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Complete List of Authors:	Schindler, Sebastian; University Hospital Münster, Institute of Medical Psychology and Systems Neuroscience Bruchmann, Maximilian; University of Münster, Institute of Medical Psychology and Systems Neurosciences Bublatzky, Florian; Zentralinstitut fur Seelische Gesundheit, Straube, Thomas; University Hospital Münster, Institute of Medical Psychology and Systems Neuroscience
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Modulation of face- and emotion-selective ERPs by the three most common types of face image manipulations

Sebastian Schindler[1*], Maximilian Bruchmann[1], Florian Bublatzky[2], and Thomas Straube[1]

[1] Institute of Medical Psychology and Systems Neuroscience, University of Muenster

[2] Central Institute of Mental Health Mannheim, Medical Faculty Mannheim/Heidelberg University, Mannheim, Germany

* Corresponding author

Correspondence address

Institute of Medical Psychology and Systems Neuroscience
University of Münster
Von-Esmarch-Str. 52, D-48149 Münster, Germany
e-mail: sebastian.schindler@ukmuenster.de

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Abstract

In neuroscientific studies, the naturalness of face presentation differs: A third of published studies makes use of close-up full coloured faces, a third uses close-up grey-scaled faces, and another third employs cutout grey-scaled faces. Whether and how these methodological choices affect emotion-sensitive components of the event-related brain potentials (ERP) is yet unclear. Therefore, this preregistered study examined ERP modulations to close-up full-coloured and grey-scaled faces as well as cutout fearful and neutral facial expressions, while attention was directed to no-face oddballs.

Results revealed no interaction of face naturalness and emotion for any ERP component, but showed (however,) large main effects (were observed). Specifically, fearful faces and decreasing face naturalness elicited substantially enlarged N170 and EPN amplitudes and lower face naturalness also resulted in a larger P1. This pattern reversed for the LPP, showing linear increases in LPP amplitudes with increasing naturalness.

We observed no interaction of emotion with face naturalness, which suggests that face naturalness and emotion are decoded in parallel at these early stages. Researchers interested in strong modulations of early components should make use of cutout grey-scaled faces, while those interested in a pronounced late positivity should use close-up coloured faces.

Keywords: EEG/ERP, faces, emotion, face naturalness, face realism

1. Introduction

Human facial expressions are a quick channel for social communication (Jack & Schyns, 2015; Tsao & Livingstone, 2008). The human face enables the observer to recognize a unique identity, exhibiting information about age, gender and race, as well as emotional states (Jack & Schyns, 2015). Not surprisingly, there is a high interest in understanding how humans process faces, as well as in determining the neurophysiological correlates of face perception (e.g. see Bentin, Allison, Puce, Perez, & McCarthy, 1996; Haxby, Hoffman, & Gobbini, 2000).

A powerful method to investigate neuronal responses towards faces are event-related potentials (ERPs), which are modulated both by cognitive (e.g., expertise or familiarity for faces; see Itier, Van Roon, & Alain, 2011; Sagiv & Bentin, 2001), and by perceptual factors. These, for example, include spatial frequencies, luminance, and colour information of the stimulus (e.g., see Balas & Pacella, 2015; Prete, Capotosto, Zappasodi, Laeng, & Tommasi, 2015; Schindler, Schettino, & Pourtois, 2018), as well as presentation features such as the temporal (flickering) frequency (e.g., see Boremanse, Norcia, & Rossion, 2013).

Often, the earliest component of interest is the occipitally scored P1, which is characterized by a positive peak between 80 and 120 ms, and is thought to reflect early stages of stimulus detection, discrimination, and vigilance (Bublatzky & Schupp, 2012; Mangun & Hillyard, 1991; Vogel & Luck, 2000). The P1 is often found to be larger for faces compared to objects (Allison, Puce, Spencer, & McCarthy, 1999; Bentin et al., 1996). Studies dealing with ERP modulations caused by emotional expressions show mixed findings regarding the P1. Some studies report emotional modulations (e.g., see Blechert et al., 2012; Foti et al., 2010), while others do not detect them (e.g., see Smith et al., 2013; Wieser et al., 2012). Lately, it was hypothesised that this might be explained by the facial expression intensity (Müller-Bardorff et al., 2018). In contrast to the P1, the later occurring negative occipito-temporal N170 potential, which peaks between 130 and 190 ms, seems to be face-sensitive (Allison et al., 1999; Ganis, Smith, & Schendan, 2012; Sagiv & Bentin, 2001; Schendan & Ganis, 2013). The N170 is viewed as a structural encoding component (Eimer, 2011). Further, a recent meta-analysis showed that the N170 component can be reliably modulated by emotional compared to neutral expressions (Hinojosa, Mercado, & Carretié, 2015). The following occipito-temporal negativities (N250r and Early Posterior Negativity, peaking between 200 and 300 ms) seem to relate to recognition processes of individual faces (Schweinberger & Neumann, 2016). The Early Posterior Negativity (EPN) is also enlarged for emotional compared to neutral stimuli, including face stimuli (Bublatzky, Gerdes, White, Riemer, & Alpers, 2014; Wieser, Pauli, Reicherts, & Mühlberger, 2010). The EPN indicates early attention mechanisms (e.g. Schupp et al., 2004). Finally, the Late Positive Potential arises from approximately 400 ms onwards over parietal regions. Faces compared to scrambles or objects seem to elicit a larger late positivity (Allison et al., 1999; González et al., 2011), while numerous studies report enhanced LPP amplitudes for emotional compared to neutral stimuli (e.g., for faces see Blechert et al., 2012; Bublatzky et al., 2014). The LPP indicates stimulus evaluation and controlled attention processes (Hajcak, Dunning, & Foti, 2009; Schupp, Flaisch, Stockburger, & Junghöfer, 2006).

To investigate emotional ERP modulations, researchers have presented emotional faces in various ways. While some studies make use of grey-scaled faces (e.g., see Peltola et al., 2014; Righi et al., 2012), others use full-coloured faces (e.g., see Calvo, Marrero, & Beltrán, 2013; Bublatzky, Pittig, Schupp, & Alpers, 2017). Further, to reduce perceptual differences, faces are often presented as cutouts, showing only core parts of the face. This follows the notion that not all parts of the face exhibit relevant information about the emotional expression. As an example, for fearful faces, the eyes constitute a crucial region for recognizing the emotional expression (e.g., see Adolphs, 2008; Wegrzyn, Bruckhaus, & Kissler, 2015), as well as for modulating ERP responses (Li, Li, Wang, Zhu, & Luo, 2018).

By reviewing the last decade of scientific literature on emotional ERP modulations for faces (2008–2018; see Supplementary Table S1 for detailed references), we found for 100 published studies that almost a third of the studies used close-up coloured faces (28), close-up grey-scaled faces (22), or cutout grey-scaled faces (27). However, in most cases, the rationale of the stimulus selection is missing or is not clearly described, nor is the stimulus´ effect on ERP responses sufficiently explained. In some cases, the heterogeneous use of face manipulations might contribute to conflicting findings. So far, all studies which did not find an EPN emotion effect used close-up coloured faces (Brenner, Rumak, Burns, & Kieffaber, 2014; Herbert, Sfaerlea, & Blumenthal, 2013; Thom et al., 2013). Regarding P1, N170, and LPP components, emotion effects, as well as null findings, have been reported with all face manipulations. However, the size of emotion effects might differ depending on a given face manipulation. Thus, the present study aimed to investigate effects of the three most employed face manipulations in a within subject design.

Cutting out uninformative noise homogenises the stimulus set, which reduces inter-stimulus perceptual variance (IPSV) known to influence the N170 (e.g., see Thierry, Martin, Downing, & Pegna, 2007a, 2007b; but see also Bentin et al., 2007; Rossion & Jacques, 2008). On the other hand, it can be hypothsized that face-specific context enhances emotional responsiveness, since specific facial features (colour, hair, etc.) might contribute to a perceived unique identity. Hence, early and late stages of processing could be affected by increasing the emotional salience of the expressions of a unique person (e.g., see Schindler et al., 2017; Schulz et al., 2012; Itz et al., 2014).

In this vein, a multitude of studies shows that broader contextual information modulates face perception. Here, ERP modulations were observed if contextual information was provided for a face, either being affective background pictures (Wieser & Keil, 2013), or verbal information (Wieser & Brosch, 2012). Further, preceding emotional or neutral sentences modulated EPN as well as LPP responses towards inherently neutral expressions. Thus, stimuli are integrated and processed with available contextual features, which in turn could even include peripheral facial features.

To explore the impact of face naturalness on emotional responses, we presented the three most common face naturalness levels, showing close-up coloured faces, close-up grey-scaled faces, and cutout grey-scaled faces. Based on the literature (on ERP modulations), we expected main effects of emotional expression, leading to larger N170, EPN, and – if LPP modulations could be observed – LPP amplitudes. Since there are perceptual differences between the three different types of face image manipulations, main effects for the P1 and N170 component were expected as well. Furthermore, an enlarged LPP for more naturalistic faces was hypothesised (please note, this was mentioned, but no formal preregistered hypothesis). Crucially, we tested interactions of emotional expression and face naturalness. We tested if either contextual face information, or, as an alternative, the reduction of uninformative noise lead to more pronounced emotional modulations. These theoretical predictions, together with a detailed description of the analysis pipeline, were preregistered on the Open Science Framework (https://osf.io/5fkt4/).

2. Methods

Participants. Thirty-seven participants were recruited at the University of Münster. Participants gave written informed consent and received 10 euros per hour for participation. All participants had normal or corrected-to-normal vision, were righthanded and had no reported history of neurological or psychiatric disorders. One participant aborted the experiment, leading to 36 participants in the final EEG analyses. On average, the 36 participants (24 female) were 24.06 (*SD* = 3.43) years old (on average). Average rated tiredness (1 = fully awake, 10 = fully tired) before testing was 2.73 (*SD* = 1.51), during the face perception experiment 5.52 (*SD* = 1.73), and after testing 5.09 (*SD* = 2.03).

Stimuli. The faces were taken from the Radboud Faces database (Langner et al., 2010). For the experiment, faces were converted into greyscale and cutouts from the faces were used, showing no facial hair. Thirty-six identities (18 male, 18 female) were used, showing either fearful or neutral expressions, both presented in three different naturalness conditions: In the first condition, a coloured close-up of each face was used, while in the second condition, a grey-scaled close-up was used, and in the third condition, a grey-scaled cutout of the core face was presented. The cutout had an elliptical shape with x- and y-radii of 2.29° and 3.77° with blurred edges. As exemplified in Fig.1, the cutout removed any facial hair, the ears and the neck in each image. In line with the suggested maximal influence of fearful faces in naturalistic environments (Hedger, Adams, & Garner, 2015), presented face-pictures exhibited a visual angle of about 6.2° (bizygomatic diameter). Stimuli were presented on a Gamma-corrected display (Iiyama G-Master GB2488HSU) running at 60 Hz with a Michelson contrast of .9979 (L_{min} = 0.35 cd/m^2; L_{max} = 327.43 cd/m^2). The background luminance was kept at 262.53 cd/m^2.

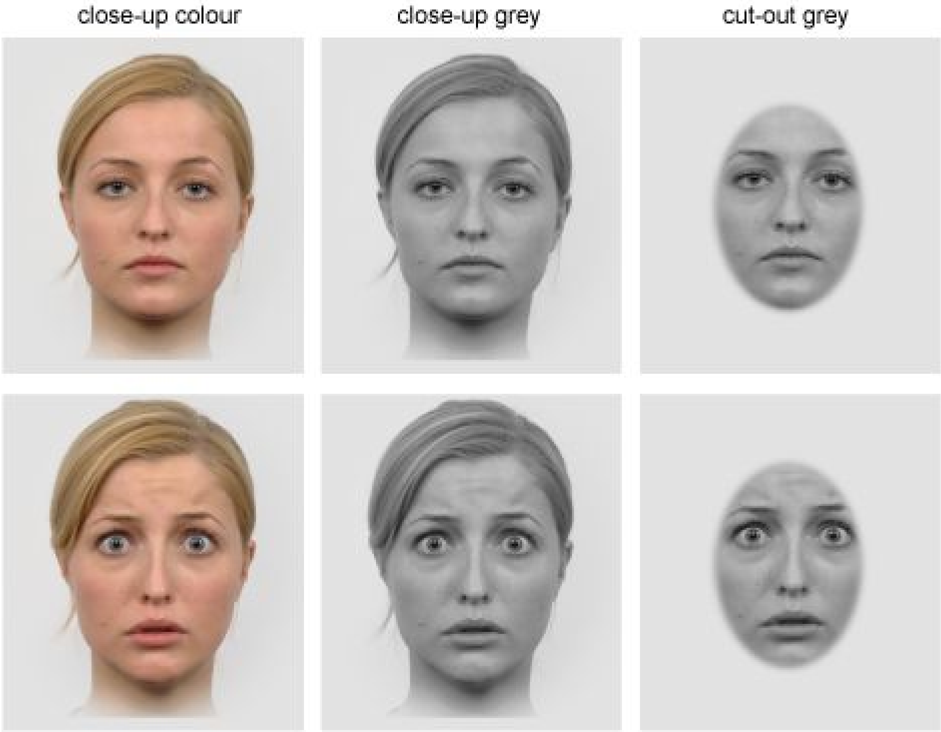

Figure 1: Example facial stimuli showing fearful and neutral expressions. Please note that background colour was identical in all experiments and displayed facial features size (e.g. eyes, nose, and mouth) was kept constant.

Procedure. Participants were instructed to avoid eye-movements and blinks during stimulus presentation. To ensure that participants paid attention to the presented faces, gaze position was evaluated online with an eye tracker (EyeLink 1000, SR Research Ltd., Mississauga, Canada), stopping the presentation whenever the centre was not fixated. Thus, stimulus presentation was paused whenever participants were not directing their gaze at a circular region with a radius of 0.7° around the fixation mark. If a gaze deviation was detected for more than five seconds despite a participant's attempt to fixate the centre, the eye-tracker calibration procedure was automatically initiated. For eleven participants, eye-tracking data could not be recorded due to technical difficulties. In these cases, we relied on the participants' following the instructions (to focus) and focussing on the central fixation mark. Additionally, participants were instructed to respond to a non-face trial by pressing the space bar.

Response feedback was provided for hits (key presses within 1 second after non-face presentation), slow responses (key presses within 1 to 3 seconds) and false alarms (key presses outside these windows) through a corresponding text presented for 2 s at screen centre. Non-faces consisted of phase-scrambled faces, i.e. random patterns. The three image naturalness levels were presented in separate blocks, with the order of blocks counterbalanced across participants. Within each block of a given face naturalness, 60 fearful, 60 neutral faces and 5 non-face oddballs were presented in randomized order. In each trial, a fixation mark was presented jittering between 300 and 700 ms, followed by a face for 50 ms, and then followed by a blank screen presented for 500 ms before the next trial started. After testing, participants were asked about effort and difficulty of the experiment, tiredness during and after the experiment, and their subjective most intense emotional responsiveness towards given face categories.

It is important to note that participants completed two preceding experiments. The first experiment took approximately 50 minutes, manipulating perceptual load and directing attention to letters while task-irrelevant angry, happy or neutral faces or scrambled distracters were presented. Afterwards, participants had a long break to rest and refresh. Then, they started a face perception experiment, each lasting for approximately 10 minutes, presenting fearful and neutral faces with manipulated spatial frequencies.

EEG recording and preprocessing. EEG signal was recorded from 64 BioSemi active electrodes using Biosemi’s Actiview software (www.biosemi.com). Four additional electrodes measured horizontal and vertical eye-movements. The recording sampling rate was 512 Hz. As recording reference, Biosemi uses two separate electrodes as ground electrodes, a Common Mode Sense active electrode (CMS) and a Driven Right Leg passive electrode (DLR), which form a feedback loop that enables measuring the average potential close to the reference in the A/D-box. Data were re-referenced offline to an average reference, and a 0.1 Hz high-pass forward filter (6 db/oct) as well as a 30 Hz low-pass zero phase filter (24 db/oct) were applied. Recorded eye-movement was corrected using the automatic eye-artefact correction method implemented in BESA (Ille, Berg, & Scherg, 2002). Filtered data were segmented from 100 ms before stimulus onset until 800 ms after stimulus presentation. Baseline-correction was used 100 ms before stimulus onset. On average, 4.49 electrodes (SD = 2.21) were interpolated. For close-up coloured fearful faces, an average of 52.83 trials was kept, for close-up coloured neutral faces 52.36 trials, for close-up grey-scaled fearful faces 52.06 trials, for close-up grey-scaled neutral faces 53.75 trials, for cutout grey-scaled fearful faces 53.64 trials, and for cutout grey-scaled neutral faces 53.75 trials. . There were no differences in the number of kept trials between emotional expressions ($F_{(1,35)}$ = 0.44, p = .513, partial η^2 = .012), face naturalness ($F_{(2,70)}$ = 0.72, p = .492, partial η^2 = .020), or an interaction (between) of both ($F_{(2,70)}$ = 1.25, p = .294, partial η^2 = .034).

EEG data analyses. EEG scalp-data was statistically analysed with EMEGS (Peyk, De Cesarei, & Junghöfer, 2011). Two (emotion: fearful vs. neutral expression) by three (face naturalness: close-up colour vs. close-up grey-scale vs. cutout grey-scale) repeated measure ANOVAs were set-up to investigate main effects of emotional expression and face naturalness, as well as their interaction in time windows and electrode clusters of interest. Finally, we preregistered that ERP modulations might not be sufficiently large enough to detect slight effects of naturalness, planning Bayesian t-tests to detect possible differences in emotional modulations between close-up coloured faces and cutout grey-scale faces (see https://osf.io/5fkt4/). The null hypothesis was specified as a point-null prior (i.e., standardized effect size δ = 0), whereas the alternative hypothesis was defined as a Jeffrey-Zellner-Siow (*JZS*) prior, i.e., a folded Cauchy distribution centred around $\delta = 0$ with scaling factors of $r = 0.707$, and BF scores above (below) 1 indicating that the data are less (more) likely under the null relative to the alternative hypothesis. Partial eta-squared (partial η^2) were estimated to describe effect sizes, where $\eta_P^2 = 0.02$ describes a small, $\eta_P^2 = 0.13$ a medium and $\eta_P^2 = 0.26$ a large effect (Cohen, 1988). Time windows were segmented from 80 to 100 ms for the P1, from 130 to 170 ms for the N170, from 230 to 330 ms to investigate EPN effects, and from 400 to 600 ms to investigate LPP effects. Since the N170 peaked at about 140 ms (in line with the literature, e.g., see Itier & Taylor, 2004), we carefully re-checked and validated the correct trigger timing. For the P1, an occipital cluster (O1, O2, Oz, PO7, PO8) was examined, while for the N170 and EPN time windows, two symmetrical occipital clusters were examined (left: O1, PO7, P7, P9; right: O2, PO8, P8, P10). However, laterality did not affect the results (for detailed analyses see the Supplement). For the LPP, a centro-parietal cluster was examined (P1, P2, Pz, CP1, CP2, CPz; see the Supplementary Figure S1 for an overview of the data and the used electrode clusters).

Eye-tracking data: The eye-tracking data were only used for online gaze control. We chose not to perform any offline analyses as the experiment was designed to discourage eye movements anyway and inter-stimulus intervals were likely too small to observe systematic changes in pupil dilation.

3. Results

Manipulation check

In an open questionnaire, participants reported highest emotionality for close-up coloured faces. While most reported similar emotional responses to all fearful faces

(19 participants), some reported no intensive emotional experience for any given face (5 participants) or did not comment (8 participants).

P1 component

For the P1, no main effects of emotion ($F_{(1,35)}$ = 3.02, p = .091, partial η² = .079), or (face) naturalness ($F_{(2,70)}$ = 1.79, p = .175, partial η² = .049; see Figure 2), as well as no interaction between emotion and face naturalness ($F_{(2,70)}$ = 0.59, p = .942, partial η² = .002) were observed. Explorations between the extreme positions conducted by Bayesian *t*-tests (please see the preregistered protocol in the Open Science Framework, https://osf.io/5fkt4/), revealed that no difference in emotion effects between the close-up coloured faces and the grey-scaled cutout faces was about five times more likely than the existence of actual differences (BF_{01} = 5.316, error % 0.0000207).

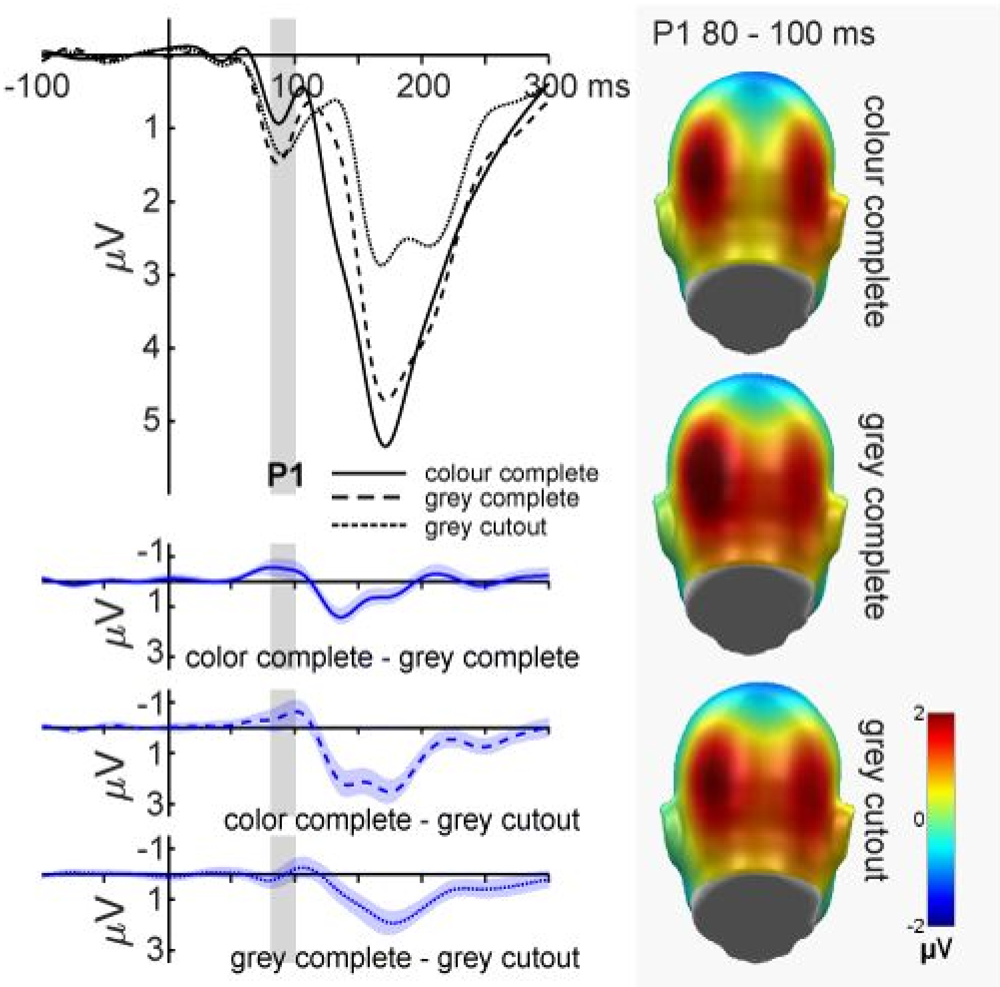

Figure 2: P1 modulations by depicted face naturalness. The left panel shows the time course for all face naturalness conditions, averaged over electrodes O1, Oz, O2. The right panel shows the amplitudes for each face naturalness condition. P1 amplitudes did not significantly differ between the naturalness levels. All difference plots (blue) contain 95% bootstrap confidence intervals of intra-individual differences.

Exploratory P1 component analyses for face naturalness:

Since main effects of face naturalness were expected but absent at the P1, we first re-analysed the P1 with more lateralized sensors (left: P9, P7, PO7, O1; right: P10, P8, PO8, O2; see Supplementary Figures S1 and S2 and the Supplement for detailed analyses) and more medial sensors (O1, Oz, O2). For the medial sensor group, no main effect of emotion was found ($F_{(1,35)}$ = 3.74, p = .061, partial η^2 = .061), but a significant main effect of face naturalness was observed ($F_{(1.69,59.25)}$ = 3.37, p = .048, partial η^2 = .088; see Figure 2). Here, close-up coloured faces elicited a smaller P1 compared to close-up grey-scaled faces (p = .008), but not significantly compared to cutout grey-scaled faces (p = .081). The two grey-scaled face conditions did not differ from one another (p = .821). Again, no interaction between emotion and face naturalness was detected ($F_{(2,70)}$ = 0.18, p = .840, partial η^2 = .005).

N170

For the N170, large main effects of emotion ($F_{(1,35)}$ = 40.34, p < .001, partial η^2 = .535; see Figure 3a, 3c, 3d), and naturalness were found ($F_{(2,70)}$ = 60.55, p < .001, partial η^2 = .634; see Figure 4a, 4b, 4c), but no interaction between emotion and face naturalness ($F_{(2,70)}$ = 1.44, p = .243, partial η^2 = .040; see Figure 3e, 3f). For the main effect of emotion, fearful expressions elicited a larger N170 compared to neutral expressions. Regarding face naturalness, cutout grey-scaled faces showed the largest N170 amplitudes, followed by close-up grey-scaled faces, and eventually close-up coloured faces. To investigate this closer, polynomial trends were tested, showing linearly increasing N170 amplitudes with decreasing face naturalness ($F_{(1, 35)}$ = 78.79, p < .001; explained 92% of the naturalness variance), while a quadratic contrast was also significant ($F_{(1, 35)}$ = 15.13, p < .001; 8% variance explained). Explorations for differences between fearful and neutral faces were tested for the extreme positions of face naturalness by using Bayesian *t*-tests. These tests showed that no difference in emotion effects between the close-up coloured faces and the grey-scaled cutout faces was approximately four times more likely than the existence of actual differences (BF_{01} = 4.392, error % 0.00001435).

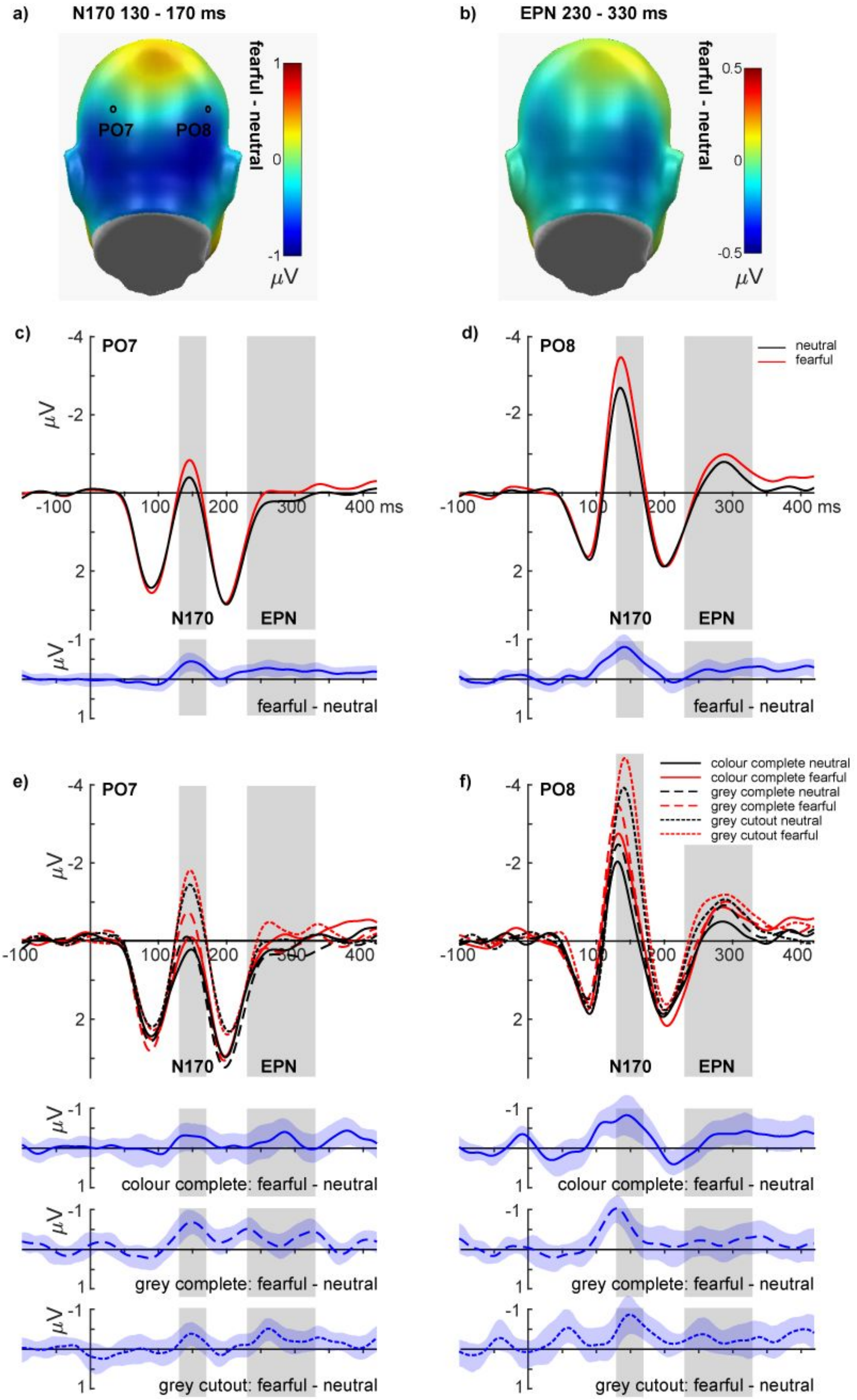

Figure 3: Emotion effects for the N170 and EPN components. a and **b)** Difference topographies, showing enhanced negativity for fearful faces over occipital areas. **c and d)** The time course for main effects of emotions at electrodes PO7 and PO8. **e and f)** Time course for all conditions, showing similar emotion increases at electrodes PO7 and PO8. All difference plots (blue) contain 95% bootstrap confidence intervals of intra-individual differences.

EPN

Regarding the EPN, main effects of emotion ($F_{(1,35)}$ = 8.21, *p* = .007, partial η² = .190; see Figure 3b, 3c, 3d), and (face) naturalness were found ($F_{(2,70)}$ = 4.40, *p* = .016, partial η² = .112; see Figure 4a, 4b, 4d), while no interaction between emotion and face naturalness was observed ($F_{(2,70)}$ = 0.104, *p* = .901, partial η² = .003; see Figure 3e, 3f). For the main effect of emotion, fearful expressions elicited a larger posterior negativity compared to neutral expressions. Regarding face naturalness, cutout grey-scaled faces elicited a larger EPN compared to both close-up grey-scaled faces and close-up coloured faces (*ps* < .05). To investigate this closer, polynomial trends were tested, showing linearly increasing EPN amplitudes with decreasing face naturalness ($F_{(1, 35)}$ = 4.766, *p* = .036; explained 77% of the naturalness variance). Here, a quadratic contrast was not significant ($F_{(1, 35)}$ = 3.48, *p* = .071; 23% variance explained). Explorations for differences between fearful and neutral faces were conducted for the extreme positions of face naturalness by using Bayesian *t*-tests. These tests revealed that no difference in emotion effects between the close-up coloured faces and the grey-scaled cutout faces was about five times more likely than the existence of actual differences (BF_{01} = 5.555, error % 0.00002235).

LPP

For the late positive potential, no main effect of emotion was found ($F_{(1,35)}$ = 0.002, *p* = .968, partial η² < .001), while a main effect of naturalness could be observed ($F_{(2,70)}$ = 5.28, *p* = .007, partial η² = .131; see Figure 4e, 4f). Again, no interaction between emotion and face naturalness was observed ($F_{(2,70)}$ = 0.640, *p* = .531, partial η² = .018). For the main effect of face naturalness, close-up coloured faces elicited the largest LPP amplitudes, being significantly larger than for cutout grey-scaled faces (*p* = .002) while statistically not being significantly larger than close-up grey-scaled faces (*p* =

.148). There were also no significant differences between close-up and cutout grey-scaled faces (p = .097). To investigate this closer, polynomial trends were tested, this time showing strongly linearly increasing LPP amplitudes with increasing face naturalness ($F_{(1, 35)}$ = 11.343, p = .002; explained 99,7% of the naturalness variance), and the quadratic contrast was not significant ($F_{(1, 35)}$ = 0.034, p = .071; 0,3% variance explained). Explorative analyses for differences between fearful and neutral faces were tested for the extreme positions of face naturalness by using Bayesian t-tests. No difference in emotion effects between the close-up coloured faces and the grey-scaled cutout faces was about three times more likely than the existence of actual differences (BF_{01} = 3.221, error % 0.00000322).

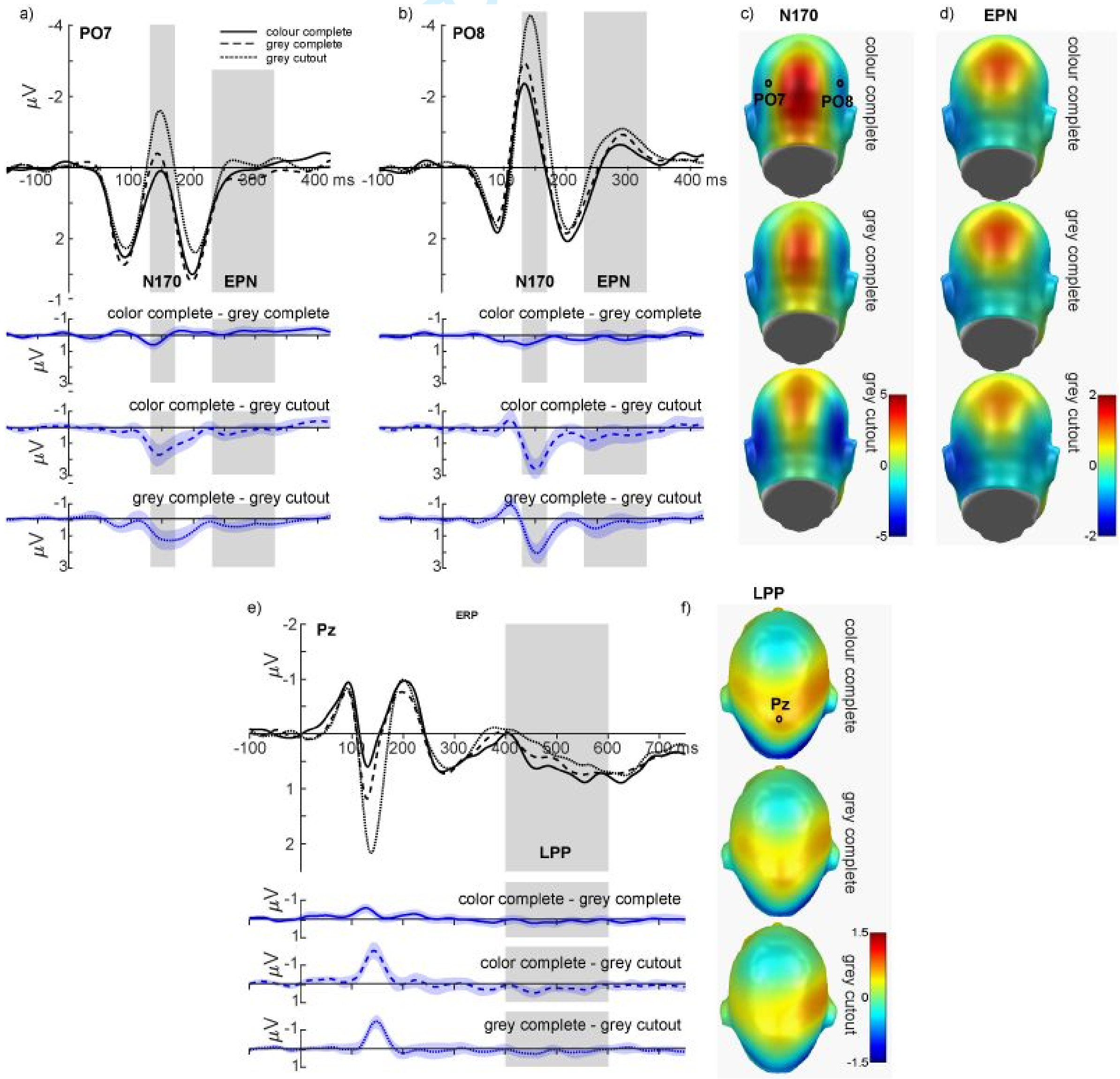

Figure 4: Naturalness effects for the N170, EPN and LPP components. a and **b)** display the time course for electrodes PO7, PO8, respectively. **c** and **d)** show the topographies for each face naturalness level in the EPN and LPP interval, respectively, indicating stronger negativity and lower positivity for decreasing face naturalness. **e** and **f)** display time courses and topographies for the LPP component. All difference plots (blue) contain 95% bootstrap confidence intervals of intra-individual differences.

4. Discussion

As predicted, main effects of emotion were detected for the N170 and EPN component. In line with a recent meta-analysis (Hinojosa et al., 2015), emotional expressions already influenced the N170, showing pronounced amplitudes for fearful relative to neutral faces. Drawing from their literature review, Hinojosa and colleagues (2015) reasoned that this might reflect parallel processing of the emotional expression and facial information (see also Eimer, 2011; Joyce & Rossion, 2005; for a review on structural encoding and person discrimination, see Calder & Young, 2005). Further, in line with previous research, an enhanced processing of fearful compared to neutral faces was found for the EPN (Luo, Feng, He, Wang, & Luo, 2010; Morel, George, Foucher, Chammat, & Dubal, 2014; Peltola et al., 2014; Wieser et al., 2012). Interestingly, modulations of the N170 and EPN by emotional expressions were found to be present across different common tasks, while the size of the emotion effect did not vary between a gender discrimination, an explicit emotion discrimination and an oddball detection task (Itier & Neath-Tavares, 2017). The EPN component is related to early attentional selection and this differential processing is thought to reflect enhanced early attention devoted to evolutionary more relevant (i.e. fearful) faces (Schupp et al., 2006).

No emotional modulation was observed with regard to very early (P1 component) and later elaborative stimulus processing (LPP). This is partly in line with the mixed results of previous research, and regarding the LPP, might be due to the relatively lower emotional engagement of the present face perception task. Specifically when using passive viewing designs, LPP emotion effects are sometimes not found (Rellecke, Sommer, & Schacht, 2012; Schindler et al., 2017; Yuan, Zhou, & Hu, 2014). In this study, participants had to simply look at the face stimuli and respond from time to time to a non-facial oddball stimulus. Thus, no elaborate attention to the briefly presented facial expression was needed for correct task performance, which might explain the absence of late emotion effects in the present study.

For face naturalness main effects, we expected modulations of early components (P1, N170), as well as for the LPP, where enlarged LPP amplitudes might reflect perceived higher distinctiveness. Surprisingly, the initial, preregistered analyses for the P1 showed no main effect of face naturalness. However, exploratory analyses using more occipital sensors (O1, Oz, and O2) revealed a significant main effect of face naturalness. Here, a decreased P1 for close-up coloured faces was found compared to close-up grey-scaled faces, and, in tendency, compared to cutout grey-scaled faces. Thus, while P1 effects are detectable, the (spatial) extension of these effects is limited, which could relate to the rather small visual angle of the stimuli, and/or the blockwise presentation mode, possibly introducing adaptation effects.

The subsequently peaking N170, EPN, and LPP amplitudes were found to be linearly modulated by face naturalness. Here, N170 and EPN amplitudes were enlarged in a linear fashion for decreasing face naturalness. An explanation for the strong effects at the N170 might be the decreasing interstimulus perceptual variance (ISPV) going along with decreasing naturalness (e.g., see Thierry et al., 2007a, 2007b). It is important to note that for each level of decreasing face naturalness, we removed information (first colour, then hair information), which logically decreased stimulus-variance of all faces in the respective condition. Indeed, controlling for ISPV has been found to reduce or even abolish differences in N170 amplitudes between faces and objects (e.g., see Thierry et al., 2007a, 2007b), although it is important to note that even with zero variance, faces elicit larger N170 amplitudes than objects (Ganis et al., 2012; Schendan & Ganis, 2013). In our study, by cutting out more variable colour, and especially hair/neck information, stimuli became more alike (e.g., see Figure 1). Whereas ISPV has been related to the N170 component (i.e. less variable stimuli by pixel-by-pixel correlations), we are not aware of any study showing that stimulus variability could also affect the EPN.

Another interpretation for the enlarged N170 and EPN amplitudes might relate to an increased processing difficulty for less natural faces. Although identity recognition was not task-relevant, this often occurs spontaneously and is much harder for cutout faces. Task difficulty has been shown to elicit larger N170 amplitudes, for instance, for low-frequency filtered faces (LSF) in a challenging gender categorization task (Goffaux, Jemel, Jacques, Rossion, & Schyns, 2003). Furthermore, larger N170 amplitudes have been reported for inverted compared to upright faces (e.g., see Latinus & Taylor, 2006), this face inversion effect even correlates with task performance (Jacques & Rossion, 2007).

Interestingly, at late stages of processing, we observed an opposite pattern, with enlarged amplitudes in the LPP time window for more naturalistic faces. Enhanced LPP responses have been observed in previous studies for faces with exaggerated facial features or real compared to less realistic and distinctive cartoon faces (e.g., see Schindler et al., 2017; Schulz et al., 2012; Itz et al., 2014). In this experiment, the very same faces were shown – while only colour and hair information was added. This manipulation might have increased subjective distinctiveness or face uniqueness. A relation between distinctive (and) unique faces and enhanced LPPs has been reported previously (similar to e.g. Kaufmann & Schweinberger, 2008; Schulz et al., 2012). However, our manipulation of face naturalness is no strict manipulation of face-uniqueness or face-distinctiveness. Thus, according to our predictions, faces with richer information (including colour and hair) might be perceived as more unique and/or distinct, leading to a larger late positivity.

Crucially, we predicted interaction effects between emotional expression and face naturalness. The basic idea was that faces with more contextual information (i.e., colour and hair), display more diagnostic emotion features (relative to grey-scaled cutout faces), thus leading to pronounced neural differentiation between fearful and neutral faces. However, the present data does not show significant interaction effects between face naturalness and emotion for any of the investigated ERP components. Moreover, using a Bayesian approach, moderate support for the null hypothesis was observed (i.e., no interaction), even when comparing only the two extreme points (coloured complete faces versus cutout grey-scaled faces). Thus, the present results are in line with approximately a third of the reviewed studies (see Supplementary Table S1), which suggest effects of emotion and naturalness on face processing being relatively independent from one another.

Limitations and future directions

It has to be noted that we only used fearful and neutral facial expressions, thus, our findings should not be generalised to other emotional expressions. Furthermore, face pictures were presented very briefly (50 ms), which likely precluded a more in-depth elaboration of facial expressions. This might have caused the absence of emotion effects for the LPP component. However, similar to previous studies which used even shorter presentation times (e.g., 8 ms or 20 ms M. L. Smith, 2012; Walentowska & Wronka, 2012), emotional modulations have been observed for the N170 and EPN components. These findings support the notion of spontaneous and rather automatic selective emotion processing at such early stages of the visual processing stream (e.g., Schupp et al., 2006). In addition, overall stimulus size might have modulated the present ERP findings. Specifically, the cutout faces display less information (i.e. no hair), though this was necessary to avoid changing the size of the core facial features which are known to strongly impact ERP amplitudes (e.g., eyes, see Li et al., 2018). Moreover, tiredness or habituation effects might be involved, as participants completed two other face experiments directly preceding the present study. Whereas previous research showed that emotional ERP effects are presumably not affected by massive repetitions (for a review, see Ferrari, Codispoti, & Bradley, 2017), future research may account for habituation effects regarding facial naturalness. Finally, our manipulation of face naturalness is not universal, as, for example, various levels of public concealment of the face are common in different cultures.

Future studies may detail whether face naturalness, uniqueness, and realism act in parallel or interact with facial emotion and/or identity processing. Moreover, the impact of various levels of attention on the different levels of face naturalness is of interest and should be examined further. For instance, the present findings of independent emotion and face naturalness effects may vary depending on whether people pay attention to faces or whether faces are distractors. By strictly manipulating both face naturalness as well as perceived uniqueness, the (dis-)similarities of these concepts could be better understood. This could be achieved, for instance, by manipulating facial features in real, caricature, or cartoon faces.

Conclusion

As the key finding, we showed that emotion ERP effects towards fearful expressions were not interacting with the most commonly used face naturalness manipulations.

Although large main effects were observed for facial fear as well as for face naturalness (N170 and EPN component), no interactions were detected for both components. Moreover, face naturalness seems to modulate the N170, EPN and LPP component in a linear fashion, and early components (N170 and EPN) were enlarged for facial stimuli depicting less distracting information (e.g., no hair). In contrast, later processing stages (LPP) were generally enhanced for faces depicting more detailed contextual information. We recommend that researchers interested in strong modulations of early components should make use of cutout grey-scaled faces, while those interested in a pronounced late positivity should use close-up coloured faces providing more realistic information.

Acknowledgments

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Figure Legends

Figure 1: Example facial stimuli showing fearful and neutral expressions. Please note that background colour was identical in all experiments and displayed facial features size (e.g. eyes, nose, and mouth) was kept constant.

Figure 2: P1 modulations by depicted face naturalness. The left panel shows the time course for all face naturalness conditions, averaged over electrodes O1, Oz, O2. The right panel shows the amplitudes for each face naturalness condition. P1 amplitudes did not significantly differ between the naturalness levels. All difference plots (blue) contain 95% bootstrap confidence intervals of intra-individual differences.

Figure 3: Emotion effects for the N170 and EPN components. a and b) Difference topographies, showing enhanced negativity for fearful faces over occipital areas. **c and d)** The time course for main effects of emotions at electrodes PO7 and PO8. **e and f)** Time course for all conditions, showing similar emotion increases at electrodes PO7 and PO8. All difference plots (blue) contain 95% bootstrap confidence intervals of intra-individual differences.

Figure 4: Naturalness effects for the N170, EPN and LPP components. a and **b)** display the time course for electrodes PO7, PO8, respectively. **c** and **d)** show the topographies for each face naturalness level in the EPN and LPP interval, respectively, indicating stronger negativity and lower positivity for decreasing face naturalness. **e** and **f)** display time courses and topographies for the LPP component. All difference plots (blue) contain 95% bootstrap confidence intervals of intra-individual differences.

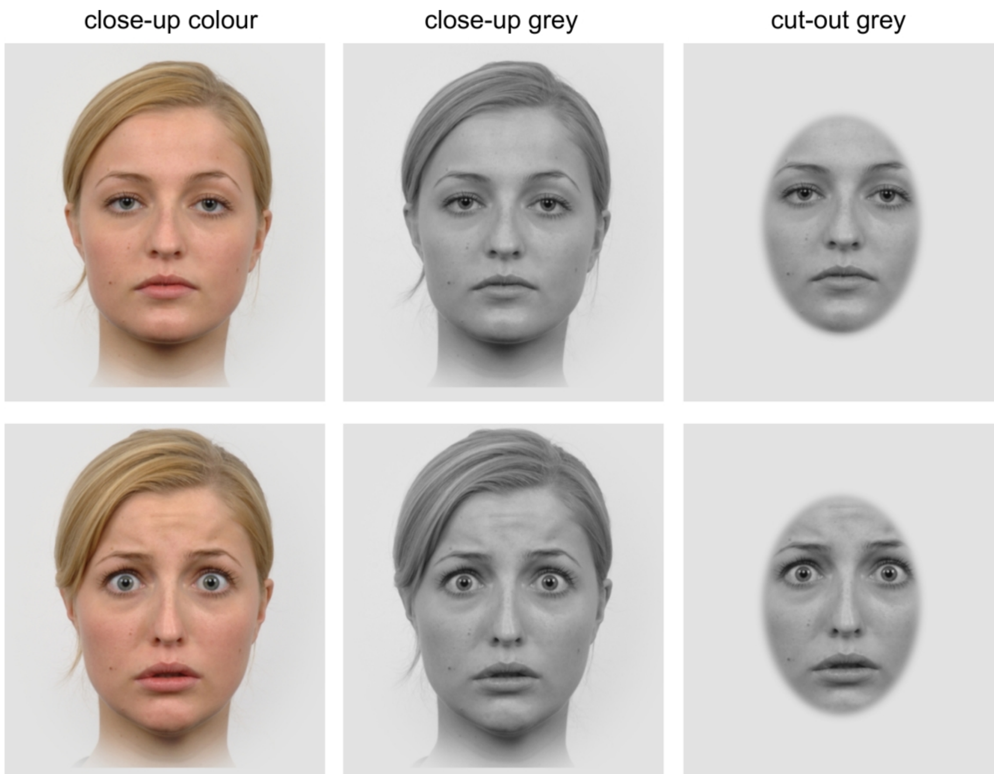
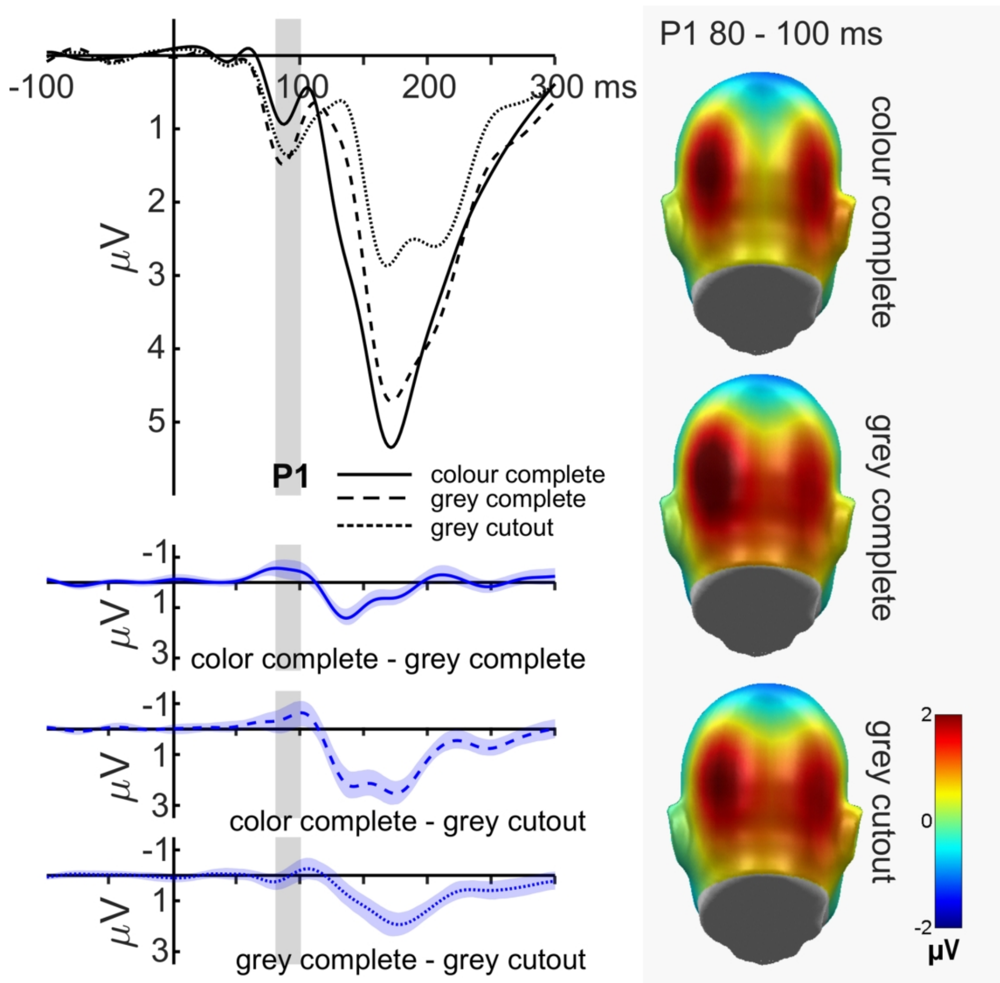


Figure 1: Example facial stimuli showing fearful and neutral expressions. Please note that background colour was identical in all experiments and displayed facial features size (e.g. eyes, nose, and mouth) was kept constant.

165x127mm (300 x 300 DPI)



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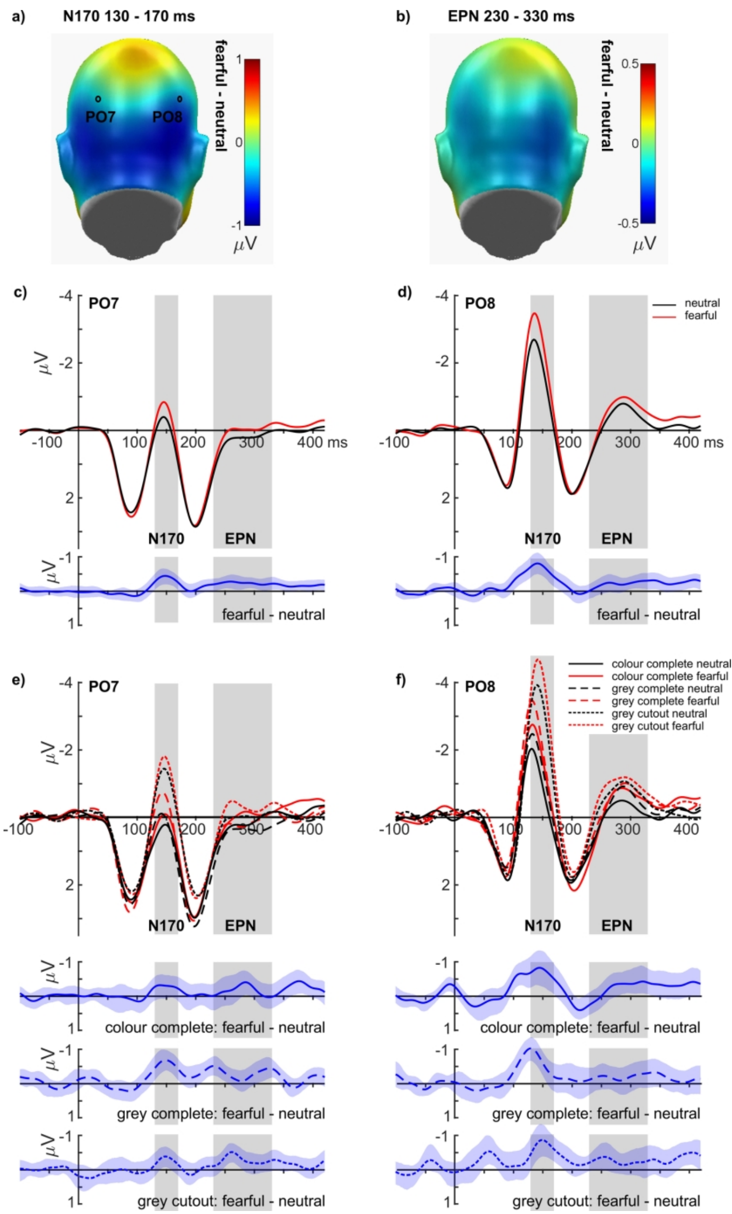
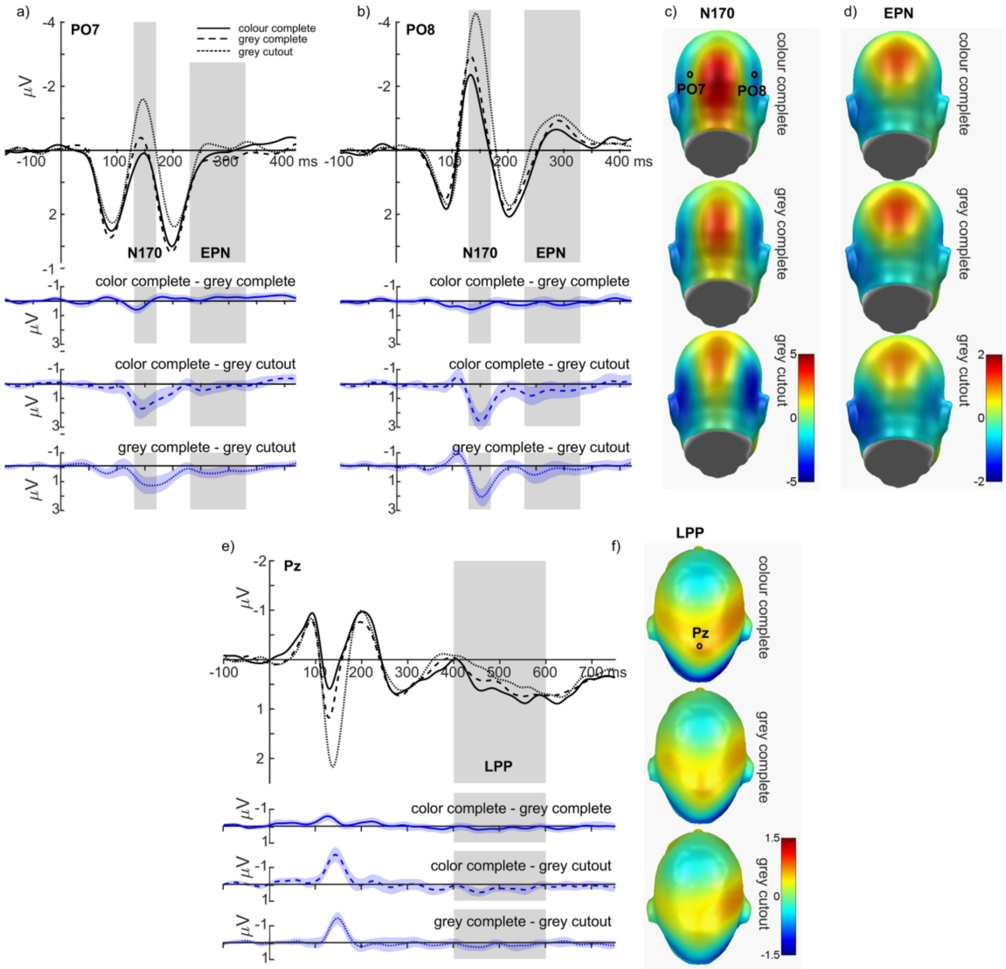


Figure 3: Emotion effects for the N170 and EPN components. a and b) Difference topographies, showing enhanced negativity for fearful faces over occipital areas. c and d) The time course for main effects of emotions at electrodes PO7 and PO8. e and f) Time course for all conditions, showing similar emotion increases at electrodes PO7 and PO8. All difference plots (blue) contain 95% bootstrap confidence intervals of intra-individual differences.

133x219mm (300 x 300 DPI)



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192x185mm (300 x 300 DPI)

Modulation of face- and emotion-selective ERPs by the three most common types of face image manipulations

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Supplementary Materials

Sebastian Schindler[1*], Maximilian Bruchmann[1], Florian Bublatzky[2], and Thomas Straube[1]

[1] Institute of Medical Psychology and Systems Neuroscience, University of Muenster
[2] Central Institute of Mental Health Mannheim, Medical Faculty Mannheim/Heidelberg University, Mannheim, Germany

* Corresponding author

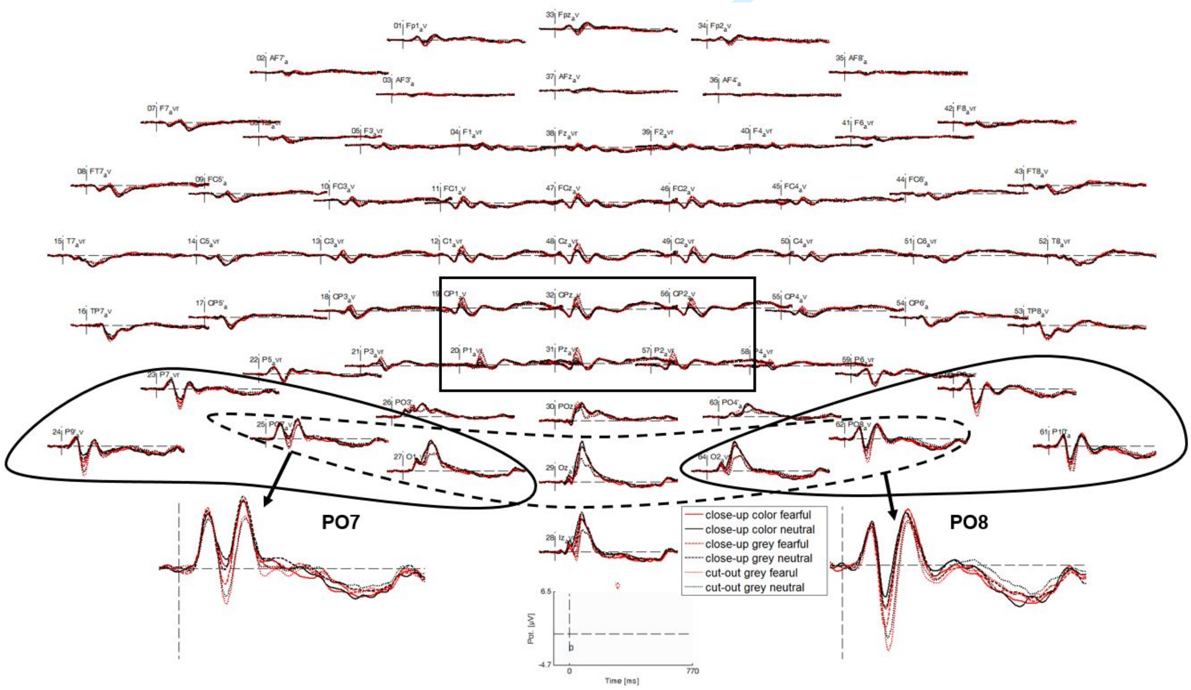
Correspondence address

Institute of Medical Psychology and Systems Neuroscience
University of Münster
Von-Esmarch-Str. 52, D-48149 Münster, Germany
e-mail: sebastian.schindler@ukmuenster.de

Supplementary Materials: Modulation of face- and emotion-selective ERPs by the three most common types of face image manipulations

1. Overview of the complete data and electrode clusters

According to the pre-registration, we initially scored the P1 from 80 to 100 over an occipital cluster (O1, Oz, O2, PO7, PO8). While visual inspection suggest that the P1 was most pronounced visible over two more lateralized clusters (left: P9, P7, PO7; right: P10, P8, PO8; see Supplementary Figure S1), using these electrodes did not change any observed result for the P1. A final explorative analyses only used medial electrodes (O1, Oz, O2). Similarly, the N170 and EPN over more lateral, temporo-occipital clusters were examined (left: P9, P7, PO7; right: P10, P8, PO8), which had no effect on the results. In contrast to the pre-registered hypotheses, the LPP was observed to be pronounced over centro-parietal, rather than parieto-occipital regions, accordingly, we therefore shifted the sensors of interest to a more centro-parietal locations (CP1, CPz, CP2, P1, Pz, P2; see Supplementary Figure S1).



Supplementary Figure S1: Overview for all electrodes and all conditions. Highlighted are all used electrode clusters. The dashed lines include the occipital P1 cluster, the straight black circles the two occipito-temporal N170/EPN clusters, and the black rectangle the centro-parietal LPP cluster. Electrodes PO7 and PO8 are superimposed to show the differential effects of each condition.

2. Additional explorative ERP analyses

P1 face naturalness main effects

As described in the main text, in addition to the medial electrodes (O1, Oz, O2), showing the expected P1 modulations, we performed explorative analyses of lateral sensors. As the collapsed localizer suggests that over lateral regions the absolute P1 seem to be largest (see Supplementary Figure S1), additionally, a re-analyses with more lateralized electrode clusters were performed for the P1 between 80 and 100ms, to better cover possible P1 modulations (left: P9, P7, PO7, O1; right: P10, P8, PO8, O2). However, this neither revealed a P1 main effect of emotion ($F_{(1,35)}$ = 0.55, p = .463, partial η^2 = .015), nor an effect of naturalness ($F_{(2,70)}$ = 0.34, p = .716, partial η^2 = .010), as well as no interaction between emotion and face naturalness ($F_{(2,70)}$ = 0.11, p = .893, partial η^2 = .003).

P1, N170, and EPN effects of laterality

For the P1, using lateralized electrode clusters (left: P9, P7, PO7, O1; right: P10, P8, PO8, O2), no main effect of laterality was emerged ($F_{(1,35)}$ = 1.10, p = .302, partial η^2 = .030). There was no interaction of laterality with emotion ($F_{(1,35)}$ = 0.54, p = .466, partial η^2 = .015), or with face naturalness ($F_{(2,70)}$ = 0.11, p = .893, partial η^2 = .003), as well as no triple interaction ($F_{(2,70)}$ = 0.03, p = .970, partial η^2 = .001). For the N170, again no main effect of laterality was found ($F_{(1,35)}$ = 2.03, p = .163, partial η^2 = .055). There was no interaction of laterality with emotion ($F_{(1,35)}$ = 0.37, p = .547, partial η^2 = .010), or with face naturalness ($F_{(1.67,58.29)}$ = 1.70, p = .197, partial η^2 = .046), as well as no triple interaction ($F_{(2,70)}$ = 0.74, p = .483, partial η^2 = .021). For the EPN, similarly, no main effect of laterality was found ($F_{(1,35)}$ = 0.12, p = .729, partial η² = .003). There was no interaction of laterality with emotion ($F_{(1,35)}$ = 0.02, p = .897, partial η² < .001), or with face naturalness ($F_{(2,70)}$ = 0.64, p = .531, partial η² = .018), as well as no triple interaction ($F_{(2,70)}$ = 0.06, p = .940, partial η² = .002).

3. Overview of used face stimuli in the recent literature

Reviewing the last decade (2008 until 2018) of ERP research on emotional face processing, a relatively heterogeneous use of facial stimuli was found. For a review not related to the topic of this paper, a literature search for relevant studies was done with electronic search engines, data bases (i.e., PubMed©, Google Scholar©), and the reference lists of related reviews (e.g., Hinojosa et al., 2015). The search depicted the terms “ERP” AND “face” AND “emotion” resulting in 599 matches in PubMed, as well as with the terms "ERP" AND "emotional face processing" AND "attention to emotion" resulting in 200 matches in Google Scholar, performed in May 2018. Next, studies were independently reviewed regarding inclusion criteria by the authors. A table of 101 studies is shown in supplementary Table S1, showing the kind used faces and literature reference. Please note that cutout faces vary considerably across different studies. For instance, some studies used oval or rectangle shapes depicting more or less of facial hair and/or other features (e.g. the neck). Most studies used close-up coloured faces (28), close-up grey-scaled faces (22) or cutout grey-scaled faces (27), while a large number of studies use cutout coloured faces as well (11). The remaining studies either used schematic face stimuli (3, close-up or cutout grey-scaled faces), artificial faces (4, close-up or cutout colour faces), or could not clearly assigned (1 showing full body postures, 1 varying background colour, 3 with no clear face colour / size definition retrieved).

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Supplementary Table S1. Review of 100 recently published ERP studies using emotional and neutral faces

Used facial stimuli	Reference
cutout coloured faces	Aarts & Pourtois (2012) Anxiety disrupts the evaluative component of performance monitoring: An ERP study. Neuropsychologia
cutout grey-scaled faces	Aguado, L., Valdés-Conroy, V., Rodríguez, S., Román, F. J., Diéguez-Risco, T., & Fernández-Cahill, M. (2012). Modulation of early perceptual processing by emotional expression and acquired valence of faces. Journal of Psychophysiology, 26, 29-41.
cutout grey-scaled faces	Akbarfahimi, M., Tehrani-Doost, M., & Ghassemi, F. (2013). Emotional Face Perception in Patients with Schizophrenia: an Event-Related Potential Study. Neurophysiology, 45, 249-257.
cutout grey-scaled faces	Almeida, P.R., Ferreira-Santos, F., Vieira, J.B., Moreira, P.S., Barbosa, F., & Marques-Teixeira. (2014). Dissociable effects of psychopathic traits on cortical and subcortical visual pathways during facial emotion processing: an ERP study on the N170. Psychophysiology, 51, 645-657.
clear definition could not be retrieved	Andreatta, M., Puschmann, A.K., Sommer, C., Weyers, P., Pauli, P., & Mühlberger, A. (2012). Altered processing of emotional stimuli in migraine: an event-related potential study. Cephalalgia, 32, 1101-1108.
cutout grey-scaled faces	Baggott, S., Palermo, R., & Fox, A.M. (2011). Processing emotional category congruency between emotional facial expressions and emotional words. Cognition and Emotion, 25, 369-379.
other (artificial close-up coloured faces)	Bauser, D. S., Thoma, P., & Suchan, B. (2012). Turn to me electrophysiological correlates to frontal vs. averted view. Frontiers in Integrative Neuroscience, 6, (106), 1-11
cutout grey-scaled faces	Bediou, B., Eimer, M., d'Amato, T., Hauk, O., & Calder, A. J. (2009). In the eye of the beholder: Individual differences in reward-drive modulate early frontocentral ERPs to angry faces. Neuropsychologia, 47(3), 825-834.
close-up coloured faces	Blechert, J., Sheppes, G., Di Tella, C., Williams, H. & Gross, J.J. (2012). See what you think: reappraisal modulates behavioral and neural
cutout grey-scaled faces	Brennan, A.M., Harris, A.W.F. & Williams, L.M. (2014). Neural processing of facial expressions of emotion in first onset psychosis. Psychiatry Research, 219, 477-485.
close-up coloured faces	Brenner, C. A., Rumak, S. P., Burns, A. M., & Kieffaber, P. D. (2014). The role of encoding and attention in facial emotion memory: an EEG investigation. International journal of psychophysiology, 93(3), 398-410.
close-up coloured faces	Brenner,et al (2014) encoding and attention International Journal of Psychophysiology,.pdf
close-up coloured faces	Bublatzky, F., Gerdes, A., White, A. J., Riemer, M., & Alpers, G. W. (2014). Social and emotional relevance in face processing: happy faces of future interaction partners enhance the late positive potential. Frontiers in human neuroscience, 8, 493.
coloured cutout faces	Calvo, M. G., Marrero, H., & Beltrán, D. (2013). When does the brain distinguish between genuine and ambiguous smiles? An ERP study. Brain and Cognition, 81(2), 237-246.
cutout coloured faces	Calvo, M.G., & Beltrán, D. (2014). Brain lateralization of holistic versus analytic processing of emotional facial expressions. Neuroimage, 92, 237-247.
close-up grey-scaled faces	Chammat, M., Foucher, A., Nadel, J., & Dubal, S. (2010). Reading sadness beyond human faces. Brain Research, 1348, 95-104.
close-up grey-scaled faces	Chen, J., Ma, V., Zhang, Y., Wu, X., Wei, D., Liu, G., Deng, Z., Yang, L., & Zhang, Z. (2014). Distinct facial processing related negative cognitive bias in first-episode and recurrent major depression: evidence from the N170 ERP component. PLoS ONE, 9(10), e109176.

close-up grey-scaled faces	Chronaki, G., Broyd, S. J., Garner, M., Benikos, N., Thompson, M. J., Sonuga-Barke, E. J., & Hadwin, J. A. (2018). The Moderating Effect of Self-Reported State and Trait Anxiety on the Late Positive Potential to Emotional Faces in 6–11-Year-Old Children. Frontiers in Psychology, 9, 125.
close-up coloured faces with full body	Conty, L., Dezecache, G., Hugueville, L., & Grezes, J. (2012). Early binding of gaze, gesture and emotion: neural time course and correlates. Journal of Neuroscience, 32, 4531-4539.
close-up coloured faces	Croft, R.J., McKernan, F., Gray, M., Churchyard, A., & Georgiou-Karistianis, N. (2014). Emotion perception and electrophysiological correlates in Huntington's disease. Clinical Neurophysiology, 125, 1618-1625.
close-up grey-scaled faces	Denefrio, S., Simmons, A., Jha, A., & Dennis-Tiwary, T. A. (2017). Emotional cue validity effects: The role of neurocognitive responses to emotion. PloS one, 12(7), e0179714.
close-up grey-scaled faces	DiGangi, J. A., Gorka, S., Afshar, K., Babione, J. M., Schroth, C., Greenstein, J. E., ... & Phan, K. L. (2018). Differential impact of post-deployment stress and PTSD on neural reactivity to emotional stimuli in Iraq and Afghanistan veterans. Journal of psychiatric research, 96, 9-14.
close-up grey-scaled faces	Dubal, S., Foucher, A., Jouvent, R., & Nadel, J. (2010). Human brain spots emotion in non humanoid robots. Social Cognitive and Affective Neuroscience, 6(1), 90-97.
close-up coloured faces	Fajkowska, M., Eysenck, M. W., Zagórska, A., & Jaśkowski, P. (2011). ERP responses to facial affect in low-anxious, high-anxious, repressors and defensive high-anxious individuals. Personality and Individual Differences, 50(7), 961-976.
close-up coloured faces	Fölster, M., & Werheid, K. (2016). ERP evidence for own-age effects on late stages of processing sad faces. Cognitive, Affective, & Behavioral Neuroscience, 16(4), 635-645.
close-up coloured faces	Foti, D., Olvet, D. M., Klein, D. N., & Hajcak, G. (2010). Reduced electrocortical response to threatening faces in major depressive disorder. Depression and anxiety, 27(9), 813-820.
other (schematic close-up grey-scaled faces)	Frühholz, S., Fehr, T., & Herrmann, M. (2009). Early and late temporo-spatial effects of contextual interference during perception of facial affect. International Journal of Psychophysiology, 74, 1-13.
other (schematic cutout grey-scaled faces)	Frühholz, S., Jellinghaus, A., & Herrmann, M. (2011). Time course of implicit processing and explicit processing of emotional faces and emotional words. Biological psychology, 87(2), 265-274.
close-up coloured faces	Hagemann, J., Straube, T., & Schulz, C. (2016). Too bad: Bias for angry faces in social anxiety interferes with identity processing. Neuropsychologia, 84, 136-149.
close-up coloured faces	Herbert, C., Sfärlea, A., & Blumenthal, T. (2013). Your emotion or mine: labeling feelings alters emotional face perception-an ERP study on automatic and intentional affect labeling. Frontiers in Human Neuroscience, 7:378. doi: 10.3389/fnhum.2013.00378.
close-up coloured faces	Hofman, D., Terburg, D., van Wielink, L., & Schutter, D.J. (2008). Coalescence of dominance motivation and responses to facial anger in resting-state and event-related electrophysiology. Neuroimage, 79, 138-144-
cutout grey-scaled faces	Itier, R. J., & Neath-Tavares, K. N. (2017). Effects of task demands on the early neural processing of fearful and happy facial expressions. Brain research, 1663, 38-50.
cutout grey-scaled faces	Jaworska, N., Blier, P., Fusee, W., & Knott, V. (2012). The temporal electrocortical profile of emotive facial processing in depressed males and females and healthy controls. Journal of affective disorders, 136, 1072-1081.
cutout grey-scaled faces	Jaworska, N., Thompson, A., Shah, D., Fisher, D., Ilivitsky, V., & Knott, V. (2010). Electrocortical effects of acute tryptophan depletion on emotive facial processing in depression-prone individuals. European Neuropsychopharmacology, 20, 473-486.
cutout grey-scaled faces	Jetha, M. K., Zheng, X., Schmidt, L. A., & Segalowitz, S. J. (2012). Shyness and the first 100 ms of emotional face processing. Social neuroscience, 7, 74-89.

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other (artificial cutout coloured faces)	Jiang, Y. I., Li, W., Recio, G., Liu, Y., Luo, W., Zhang, D., & Sun, D. (2014). Time pressure inhibits dynamic advantage in the classification of facial expressions of emotion. PLoS ONE, 9, e100162.
cutout grey-scaled faces	Jiang, Y. I., Shannon, R. W., Vizueta, N., Bernat, E. M., Patrick, C. J., & He, S. (2009). Dynamics of processing invisible faces in the brain: Automatic neural encoding of facial expression information. Neuroimage, 44, 1171-1177.
close-up coloured faces	Jung, H. T., Kim, D. W., Kim, S., Im, C. H., & Lee, S. H. (2012). Reduced source activity of event-related potentials for affective facial pictures in schizophrenia patients. Schizophrenia research, 136, 150-159.
cutout grey-scaled faces	Karl, C., Hewig, J., & Osinsky, R. (2016). Passing faces: sequence-dependent variations in the perceptual processing of emotional faces. Social neuroscience, 11(5), 531-544.
clear definition could not be retrieved	Kawamoto, T., Nittono, H., & Ura, M. (2014). Social exclusion induces early-stage perceptual and behavioral changes in response to social cues. Social neuroscience, 9(2), 174-185.
close-up grey-scaled faces	Kirihara, K., Kasai, K., Tada, M., Nagai, T., Kawakubo, Y., Yamasaki, S., ... & Araki, T. (2012). Neurophysiological impairment in emotional face processing is associated with low extraversion in schizophrenia. Progress in Neuro-psychopharmacology and Biological Psychiatry, 37, 270-275.
cutout grey-scaled faces	Komlósi, S., Csukly, G., Stefanics, G., Czigler, I., Bitter, I., & Czobor, P. (2013). Fearful face recognition in schizophrenia: An electrophysiological study. Schizophrenia research, 149(1), 135-140.
close-up coloured faces	Kühnpast, N., Gramann, K., & Pollatos, O. (2012). Electrophysiologic Evidence for Multilevel Deficits in Emotional Face Processing in Patients With Bulimia Nervosa. Psychosomatic medicine, 74, 736-744.
close-up grey-scaled faces	Langeslag, S. J., Morgan, H. M., Jackson, M. C., Linden, D. E., & Van Strien, J. W. (2009). Electrophysiological correlates of improved short-term memory for emotional faces. Neuropsychologia, 47, 887-896.
coloured cutout faces	Liu, T., Pinheiro, A., Zhao, Z., Nestor, P. G., McCarley, R. W., & Niznikiewicz, M. A. (2012). Emotional cues during simultaneous face and voice processing: electrophysiological insights. PloS one, 7, e31001.
close-up coloured faces	Luckhardt, C., Kröger, A., Cholemkery, H., Bender, S., & Freitag, C. M. (2017). Neural Correlates of Explicit Versus Implicit Facial Emotion Processing in ASD. Journal of autism and developmental disorders, 47(7), 1944-1955.
cutout grey-scaled faces	Luo, W., Feng, W., He, W., Wang, N. Y., & Luo, Y. J. (2010). Three stages of facial expression processing: ERP study with rapid serial visual presentation. Neuroimage, 49(2), 1857-1867.
close-up grey-scaled faces	MacNamara, A., Schmidt, J., Zelinsky, G. J., & Hajcak, G. (2012). Electrocortical and ocular indices of attention to fearful and neutral faces presented under high and low working memory load. Biological psychology, 91, 349-356.
close-up grey-scaled faces	Marzi, T., & Viggiano, M. P. (2010). When memory meets beauty: Insights from event-related potentials. Biological psychology, 84(2), 192-205.
cutout grey-scaled faces	Maurage, P., Campanella, S., Philippot, P., Timary, P., Constant, E., Gauthier, S., Micciche, M.-L., Kornreich, C., Hanak, C., Noel, X. & Verbanck, P. (2008). Alcoholism leads to early perceptive alterations, independently of comorbid depressed state: An ERP study. Clinical Neurophysiology, 38, 83-97.
coloured cutout faces	Mavratzakis, A., Herbert, C., & Walla, P. (2016). 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. Neuroimage, 124, 931-946.
close-up grey-scaled faces	Meaux, E., Roux, S. & Batty, M. (2013). Early visual ERPs are influenced by individual emotional skills. Social Cognitive and Affective Neuroscience, 2013, 1-10.

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cutout grey-scaled faces	Morel, S., George, N., Foucher, A., Chammat, M. & Dubal, S. (2014). ERP evidence for an early emotional bias towards happy faces in trait anxiety. Biological Psychology, 99, 183-192.
other (artificial close-up coloured faces)	Mühlberger, A., Wieser, M., Herrmann, M., Weyers, P., Tröger, C., & Pauli, P. (2009). Early cortical processing of natural and artificial emotional faces differs between lower and higher socially anxious persons. Journal of Neural Transmission, 116, 735-746.
cutout coloured faces	Müller-Bardorff, M., Schulz, C., Peterburs, J., Bruchmann, M., Mothes-Lasch, M., Miltner, W., & Straube, T. (2016). Effects of emotional intensity under perceptual load: an event-related potentials (ERPs) study. Biological psychology, 117, 141-149.
cutout coloured faces	Nomi, J.S., Frances, C., Nguyen, M.T., Bastidas, S., & Troup, L.J. (2013). Interaction of threat expressions and eye gaze: an event-related potential study. Neuroreport, 24, 813-817.
close-up grey-scaled faces	O'Toole, L. J., DeCicco, J. M., Berthod, S., & Dennis, T. A. (2013). The N170 to angry faces predicts anxiety in typically developing children over a two-year period. Developmental neuropsychology, 38(5), 352-363.
close-up grey-scaled faces	Obayashi, C., Nakashima, T., Onitsuka, T., Maekawa, T., Hirano, Y., Hirano, S., Oribe, N., Kaneko, K., Kanba, S. & Tobimatsu. (2009). Decreased spatial frequency sensitivities for processing faces in male patients with chronic schizophrenia. Clinical Neurophysiology, 120, 1525-1533.
close-up grey-scaled faces	Peltola, M. J., Yrttiaho, S., Puura, K., Proverbio, A. M., Mononen, N., Lehtimäki, T., & Leppänen, J. M. (2014). Motherhood and oxytocin receptor genetic variation are associated with selective changes in electrocortical responses to infant facial expressions. Emotion, 14(3), 469.
close-up grey-scaled faces	Peng, M., Beuckelaer, A., Yuan, L. & Zhou, R. (2012). The processing of anticipated and unanticipated fearful faces: An ERP study. Neuroscience Letters, 526, 85-90.
cutout grey-scaled faces (with different background colours)	Peschard, V., Philippot, P., Joassin, F. & Rossignol, M. (2013). The impact of the stimulus features and task instructions on facial processing in social anxiety: An ERP investigation. Biological Psychology, 93, 88-96.
close-up coloured faces	Raz, S. & Dan, O. (2014). Altered event-related potentials in adults with ADHD during emotional faces processing. Clinical Neurophysiology, 126, 514-523.
close-up coloured faces	Raz, S., Dan, O. & Zysberg, L. (2014). Neural correlates of emotional intelligence in a visual emotional oddball task: An ERP study. Brain and Cognition, 91, 79-86.
other (artificial cutout coloured faces)	Recio, G., Sommer, W. & Schacht, A. (2011). Electrophysiological correlates of perceiving and evaluating static and dynamic facial emotioal expressions. Brain Research, 1376, 66-75.
cutout coloured faces	Rellecke, J., Palazova, M., Sommer, W., & Schacht, A. (2011). On the automaticity of emotion processing in words and faces: event-related brain potentials evidence from a superficial task. Brain and cognition, 77(1), 23-32.
cutout coloured faces	Rellecke, J., Sommer, W. & Schacht, A. (2013). Emotion effects on the N170: A question of reference? Brain Topography, 26, 62-71.
cutout coloured faces	Rellecke, J., Sommer, W., & Schacht, A. (2012). Does processing of emotional facial expressions depend on intention? Time-resolved evidence from event-related brain potentials. Biological psychology, 90(1), 23-32.
close-up grey-scaled faces	Righi, S., Marzi, T., Toscani, M., Baldassi, S., Ottonello, S., & Viggiano, M. P. (2012). Fearful expressions enhance recognition memory: electrophysiological evidence. Acta psychologica, 139(1), 7-18.
close-up coloured faces	Rigoulot, S., D´Hondt, F., Defoort-Dhellemmes, S., Despretz, P., Honoré, J. & Sequeira, H. (2011). Fearful faces impact in peripheral vision: behavioral and neutral evidence. Neuropsychologia, 49, 2013-2021.
cutout grey-scaled faces	Rossignol, M., Campanella, S., Maurage, P. & Heeren, A. (2012). Enhanced perceptual responses during visual processing of facial stimuli in young socially anxious individuals. Neuroscience Letters, 526, 68-73.

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close-up grey-scaled faces	Rossignol, M., Philippot, P., Crommelinck, M. & Campanella, S. (2008). Visual processing of emotional expressions in mixed anxious-depressed subclinical state: An event-related potential study on a female sample. Clinical Neurophysiology, 38, 267-275.
cutout grey-scaled faces	Santesso, D., Meuret, A., Hofmann, S., Muelles, E., Ratner, K., Roesch, E. & Pizzagalli, D. (2008). Electrophysiological carrelates of spatial orienting towards angry faces: a source localization study. Neuropsychologia, 46, 1338-1348.
close-up grey-scaled faces	Schacht, A., & Sommer, W. (2009). Emotions in word and face processing: early and late cortical responses. Brain and cognition, 69(3), 538-550.
close-up coloured faces	Schindler et al. 2017 Scientific Reports
cutout grey-scaled faces	Schmidt, A., Kometer, M., Bachmann, R., Seifritz, E. & Vollenweider, F. (2013). The NMDA antagonist ketamine and the 5-HT agonist psilocybin produce dissociable effects on structural encoding of emotional face expressions. Psychopharmacology, 225, 227-239.
other (schematic close-up grey-scaled faces)	Schwab, D., & Schienle, A. (2017). Facial affect processing in social anxiety disorder with early onset: evidence of an intensity amplification bias. Social neuroscience, 1-10.
cutout grey-scaled faces	Sel, A., Forster, B. & Calvo-Merino, B. (2014). The emotional homunculus: ERP evidence for independent somatosensory responses during facial emotional processing. The Journal of Neuroscience, 34, 3263-3267.
close-up coloured faces	Smith, E., Weinberg, A., Moran, T., & Hajcak, G. (2013). Electrocortical responses to NIMSTIM facial expressions of emotion. International Journal of Psychophysiology, 88(1), 17-25.
cutout grey-scaled faces	Smith, M. L. (2011). Rapid processing of emotional expressions without conscious awareness. Cerebral Cortex, 22(8), 1748-1760.
cutout coloured faces	Sommer, W., Stürmer, B., Shmuilovich, O., Martín-Loeches, M. & Schacht, A. (2013). How about lunch? Consequences of the meal context on cognition and emotion. PLoS ONE, 8, e70314.
close-up coloured faces	Sun, D., Chan, C. C., Fan, J., Wu, Y., & Lee, T. (2015). Are happy faces attractive? The roles of early vs. late processing. Frontiers in psychology, 6, 1812.
cutout grey-scaled faces	Tamamiya, Y. & Hiraki, K. (2013). Individual differences in the recognition of facial expressions: An event-related potentials study. PLoS ONE, 8, e57325.
close-up coloured faces	Thom, N., Knight, J., Dishman, R., Sabatinelli, D., Johnson, D. & Clementz, B. (2014). Emotional scenes elicit more pronounced self-reported emotional experience and greater EPN and LPP modulation when compared to emotional faces. Cognitive Affective and Behavioral Neuroscience, 14, 849-860.
close-up coloured faces	Tortosa, M., Lupiánez, J. & Ruz, M. (2013). Race, emotion and trust: An ERP study. Brain research, 1494, 44-55.
cutout grey-scaled faces	Valdés-Conroy, B., Aguado, L., Fernández-Cahill, M., Romero-Ferreiro, V., & Diéguez-Risco, T. (2014). Following the time course of face gender and expression processing: a task-dependent ERP study. International Journal of Psychophysiology, 92, 59-66.
close-up grey-scaled faces	Van Strien, J. W., De Sonneville, L. M., & Franken, I. H. (2010). The late positive potential and explicit versus implicit processing of facial valence. Neuroreport, 21(9), 656-661.
cutout grey-scaled faces	Vlamings, P., Goffaux, V. & Kemner, C. (2009). Is the early modulation of brain activity by fearful facial expressions primarily mediated by coarse low spatial frequency information?. Journal of Vision, 9, 1-13.
close-up coloured faces	Walentowska, W. & Wronka, E. (2012). Trait anxiety and involuntary processing of facial emotions. International Journal of Psychophysiology, 85, 27-36.
close-up coloured faces	Wieser, M., Gerdes, A., Greiner, R., Reicherts, P. & Pauli, P. (2012). Tonic pain grabs attention, but leaves the processing of facial expressions intact- Evidence from event-related brain potentials. Biological Psychology, 90, 242-248.

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close-up coloured faces	Wieser, M., Klupp, E., Weyers, P., Pauli, P., Weise, D., Zeller, D., Classen, J. & Andreas Mühlberger. (2012). Reduced early visual emotion discrimination as an index of diminished emotion processing in Parkinson´s disease?- Evidence from event-related brain potentials. Cortex, 48, 1207-1217.
close-up coloured faces	Wieser, M., Pauli, P., Reicherts, P. & Mühlberger, A. (2010). Don´t look at me in anger! Enhanced processing of angry faces in anticipation of public speaking. Psychophysiology, 47, 271-280.
close-up coloured faces	Wild-Wall, N., Dimigen, O. & Sommer, W. (2008). Interaction of facial expressions and familiarity: ERP evidence. Biological Psychology, 77, 138-149.
close-up grey-scaled faces	Wronka, E., & Walentowska, W. (2011). Attention modulates emotional expression processing. Psychophysiology, 48, 1047-1056.
close-up grey-scaled faces	Yang, S., Luo, W., Zhu, X., Broster, L.S., Chen, T., Li, J., & Luo, Y. (2014). Emotional content modudales response inhibition and perceptual processing. Psychophysiology, 51, 1139-1146.
close-up coloured faces	Yoon, S., Shim, M., Kim, H. S., & Lee, S. H. (2016). Enhanced early posterior negativity to fearful faces in patients with anxiety disorder. Brain topography, 29(2), 262-272.
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Please note that a clear definition of face type was not found in all cases, in some cases due to not accessible databases or repositories.