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Recognition advantage of happy faces: Tracing the neurocognitive processes

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ABSTRACT

The present study aimed to identify the brain processes—and their time course—underlying the typical behavioral recognition advantage of happy facial expressions. To this end, we recorded EEG activity during an expression categorization task for happy, angry, fearful, sad, and neutral faces, and the correlation between event-related-potential (ERP) patterns and recognition performance was assessed. N170 (150–180 ms) was enhanced for angry, fearful and sad faces; N2 was reduced and early posterior negativity (EPN; both, 200–320 ms) was enhanced for happy and angry faces; P3b (350–450 ms) was reduced for happy and neutral faces; and slow positive wave (SPW; 700–800 ms) was reduced for happy faces. This reveals (a) an early processing (N170) of *negative* affective valence (i.e., angry, fearful, and sad), (b) discrimination (N2 and EPN) of affective *intensity* or arousal (i.e., angry and happy), and (c) facilitated categorization (P3b) and decision (SPW) due to expressive *distinctiveness* (i.e., happy). In addition, N2, EPN, P3b, and SPW were related to categorization accuracy and speed. This suggests that conscious expression recognition and the typical happy face advantage depend on encoding of expressive intensity and, especially, on later response selection, rather than on the early processing of affective valence.

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1. Introduction

Facial expressions inform how people feel and their action tendencies. This information is valuable for both expressers and observers to regulate their adaptive behavior in social interaction. Six basic categories of emotional facial expressions have been identified (happiness, sadness, anger, disgust, fear, and surprise; Ekman, 1994). Some expressions involve signals of potential harm (either as direct threat for the viewer: anger; or in various indirect ways: fear, disgust, or sadness), whereas others convey signals of potential benefit (happiness), and still others are affectively and motivationally ambiguous (surprise). Accordingly, it is important for an observer to recognize and interpret such expressions quickly and accurately, in order to decide whether and in which particular way to approach or avoid the expresser.

From a biological point of view, and given that protection and survival must be safeguarded prior to attending to benefit and pleasure, we should expect that neurocognitive systems prioritize the recognition of threat-related in comparison with non-threat expressions (see Williams, 2006). Yet, in categorization tasks where a facial expression must be consciously and explicitly identified, a consistent recognition advantage has been found for happy faces, using behavioral measures (e.g., Calder, Young, Keane, & Dean, 2000; Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004; Tottenham et al., 2009; see below). Such an advantage thus seems at odds with the biological adaptive function view. In the current study, we aimed to trace the neurocognitive processes leading to the recognition superiority of happy expressions, and account for the possible inconsistencies.

1.1. Recognition superiority for happy faces: behavioral measures

In prior behavioral research, happy facial expressions have been found to be identified more accurately and faster than all the others, as supported by the following evidence. First, this finding has been observed in studies comparing all the six basic emotional categories (Calder et al., 2000; Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004; Tottenham et al., 2009), and also in studies comparing subsets of them (Juth, Lundqvist, Karlsson, & Öhman, 2005; Leppänen & Hietanen, 2004; Loughead, Gur, Elliott, & Gur, 2008; Svärd, Wiens, & Fischer, 2012). Second, the advantage has been noted with different stimulus sets, such as the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998; e.g., Calvo & Lundqvist, 2008), the Pictures of Facial Affect (Ekman & Friesen, 1976; e.g., Leppänen & Hietanen, 2004), the NimStim Stimulus Set (Tottenham, Borscheid, Ellertsen, Marcus, & Nelson, 2002; e.g., Tottenham et al., 2009), and a combination of them

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(Palermo & Coltheart, 2004). Third, the advantage holds across different response systems: manual (Calvo & Lundqvist, 2008), verbal (Palermo & Coltheart, 2004), and saccadic (Calvo & Nummenmaa, 2009) responses. Fourth, happy faces can be recognized with shorter stimulus exposures than other expressions (Calvo & Lundqvist, 2008; Esteves & Öhman, 1993; Milders, Sahraie, & Logan, 2008; Svärd et al., 2012), and are less effectively pre- and/or post-masked (Maxwell & Davidson, 2004; Milders et al., 2008; Stone & Valentine, 2007; Svärd et al., 2012). Fifth, the advantage also occurs when face pairs (rather than single faces) are presented, with happy expressions being discriminated faster from both neutral (Calvo & Nummenmaa, 2009) and other emotional expressions (Calvo & Nummenmaa, 2011). And, finally, happy expressions can be identified more accurately not only with open mouths and exposed teeth, but also with closed-mouth smiles (Tottenham et al., 2009).

1.2. *Neural time course and mechanisms in the processing of facial expressions*

The behavioral measures and paradigms have generally shown only a final snapshot of the product, i.e., categorization performance accuracy and reaction times. Furthermore, reaction times are usually around 1 s or above in tasks involving categorization of multiple expressions (e.g., Calder et al., 2000; Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004). In terms of neural and mental chronometry, this is a large time scale. A step forward is required that traces the time course of the happy face recognition advantage (i.e., when it begins and how it unfolds over time) and isolates the underlying mechanisms that contribute to categorization performance. The ERP (event-related-potential) technique is well-suited to assessing the temporal dynamics of such mechanisms. ERPs can differentiate specific cognitive processes by linking them with neural components, depending on their activation time course and topography in brain areas (see Luck & Kappenman, 2012).

Prior research has identified various ERP components that can be related to facial expression processing (see reviews in Eimer and Holmes (2007) and Palermo and Rhodes (2007), and selected publications below). First, short-latency (100–200 ms from stimulus onset) P1 (detected at lateral-occipital brain scalp sites, with a 100 to 130-ms peak latency) and visual N1 (widely distributed over the entire scalp, although it peaks earlier over frontal than posterior regions; 100–150 ms) ERPs are sensitive to physical stimulus factors and reflect initial sensory encoding (see Olofsson, Nordin, Sequeira, & Polich, 2008). They have sometimes been found to be enhanced by negatively valenced expressions (e.g., Luo, Feng, He, Wang, & Luo, 2010; Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005; Rellecke, Sommer, & Schacht, 2012).

Second, N170 (lateral-occipital and infero-temporal; 150–200 ms), vertex positive potential (VPP: central midline sites; 150–280 ms), and P200 (frontal and central; 150–275 ms), reflect attentional capture by emotion. Both VPP (e.g., Luo et al., 2010; Willis, Palermo, Burke, Atkinson, & McArthur, 2010), and P200 (e.g., Eimer, Holmes, & McGlone, 2003; Paulmann & Pell, 2009) differentiate between emotional and non-emotional expressions. The evidence regarding the sensitivity of N170 to facial expression is controversial (for a review, see Rellecke, Sommer, and Schacht (2013)). While some studies have shown augmented N170 for emotional faces (e.g., Batty & Taylor, 2003; Williams, Palmer, Liddell, Song, & Gordon, 2006), others have reported no effects (e.g., Eimer & Holmes, 2007; Schacht & Sommer, 2009).

Third, in the mid-latency range, two components are modulated by expression: N200 (central; 200–350 ms), and early posterior negativity (EPN; temporo-occipital; 200–350 ms), which frequently overlap. Both N200 (e.g., Ashley, Vuilleumier, & Swick, 2004; Williams et al., 2006) and EPN (e.g., Rellecke, Palazova, Sommer, & Schacht, 2011; Schupp et al., 2004) respond differently to neutral, positive, and negative expressions. This allows us to infer that these ERP components involve affective discrimination. Within a more general attention-based process triggered by emotional content, the N200 and EPN would reflect the degree of attention that is needed for initial coding of the perceptual face patterns leading to expression recognition.

Finally, in the long-latency range (>300 ms; widespread over fronto-central-parietal areas), P3 and late positive potential (LPP; 300–650 ms) and the slow wave components (SPW; >650 ms, following the LPP peak) are also reactive to facial expression. P3 (e.g., Balconi & Mazza, 2009; Luo et al., 2010) and LPP (e.g., Frühholz, Fehr, & Herrmann, 2009; Leppänen, Kauppinen, Peltola, & Hietanen, 2007) reflect sustained attention and elaborative categorization processes. SPWs are related to response selection and decision, with ambiguous expressions enhancing and delaying this component in comparison with more easily identifiable expressions (Debruille, Brodeur, & Hess, 2011).

1.3. *The current study: combined ERP and behavioral recognition measures*

Given the robust finding of a superior explicit recognition of happy relative to negative (e.g., angry or fearful) expressions, and that this seems counterintuitive from an adaptive function perspective (i.e., negative faces should have preferential processing), we will focus on the mechanisms that can account for such an advantage and the discrepancies. An experimental approach in which neurocognitive mechanisms are investigated in relation to explicit recognition performance will be useful in this regard. Depending on the ERP components and neural activation patterns involved, this approach will serve to determine the extent to which expression recognition is driven by emotional (more related to the adaptive function view) or perceptual encoding.

Prior ERP studies have not directly addressed the issue of the relative recognition advantage of some expressions. To our knowledge (in 44 relevant studies between the years 2000 and 2012), happy faces were included as stimuli in 28 experiments, although only in three of them (Balconi & Mazza, 2009; Batty & Taylor, 2003; Eimer et al., 2003) were all six basic expressions compared. Most importantly, only in two studies (Leppänen et al., 2007; Rellecke et al., 2012) was expression categorization task-relevant (with participants being asked to identify the expression as fearful, neutral, or happy: Leppänen et al.; or as angry, neutral, or happy: Rellecke et al.). In all the others, task instructions did not ask for explicit expression encoding and categorization performance was not assessed. This is understandable given that the aim generally was to investigate whether emotional processing occurs automatically and unintentionally. Rather, participants were told to observe the faces (e.g., Balconi & Pozzoli, 2003; Schupp et al., 2004), identify their gender (e.g., Sprengelmeyer & Jentzsch, 2006; Wijers & Banis, 2012), respond to immediate repetitions of a face (e.g., Ashley et al., 2004; Holmes, Kiss, & Eimer, 2006), and so on. In some studies, explicit emotional evaluation of the facial expressions (e.g., as positive or negative, or as emotional or non-emotional) was required, but explicit categorization (i.e., assignment to specific semantic categories) was not (Frühholz et al., 2009; Knyazev, Slobodskoj-Plusnin, & Bocharov, 2009; Paulmann & Pell, 2009; Van Strien, De Sonneville, & Franken, 2010; Wronka & Walentowska, 2011).

In sum, from prior ERP research it is not possible to determine a potential happy face recognition advantage, due to the lack of task-relevant instructions involving expression categorization and the corresponding behavioral measures. In the current study,

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