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Associated motivational salience impacts early sensory processing of human faces

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ABSTRACT

Facial expressions of emotion have an undeniable processing advantage over neutral faces, discernible both at behavioral level and in emotion-related modulations of several event-related potentials (ERPs). Recently it was proposed that also inherently neutral stimuli might gain salience through associative learning mechanisms. The present study investigated whether acquired motivational salience leads to processing advantages similar to biologically determined origins of inherent emotional salience by applying an associative learning paradigm to human face processing. Participants (N=24) were trained to categorize neutral faces to salience categories by receiving different monetary outcomes. ERPs were recorded in a subsequent test phase consisting of gender decisions on previously associated faces, as well as on familiarized and novel faces expressing happy, angry or no emotion. Previously reward-associated faces boosted the P1 component, indicating that acquired reward-associations modulate early sensory processing in extrastriate visual cortex. However, ERP modulations to emotional – primarily angry – expressions expanded to subsequent processing stages, as reflected in well-established emotion-related ERPs. The present study offers new evidence that motivational salience associated to inherently neutral stimuli can sharpen sensory encoding but does not obligatorily lead to preferential processing at later stages.

Introduction

Faces are highly relevant for humans and other primates as they provide diverse information about others, including identity and several emotional and motivational aspects (Schupp et al., 2004; Vuilleumier, 2005; Mehu, 2014). Thus, the fast and accurate recognition of information from faces is a crucial element of human communication and supports social interactions. The multifold information that is conveyed by facial expressions ranges from signals about the environment (Öhman, 1986; Fridlund, 1994) to specific emotional states (Ellgring, 1989) or motivational tendencies (Paulus and Wentura, 2014, 2016) of the expresser. All these features are of increased salience for the receiver and might contribute to boosted attention to and facilitated processing of facial expressions of emotion compared to neutral faces as consensually reported in the literature (Vuilleumier and Pourtois, 2007; Pessoa, 2015). Due to their excellent temporal resolution, event-related brain potentials (ERPs) provide a suitable tool to investigate the processing specificities triggered by emotionally salient facial stimuli over time. Major ERP components of emotion processing in faces are the Early Posterior Negativity (EPN) and the Late Positivity Complex (LPC). Note that the LPC is often likewise termed as Late Positive Potential (LPP) (e.g. Schupp et al., 2004). The EPN has been suggested to reflect enhanced sensory encoding resulting from visual attention to facial expressions of emotion, starting around 150–200 ms after stimulus onset (Schupp et al., 2004; Recio et al., 2011; Rellecke et al., 2012), while the LPC has been linked to higher-order stages of stimulus evaluation, developing around 300 ms and typically lasting for several hundred milliseconds (Schacht and Sommer, 2009a). Recent studies showed also the P1 – an occipital positivity peaking around 100 ms after stimulus onset that reflects activation of the extrastriate visual cortex via selective attention (Di Russo et al., 2003) – to be enhanced for emotional compared to neutral facial expressions (Batty and Taylor, 2003; Pourtois et al., 2004; Rellecke et al., 2012). During face processing, the P1 is typically followed by the N170 – an occipito-temporal negativity linked to holistic face perception (Bentin et al., 1996). To date, there is still an unsolved debate about the N170 concerning ERP modulations by emotional expressions (for reviews see, Rellecke et al. (2013), Hinojosa et al. (2015)). What specifically drives the facilitated processing of facial expressions of emotion, as reflected in these ERP

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components over time, remains to be fully understood. Recently, Anderson (2013) proposed a fundamental mechanism of value-driven attention, reflected in a prioritized processing including stimuli associated with reward, even if the stimuli themselves do not carry salience, are task-irrelevant, or if the reward is absent in a given situation, similar to stimuli that carry inherent emotional salience. Further, stimuli associated with negative events or punishment have been demonstrated to allocate perceptual resources during initial visual processing (Stolarova et al., 2006; Hintze et al., 2014; Rossi et al., 2017), as reflected in very early modulations of ERPs, starting around 65 ms after stimulus onset. Therefore, one opportunity to disentangle emotional-motivational effects of face processing is provided by associative learning where neutral facial expressions can be tagged with stimulus-external salience. Aguado and colleagues (Aguado et al., 2012) presented neutral faces directly followed by facial expressions of emotion. During delayed testing, ERPs triggered by these neutral but associated faces were compared with those elicited by inherent facial expressions of emotion (happy, angry). While components reflecting early perceptual processing showed higher amplitudes for angry facial expressions as well as for neutral faces associated with positive and negative valence, EPN effects were restricted to inherently angry facial expressions. In contrast, Wieser and colleagues (Wieser et al., 2014) reported effects of neutral faces associated with affectively negative verbal descriptions compared to faces associated with neutral descriptions solely at the level of the EPN. Together, these findings indicate that motivational relevance acquired via associative learning can impact the subsequent processing of an inherently neutral stimulus on early stages of stimulus processing but the underlying neurocognitive mechanisms and specificities of acquired motivational compared to inherent emotional aspects remain to be explained. In the present study, we therefore aimed at dissociating effects of motivational salience associated to neutral face stimuli from those of inherent facial expressions of emotion that presumably carry various affective-motivational values. To this aim, our participants learned to associate inherently neutral faces with three different outcome conditions – monetary gain, loss or zero outcome – during a learning phase (adapted from Schacht et al. (2012)). After consolidation, these previously associated faces were presented without monetary feedback in a gender decision task. In addition, faces of inherent emotions (happy, angry) were presented in order to allow a direct comparison of impacts of inherent emotional and associated motivational salience on performance and neural activity. In line with literature, we expected inherent emotional salience, carried by happy and angry facial expressions to elicit well-established emotion-related EPN and LPC modulations: The EPN was frequently shown to be influenced by happy and angry expressions (Rellecke et al., 2012) whereas the LPC component is more prominently effected by angry facial expressions (Schupp et al., 2004). Furthermore, we hypothesized strengthened sensory processing of emotional – and in particular angry – expressions that should be reflected in enhanced P1 amplitudes.[1] Following the assumptions of Anderson (2013), we expected morphologically similar but presumably weaker ERP effects to associated motivational salience triggered by value-driven attention.

Materials and methods

Participants

Data was collected from twenty-nine participants. Five participants were excluded as they did not reach the required learning criterion during the learning phase. The remaining twenty-four participants (17 female) were ranging in age between 19 and 31 years (mean age=23.6 years, *SD*=3.8), with normal or corrected-to-normal vision, without any neurological or psychiatric disorders according to self-report. All participants were right-handed (according to Oldfield (1971)) and were reimbursed by 8 € per hour or course credits. The bonus won in the learning phase was disbursed in addition.

Stimuli

Stimuli were selected from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist et al., 1998). To ensure a uniform figure/ground contrast, all images were edited to the same format by applying a mask with ellipsoid aperture to the faces rendering only the facial area visible. The ellipsoid mask surrounded the stimuli within an area of 130×200 pixels (4.59×7.06 cm). For the learning phase, twelve colored pictures of faces (6 male, 6 female) with neutral expressions were used. In the test phase, emotional facial expressions (happy, angry, neutral) of the same twelve identities (N=36 colored pictures) and of twelve novel identities (N=36 colored pictures) were presented together with the previously associated neutral faces. Luminance (according to Adobe Photoshop CS6™) was matched across conditions, $F(6,83)=1.634$, $p=0.149$. Facial stimuli were presented at a central position on the screen on a light gray background, corresponding to a visual angle of 4.6°×7.1°. Feedback stimuli consisted of colored circles (248×248 pixels, 5×5 cm) in which the amount of monetary gain or loss was indicated.

Procedure

The study was conducted in accordance with the Declaration of Helsinki and approved by the local Ethics committee of the Institute of Psychology at the University of Goettingen. Participants were fully informed about the procedure and gave written informed consent prior to the experiment. The study consisted of two parts, a learning and consolidation phase where faces were associated with monetary outcome, followed by a test phase one day after the learning phase. The participants were seated at a viewing distance of 57 cm in front of a computer screen in a dimly lit, sound-attenuated room. During the learning phase, twelve inherently neutral faces were associated with monetary win, loss, or no outcome via an associative learning paradigm. Participants were instructed that their task was to learn the correct valence condition assignment for each of the faces presented. Further, the adequate interpretation of the presented feedback was explained. Responses were given by button press; response-to-button assignment was balanced across participants, as well as the face-to-feedback/valence condition assignment. Feedback scheme was as follows: Faces that had to be classified as reward-related were associated with +20 Cents (in case of correct classification) or +10 Cents (incorrect classification). In the same way, loss-related faces were associated with −10 (correct classification) or −20 Cents (incorrect classification). For faces that had to be classified as neutral, feedback was either +0 (correct) or −0 (incorrect). If the participant missed to answer a trial within 5000 ms, 50 Cents were removed from bonus. The participant knew that the valence condition assignment remained stable during the experiment. As no test trials were provided, participants had to answer the first block by chance. The stimuli were presented block-wise (each block consisted of all twelve neutral facial stimuli in fully randomized order). The blocks were separated by a self-determined pause and the information about the current amount of the particular bonus. To make sure that the participants learned the associations adequately, a learning criterion was created. Participants had a limit of 30 blocks to reach the criterion (45 of the last 50 trials correct). If they succeeded, 10 additional blocks were presented in order to consolidate the previously learned associations. If they failed to reach the criterion, they were not allowed to participate in the test

[1] As previous evidence for emotional modulation of the N170 component is entirely heterogeneous (Rellecke et al., 2013; Hinojosa et al., 2015), it appears difficult to propose hypotheses, in particular, with respect to potential effects of associated salience. In order to provide an exhaustive overview of our ERP data, analyses on N170 amplitudes are provided in the Supplement.