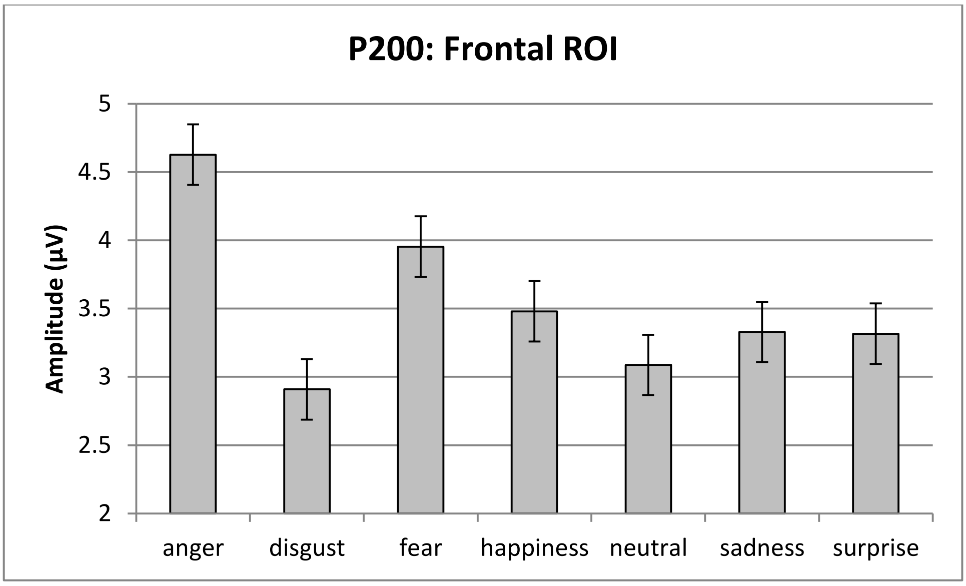
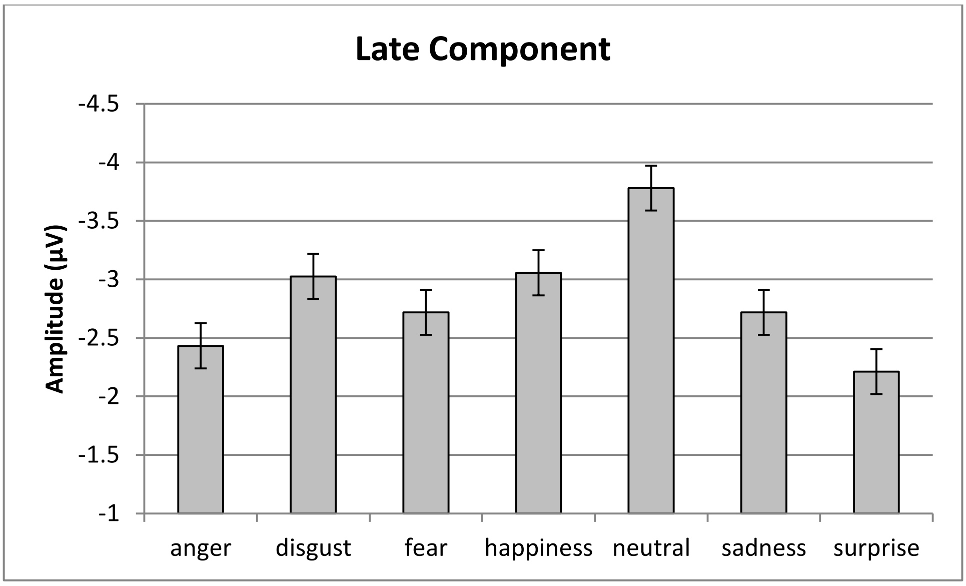
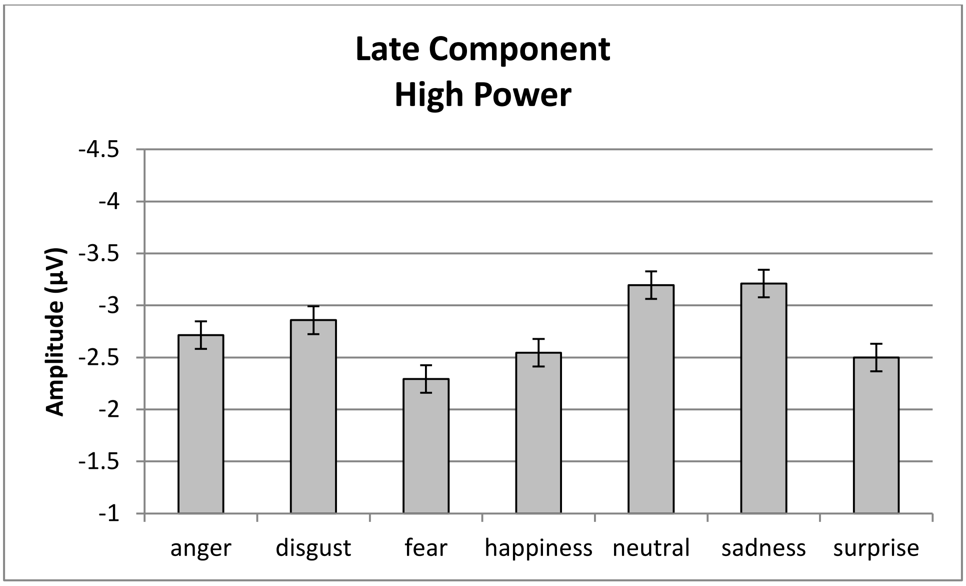
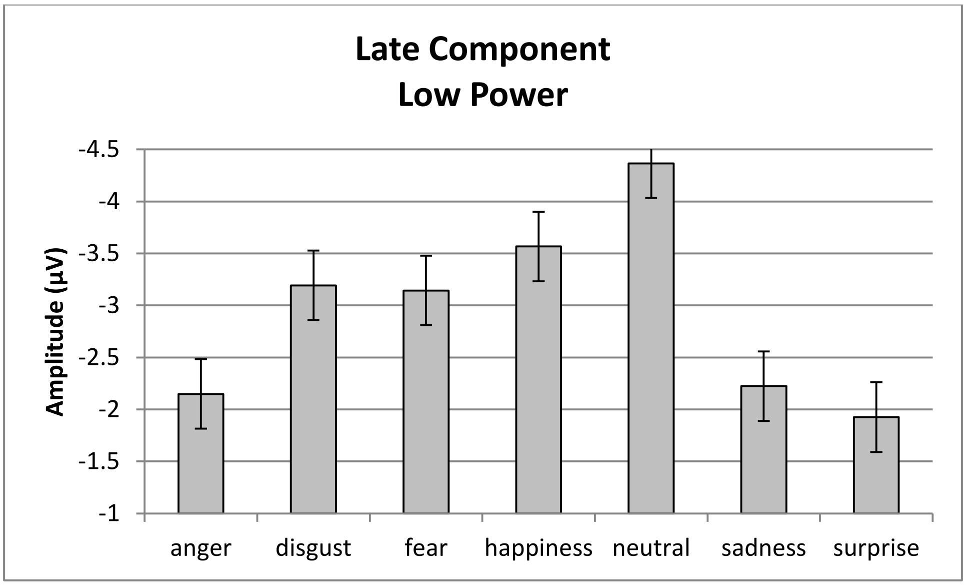

High Power Group
P200
Amplitude (µV)
2.5
2
1.5
1
0.5
0
anger
disgust
fear
happiness
neutral
sadness
surprise


Low Power Group
P200
Amplitude (µV)
2.5
2
1.5
1
0.5
0
anger
disgust
fear
happiness
neutral
sadness
surprise


P200: Frontal ROI
Amplitude (μV)
5
4.5
4
3.5
3
2.5
2
anger
disgust
fear
happiness
neutral
sadness
surprise


Late Component
Amplitude (µV)
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
anger
disgust
fear
happiness
neutral
sadness
surprise


Late Component
High Power
Amplitude (µV)
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
anger
disgust
fear
happiness
neutral
sadness
surprise


Late Component
Low Power
Amplitude (μV)
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
anger
disgust
fear
happiness
neutral
sadness
surprise