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Emotional facial expressions evoke faster orienting responses, but weaker emotional responses at neural and behavioural levels compared to scenes: A simultaneous EEG and facial EMG study

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ABSTRACT

In the current study, electroencephalography (EEG) was recorded simultaneously with facial electromyography (fEMG) to determine whether emotional faces and emotional scenes are processed differently at the neural level. In addition, it was investigated whether these differences can be observed at the behavioural level via spontaneous facial muscle activity. Emotional content of the stimuli did not affect early P1 activity. Emotional faces elicited enhanced amplitudes of the face-sensitive N170 component, while its counterpart, the scene-related N100, was not sensitive to emotional content of scenes. At 220–280 ms, the early posterior negativity (EPN) was enhanced only slightly for fearful as compared to neutral or happy faces. However, its amplitudes were significantly enhanced during processing of scenes with positive content, particularly over the right hemisphere. Scenes of positive content also elicited enhanced spontaneous zygomatic activity from 500–750 ms onwards, while happy faces elicited no such changes. Contrastingly, both fearful faces and negative scenes elicited enhanced spontaneous corrugator activity at 500–750 ms after stimulus onset. However, relative to baseline EMG changes occurred earlier for faces (250 ms) than for scenes (500 ms) whereas for scenes activity changes were more pronounced over the whole viewing period. Taking into account all effects, the data suggests that emotional facial expressions evoke faster attentional orienting, but weaker affective neural activity and emotional behavioural responses compared to emotional scenes.

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Introduction

In emotion research two kinds of stimuli are frequently used: facial expressions (e.g. a smiling or sad face) and emotionally evocative scenes (e.g. snakes, erotic pictures). But, do these forms of emotional stimuli undergo the same neural processing? Despite each being intrinsically emotionally evocative, only a few studies exist that have compared affective processing of faces and scenes in the same experiment and context.

A recent meta-analysis comparing 157 functional Magnetic Resonance Imaging (fMRI) studies that used either emotional faces or emotional scenes (Sabatinelli et al., 2011) revealed multiple clusters of brain activations unique to these different forms of stimuli even after the subtraction of neural activity related to basic visual processing. Although this suggests that both types of stimuli might be processed differently

in the brain, direct comparisons of the time course of affective processing for faces and scenes are lacking and little is known about whether both stimulus classes elicit similar expressive behavioural reactions.

In other contexts it is obvious that faces and scenes are indeed quite different. For example, facial expressions elicit mimicry and facial feedback mechanisms might modify emotion-related processing (see Niedenthal et al., 2001). Facial expressions can be understood as interpersonal, facilitating social transactions, and require complex neural processing to translate these emotional cues into social meaning. Emotional scenes on the other hand are more intrapersonal and directly elicit motivational behaviours without needing to translate their meaning beyond knowing whether to approach or avoid. Different facial expressions are more similar to each other than different scene pictures are. Various processing differences between face and scene stimuli have been described. Hariri et al. (2002) found varying amygdala activity depending on whether a fearful face or a threatening scene was presented to their participants. In their fMRI study, Keightley et al. (2011) reported about their conclusion that the contextual information in emotional

scenes may facilitate memory via additional visual processing, whereas memory for emotional faces may rely more on cognitive control mediated by rostrolateral prefrontal regions. Epstein et al. (2006) investigated differences between face and scene inversion. Their results demonstrate that both face and scene inversion cause a shift from specialised processing streams towards generic object-processing mechanisms, but this shift only leads to a reliable behavioural deficit in the case of face inversion.

The temporal characteristics of neural affective processing have been relatively well documented for emotional faces (Vuilleumier and Pourtois, 2007; Wieser and Brosch, 2012) and emotional scenes (Olofsson et al., 2008; Schupp et al., 2006a). Anatomically, visual information passes through the extrastriate visual cortex where low-lying physical stimulus properties such as luminance and spatial complexity determine which aspects of visual information receive rapid attentional capture and further processing (Clark and Hillyard, 1996; Givre et al., 1994; Hillyard and Anllo-Vento, 1998; Mangun et al., 1993; Rugg et al., 1987). This rapid-attentional capture is seen in scalp-recorded potentials as a prominent positively charged deflection in amplitude over lateral posterior occipital sites at approximately 100 ms post-stimulus (termed the P100 component, or P1 to represent the first positive peak in neural activity), where the size of the amplitude deflection indexes the degree of attentional capture of the related stimulus. Attended-to information then undergoes object recognition processing in neural circuits proceeding through bilateral ventral–lateral streams from the visual cortex into the temporal cortices (Allison et al., 1999). Here, the fusiform gyrus, a well-studied structure located in the inferior temporal lobes, facilitates face recognition via a highly specialised process of collating local facial features into a holistic global face representation (Rossion et al., 2003). This activity is observed in scalp-recorded potentials as a strong negatively charged deflection in amplitude over lateral temporal–occipital areas approximately 170 ms post-stimulus onset (Bentin et al., 1996; Deffke et al., 2007), hence the name N170. Other stimuli such as complex scenes also undergo category-specific processing across more widely distributed hierarchically organised circuits in the ventral–lateral streams, with this activity being observed as a more modest negative deflection in amplitude at around 150–200 ms after stimulus onset over lateral temporal-occipital scalp locations (termed the N100). From here, it has been posited that affective information of faces and scenes begins to influence neural activity, seen at lateral–occipital scalp recordings as a more stable negative shift in polarity when viewing emotionally-evocative relative to neutral stimuli. This posterior negativity (i.e. the early posterior negativity or EPN) typically emerges at the offset of the N100/N170, around 200 to 250 ms post-stimulus and has been found to be modulated as a function of increased attentional allocation and greater motivational relevance of the emotionally evocative stimuli (Bublatzky and Schupp, 2011; Foti et al., 2009; Schupp et al., 2006a; Weinberg and Hajcak, 2010).

There is however evidence that affective information can influence activity at earlier stages of processing relative to the EPN. Several studies have reported larger N170 amplitudes when viewing negatively-valanced facial expressions such as fear and anger (e.g. Batty and Taylor, 2003; Leppänen et al., 2008; Pourtois et al., 2005; Stekelenburg and de Gelder, 2004), which has been interpreted as an innate attentional 'negativity bias' (Carretie et al., 2009; Holmes et al., 2005). The same controversy exists for emotional scenes, with some studies reporting a negativity bias for highly unpleasant threatening or fearful scenes in the time window of the N100. Affective modulation has even been reported as early as 100 ms post-stimulus (Batty and Taylor, 2003; Eger et al., 2003; Eimer and Holmes, 2002; Holmes et al., 2003; Pizzagalli et al., 1999; Pourtois et al., 2005; Recio et al., 2014; Smith et al., 2013; Streit et al., 2003). Differences as well as similarities in affective stimulus processing may be better understood by directly comparing when these processes occur for emotional faces and scenes in a single experimental framework. This would also allow a direct comparison of behavioural reactions elicited by faces and scenes.

In the current study, we were interested in investigating how affective neural activity during emotional face and scene perceptions translates into emotional behaviour, building on the idea that emotional behaviour should be understood as a consequence of subcortical affective neural activity (Walla and Panksepp, 2013). Spontaneous facial muscle activity is an emotion-related behavioural phenomenon that is thought to play a crucial role in social emotion recognition, whereby perceiving an emotional facial expression elicits a rapid or spontaneous micro-simulation of the perceived facial expression by the perceiver less than 1000 ms post onset (Achaibou et al., 2008; Dimberg et al., 2000a; Grèzes et al., 2013; Korb et al., 2010; Moody et al., 2007). By utilising the excellent temporal resolution offered by electromyography to measure facial muscle activity (fEMG), these studies have shown that zygomaticus major 'cheek' muscles rapidly and spontaneously contract in response to smiling faces while corrugator supercilii 'eyebrow' muscles rapidly and spontaneously contract in response to angry or fearful faces. The phenomenon is thought to facilitate emotion recognition by triggering the reactivation of specific neural regions that are involved in producing that same emotion in the perceiver, leading to a realisation of the other person's emotional state (e.g. Barsalou, 2003a; Barsalou et al., 2003b; Clark et al., 2008; Niedenthal, 2007). Moreover, empirical evidence suggests that spontaneous facial reactions play a causal role in emotion recognition whereby selectively preventing movement in facial muscle/s required to simulate an expression leads to poor recognition ability for that facial expression in another person (Foroni and Semin, 2011; Niedenthal et al., 2001; Oberman et al., 2007; Ponari et al., 2012).

However, emotional scenes have also been shown to evoke spontaneous facial reactions (Dimberg et al., 1998). In contrast to faces emotional scenes often do not contain any third-party emotion to recognise. This raises the question of whether and in what ways spontaneous facial muscle activity may differ when elicited by emotional faces compared to scenes, such as in latency or strength of the response. To this extent, the objective of the current study was to investigate differences in emotional responses evoked by happy, fearful and neutral faces versus positive, neutral and negative scenes: (1) during early visually-evoked stages of neural activity including the P1, N100/N170, and EPN; and (2) in spontaneous zygomatic and corrugator facial reactions; and (3) to examine correlations between affective neural activity and emotional behaviour.

When considering motivationally-relevant emotion processing, arousal must be taken into consideration, because stimuli that evoke heightened arousal have been shown to modulate both neural and facial muscle activity independent of emotional valence or stimulus type (Cacioppo et al., 1986; Cuthbert et al., 2000; Feng et al., 2014; Lang et al., 1993). For this reason the face and scene stimuli chosen for the current study were relatively low-arousing (see Fig. 1 bottom right graph). However, it was still possible that face and scene stimuli could evoke different degrees of arousal. Therefore, arousal responses to pictures were also recorded via the skin conductance response (SCR), a neurophysiological measure of sweat gland activity which is controlled by the sympathetic part of the autonomic nervous system. SCRs could therefore be used to differentiate neural and behavioural effects associated with enhanced levels of arousal from those associated with emotional valence or stimulus type.

A secondary aim of this study was to examine whether or not early emotion processing is influenced by the depth of conceptual emotion processing, and, if so, whether such effects might suppress or enhance spontaneous facial reactions. Traditionally, the delayed match-to-sample task involves the 'passive' presentation of a first stimulus (e.g. an emotional facial expression) followed by an 'active' presentation of a second stimulus, at which point some judgement must be made regarding the second stimulus as a function of the first, usually whether or not they express the same type of emotion. In the current study, we varied the semantic format of emotion recognition between three 'delayed match-to-sample' emotion-matching tasks. A consistent