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# Electrocortical responses to NIMSTIM facial expressions of emotion

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ABSTRACT

Emotional faces are motivationally salient stimuli that automatically capture attention and rapidly potentiate neural processing. Because of their superior temporal resolution, scalp-recorded event-related potentials (ERPs) are ideal for examining rapid changes in neural activity. Some reports have found larger ERPs for fearful and angry faces compared with both neutral and other emotional faces, and a key aim of the present study was to assess neural response to multiple emotional expressions using the NIMSTIM. Importantly, no study has yet systematically evaluated neural activity and self-report ratings for multiple NIMSTIM expressions. Study 1 examined the time-course of electrocortical activity in response to fearful, angry, sad, happy, and neutral NIMSTIM faces. In Study 2, valence and arousal ratings were collected for the same faces in a separate sample. In line with previous findings, the early P1 was larger for fearful compared with neutral faces. The vertex positivity (VPP) was enhanced for fearful, angry, and happy expressions compared to neutral. There was no effect of expression on the N170. Marginally significant enhancements were observed for all expressions during the early posterior negativity (EPN). The late positive potential (LPP) was enhanced only for fearful and angry faces. All emotional expressions were rated as more arousing and more pleasant/unpleasant than neutral expressions. Overall, findings suggest that angry and fearful faces might be especially potent in terms of eliciting ERP responses and ideal for emotion research when more evocative images cannot be used.



## 1. Introduction

Decoding facial expressions of emotion is crucial for inferring the states and intentions of others. In this regard, faces might be an especially salient type of emotional stimulus. Indeed, facial expressions of emotion increase cortical arousal and capture attention (Armony and Dolan, 2002; Jiang et al., 2009; Öhman, 2002; Vuilleumier, 2005; West et al., 2009; Whalen et al., 1998). Because emotional processing tends to be rapid and dynamic, the millisecond resolution of event-related potentials (ERPs) might be ideal for examining neural activity in the context of facial expressions of emotion (e.g., Hajcak et al., 2012).

For example, the time-course of neural response to emotional scenes (i.e., International Affective Picture System [IAPS]; Lang et al., 2005) is well documented (Cuthbert et al., 1999; Foti et al., 2009; Keil et al., 2002; Olofsson et al., 2008; Smith et al., 2003; Weinberg and Hajcak, 2010), and there is evidence that emotional scenes enhance neural processing beginning as early as 100 ms, with sustained increases in neural activity evident for the duration of stimulus presentation (e.g., Hajcak et al., 2010). Taken together, these findings suggest that emotional scenes robustly impact neural activity across multiple processing stages.

However, many IAPS pictures include images of mutilated bodies, physical assault, and erotica, which may be inappropriate for certain populations (e.g., children and psychiatric patients). In these instances, stimulus sets using facial expressions of emotion—which have also been shown to potentiate ERPs—might be more appropriate. Indeed, many studies have examined ERPs in response to emotional and neutral faces; however, these studies vary widely in terms of the emotional expressions and stimulus sets employed, as well as the specific ERPs examined. The current study focused on the time-course of neural processing of fearful, angry, happy, sad, and neutral faces using the NIMSTIM facial stimulus set. NIMSTIM is large (i.e., there are more than 600 photos), freely available, full color, and is increasingly-used in studies of emotion (Tottenham et al., 2009). However, no study has systematically assessed ERP responses for multiple NIMSTIM expressions (cf. Blau et al., 2007). In terms of specific ERPs, we evaluated multiple components believed to be sensitive to emotional content (e.g., Eimer and Holmes, 2007): the P1/N1, Vertex Positive Potential (VPP)/N170, Early Posterior Negativity (EPN), and Late Positive Potential (LPP).

The P1/N1 complex presents as a positive-going ERP over occipital electrodes, and a negative-going ERP over frontocentral electrodes around 100 ms. The P1 and N1 putatively instantiate early selective attention, and are enhanced for stimuli presented in attended compared

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to unattended locations (Luck, 1995; Vogel and Luck, 2000). The P1/N1 is also larger/smaller for emotional compared to neutral scenes (Carretié et al., 2004; Delplanque et al., 2004; Foti et al., 2009; Hot et al., 2006; Keil et al., 2002; Smith et al., 2003), and the P1/N1 likely originates from regions of occipital and frontal cortex (Carretié, et al., 2004; Pessoa and Adolphs, 2010; Vuilleumier, 2005). However, evidence is less consistent in terms of whether emotional *faces* modulate the P1 and N1. Some reports observed a greater P1 for unpleasant faces compared to pleasant and neutral faces (i.e., a negativity bias; Bel-Bahar, 2008; Foti et al., 2010; Luo, et al., 2010; Williams et al., 2006), whereas other reports found an enhanced P1 for pleasant and unpleasant faces compared with neutral faces (Batty and Taylor, 2003; Esslen et al., 2004). The N1 is relatively understudied in terms of emotional faces. One study observed a more negative N1 for fearful compared to neutral and happy faces (Luo et al., 2010). Another report found a more negative N1 for neutral compared with fearful faces (Eimer and Holmes, 2002), and yet another observed no difference between emotional and neutral expressions for the N1 and the P1 (Eimer et al., 2003). Cross-study discrepancies could be due to variation in task demands (e.g., attention cues, Vogel and Luck, 2000) or stimulus luminosity (Johannes et al., 1995)—which influence the P1 and N1. Nonetheless, the literature as a whole suggests that under certain circumstances emotional faces can rapidly potentiate sensory and attention processing, and this effect may be especially robust for fearful or angry faces.

Following the P1/N1 complex, the VPP is a positive-going ERP maximal over mid-central sites approximately 170 ms after the presentation of faces. Neural processing during the time window of the VPP is enhanced for faces compared with non-faces (Bentin et al., 1996; Sagiv and Bentin, 2001; Wheatley et al., 2011), and for emotional compared with neutral facial expressions (Ashley et al., 2004; Blau et al., 2007; Eger et al., 2003; Eimer et al., 2003; Eimer and Holmes, 2007). The VPP also has a lateralized counterpart—the N170—a negative-going ERP that is prominent over occipital-temporal sites when using a nose or average-electrode reference (see Joyce and Rossion, 2005, Fig. 1)[1]. It has been suggested that the VPP is more sensitive to emotion in faces compared with the N170, and this might result from the VPP being better positioned to reflect contributions from frontal sources (e.g., Eimer and Holmes, 2007; Esslen et al., 2004; Kawasaki et al., 2001; Williams et al., 2006). Indeed, reports examining the VPP frequently observe enhancement in response to multiple emotional expressions (Ashley et al., 2004; Batty and Taylor, 2003; Eimer, et al., 2003; Foti et al., 2010; Luo et al., 2010), whereas the N170 was not sensitive to emotional content in at least three reports (Ashley et al., 2004; Eimer and Holmes, 2002; Eimer et al., 2003; cf., Blau et al., 2007). Moreover, similar to the other ERPs discussed herein, the VPP/N170 may be particularly enhanced for fearful or angry faces (Ashley et al., 2004; Batty and Taylor, 2003; Foti et al., 2010; Vuilleumier, 2005). Overall, the results suggest that processing enhancements in response to facial-affect are particularly evident for the VPP, and fearful expressions may increase processing even more than other emotional expressions.

The Early Posterior Negativity (EPN) follows the VPP/N170 and is a negative-going deflection in the waveform which becomes maximal at temporal-occipital sites between 175 and 275 ms (Foti et al., 2009; Schupp et al., 2006; Schupp et al., 2003). The EPN is enhanced for emotional compared with neutral stimuli (Foti et al., 2009; Schupp et al., 2004), including emotional faces (Leppänen et al., 2007; Mühlberger et al., 2009; Schupp et al., 2004). Emotional enhancement of the EPN putatively indexes enhanced visual processing in the occipital and temporal cortex (Schupp et al., 2003, 2006). Moreover, the EPN may be preferentially sensitive to threatening faces (fear and anger) compared with both pleasant and neutral faces (Holmes et al., 2008; Schupp et al., 2004). As with the N170/VPP, both the EPN and LPP can be observed when using the non-optimal reference scheme, but they emerge more clearly when using the average-electrode or average-mastoid reference, respectively. Moreover, reference choices also impact the emotion enhancement effects on the EPN and LPP: emotional modulation is more prominent when using the optimal reference for a given ERP (Hajcak et al., 2012).

The LPP is a positive-going slow wave that is maximal over central-parietal sites around 300 ms. The LPP is associated with sustained attention to motivationally-salient visual scenes (Hajcak et al., 2009, 2010; Schupp et al., 2000; Weinberg and Hajcak, 2011). Importantly, emotional expressions, compared with neutral expressions, also enhance the magnitude of the LPP, suggesting that emotional expressions also cue attention and sustained processing (Eimer, et al., 2003; Krolak Salmon et al., 2001; Luo et al., 2010). However, some studies have observed differential enhancement of the LPP as a function of expression type, with fearful and angry faces eliciting a larger LPP than happy, sad, or neutral faces (Foti et al., 2010; Morel et al., 2009; Schupp et al., 2004; Williams et al., 2006). Altogether, LPP enhancements are often observed in response to emotional faces, and in some cases, fearful and angry faces may be especially potent in terms of enhancing the LPP (e.g., Eimer, et al., 2003; Krolak Salmon et al., 2001; Luo et al., 2010; Schupp et al., 2004).

Altogether, the literature suggests that fearful and angry faces may be especially salient emotional expressions that capture attention and processing resources automatically, similar to emotional scenes containing fearful or threatening images (e.g., Schupp et al., 2004; Vuilleumier, 2005; Weinberg and Hajcak, 2010). By contrast, processing enhancements for other emotional expressions (i.e., happy, sad) might be less robust, and result from task demands and attention–emotion interactions. For example, passive viewing designs often report increased neural processing across the entire time-course of picture presentation for fearful and angry faces (Eimer and Holmes, 2002; Foti et al., 2010; Schupp et al., 2004; Williams, et al., 2006), whereas emotion discrimination or categorization tasks result in processing enhancements for other emotional expressions (Batty and Taylor, 2003; Bel-Bahar, 2008; Eimer et al., 2003; Krolak Salmon et al., 2001; Luo et al., 2010). Finally, referencing choices also impact ERP findings, and non-optimal reference schemes can attenuate the effect of emotion on ERPs (Hajcak et al., 2012; Joyce and Rossion, 2005).

In the current study, we utilized a passive viewing paradigm to evaluate the P1/N1, VPP/N170, EPN and LPP in response to angry, sad, happy, fearful, and neutral NIMSTIM faces. A passive viewing design was used to assess which emotional expressions automatically capture attention and enhance neural processing without added task demands. This approach is akin to psychophysiological studies of passively viewed emotional scenes (IAPS; see Bradley et al., 2001, for a review). Given prior reports on face processing and ERPs, we expected all emotional expressions to differ from neutral for the VPP, but fearful and angry expressions were expected to elicit greater processing enhancements than happy, sad, and neutral faces for other ERPs.

Study 2 collected arousal and valence self-report ratings to verify that the emotional faces used in Study 1 were perceived as more emotional than neutral, and to record normative valence and arousal ratings for the NIMSTIM set. Although normative ratings exist for angry, fearful, and happy NIMSTIM faces (Adolph and Alpers, 2010; Blau et al., 2007), self-report ratings have not been collected for sad NIMSTIM expressions, despite their increasing use in studies on depression (e.g., Wisco et al., 2012; Hankin et al., 2010). Based on previous reports for the NIMSTIM (Adolph and Alpers, 2010; Blau et al., 2007), and on previous reports for other facial stimulus sets (e.g., Goeleven et al., 2008), all emotional expressions were expected to be rated as more arousing and pleasant/unpleasant than neutral faces.

[1] There is evidence suggesting that the VPP and N170 are opposite ends of the same dipole, and their presentation is a function of referencing montage. The VPP is prominent over the vertex when using an earlobe, mastoid, and non-cephalic reference, whereas the N170 is prominent over occipital-temporal sites when using a nose and average-electrode reference (see Fig. 1 Joyce and Rossion, 2005).