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Registered Report

Testing stimulus exposure time as the critical factor of increased EPN and LPP amplitudes for fearful faces during perceptual distraction tasks

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ABSTRACT

Fearful facial expressions are prioritized across different information processing stages, as evident in early, intermediate, and late components of event-related brain potentials (ERPs). Recent studies showed that, in contrast to early N170 modulations, mid-latency (Early Posterior Negativity, EPN) and late (Late Positive Potential, LPP) emotional modulations depend on the attended perceptual feature. Nevertheless, several studies reported significant differences between emotional and neutral faces for the EPN or LPP components during distraction tasks. One cause for these conflicting findings might be that when faces are presented sufficiently long, participants attend to task-irrelevant features of the faces. In this registered report, we tested whether the presentation duration of faces is the critical factor for differences between reported emotional modulations during perceptual distraction tasks. To this end, 48 participants were required to discriminate the orientation of lines overlaid onto fearful or neutral faces, while face presentation varied (100 msec, 300 msec, 1,000 msec, 2,000 msec). While participants did not need to pay attention to the faces, we observed main effects of emotion for the EPN and LPP, but no interaction between emotion and presentation duration. Of note, unregistered exploratory tests per presentation duration showed no significant EPN and LPP emotion differences during short durations (100 and 300 msec) but significant differences with longer durations. While the presentation duration seems not to be a critical factor for EPN and LPP emotion effects, future studies are needed to investigate the role of threshold effects and the applied analytic designs to explain conflicting findings in the literature.

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1. Introduction

Rapid detection of potential threats, even when irrelevant for the current task, is important for humans to react adequately. The reaction to threat varies greatly between people, while the increased attention to threatening stimuli and attentional capture by threat-related stimuli are reported in clinical and non-clinical populations (for views and reviews, see Bar-Haim, Lamy, & Glickman, 2005; Cisler & Koster, 2010). Some theoretical accounts suggest that emotional information is, at least to a certain extent, immune to attentional manipulations (Vuilleumier & Huang, 2009; see also Carretié, 2014). Such accounts are based on findings that differential emotion processing during distraction tasks or limited stimulus exposure has been interpreted as an automatic response to emotional information. This assumed rapid and automatic processing of emotional information, for example, demonstrated for subliminally presented fearful faces (e.g., see Pegna, Landis, & Khateb, 2008; Smith, 2012), has been suggested to be better captured by electrophysiological methods due to the high temporal sensitivity (e.g., see Brosch & Wieser, 2011; Straube et al., 2011). Other views propose that the processing of emotional stimuli strongly depends on available resources (e.g., see Pessoa, 2009; Pessoa, Oliveira, & Pereira, 2013). According to this view, available resources can be limited by conflicting goal-relevant attention tasks or perceptual information that has to be discriminated (see also Lavie, 2005; Lavie, Beck, & Konstantinou, 2014), reducing the ability to process task-irrelevant features, such as emotional information. In line with this latter view, Lim, Padmala, and Pessoa (2008) found that threat stimuli are processed in the same fronto-parietal areas as the attention network and concluded that attention tasks and threat processing require at least partly the same cognitive resources. Pessoa (2009) reasoned that perceptual competition takes place in the visual cortex and emotional stimuli have an advantage in these competitions. However, this advantage for processing emotional stimuli depends on available processing resources (Pessoa, 2009).

Fearful faces are highly relevant for humans because they provide information about danger, eliciting a processing advantage compared to neutral faces concerning specific event-related potentials (ERPs; e.g., see Eimer & Holmes, 2007; Hinojosa, Mercado, & Carretié, 2015; Schindler & Bublatzky, 2020). This is typically reflected in an increase of the N170 (for a meta-analysis, see Hinojosa et al., 2015), the Early Posterior Negativity (EPN; e.g., see Frühholz, Fehr, & Herrmann, 2009; Walentowska & Wronka, 2012), and the Late Positive Potential (LPP; e.g., see Frühholz et al., 2009; Santos, Iglesias, Olivares, & Young, 2008). A recent review shows that emotion effects can be reliably observed for all three ERP components, while especially late emotion effects depend stronger on the used task properties (Schindler & Bublatzky, 2020). Furthermore, emotional modulations of the N170 have also been influenced by preprocessing characteristics, showing smaller emotion effects when using a reference close to the electrodes of interest (mastoid reference) compared to an average reference (Rellecke, Sommer, & Schacht, 2013). These three ERP components index different processing stages of the face and emotional expression. The N170 is a structural and configural encoding component, being increased by faces in contrast to objects (Eimer, 2011). The EPN is a mid-latency component and indexes early attentional selection, where task and emotion processing have been found to co-occur (Junghöfer, Bradley, Elbert, & Lang, 2001; Schupp et al., 2007). The LPP indicates more elaborate stimulus evaluation and controlled attention processes and is most vulnerable towards competing tasks or goals (Hajcak, Dunning, & Foti, 2009b; Schupp, Flaisch, Stockburger, & Junghöfer, 2006).

In line with the notion of the above-outlined idea of the mandatory processing of emotional information, ERP studies showed increased N170 amplitudes for fearful expressions, neither affected by attention task nor by load manipulations (e.g., see Itier & Neath-Tavares, 2017; Neath-Tavares & Itier, 2016; Rellecke, Sommer, & Schacht, 2012; Schindler, Bruchmann, Steinweg, Moeck, & Straube, 2020; Schindler, Bruchmann, Gathmann, Moeck, & Straube, 2021). Further, studies reported increased EPN or LPP amplitudes for emotional expressions during perceptual distraction tasks (e.g., see Frühholz, Jellinghaus, & Herrmann, 2011a; Hudson, Durston, McCrackin, & Itier, 2021; Durston & Itier, 2021; Valdés-Conroy, Aguado, Fernández-Cahill, Romero-Ferreiro, & Diéguez-Risco, 2014; Wu, Müller, Zhou, & Wei, 2019). These studies required participants to monitor fixation cross changes (Frühholz et al., 2011a), or had participants to discriminate overlaid symbols (Valdés-Conroy et al., 2014), numbers (Wu et al., 2019), or the length of overlaid lines (Müller-Bardorff et al., 2016). Other studies used working-memory-related distraction tasks, having participants memorize either six- or two-letter arrays (MacNamara, Schmidt, Zelinsky, & Hajcak, 2012). In contrast to these findings, more recent studies showed that mid-latency (EPN) effects depend on attention directed to the face. These studies used either a peripheral letter identification task, or required participants to discriminate the orientation of overlaid lines (horizontal *vs* vertical), or asked participants to detect color changes from peripherally rotating dots (Schindler, Bruchmann, et al., 2020; Schindler et al., 2021; Schindler, Caldarone, Bruchmann, Moeck, & Straube, 2020; Schindler et al., 2021). EPN differences between fearful and neutral faces are absent when attention was directed to perceptual overlaid lines (Schindler, Bruchmann, et al., 2020), or when faces follow shortly (i.e., 100, 300, or 600 msec) after a demanding preceding perceptual load task (Schindler, Caldarone, et al., 2020). In addition, late effects (LPP) were found to depend even on attention to the emotional expression (e.g., see Rellecke et al., 2012; Schindler, Bruchmann, et al., 2020; but absent interactions are also reported, see Hudson et al., 2021). Based on these findings, it might be concluded that later ERP components are increasingly dependent on attention to emotionally relevant information for significantly increased amplitudes. This can be explained by the assumed different functions of these ERP components, where early, face-sensitive, and reflexive N170 modulations seem almost not constrained by attention tasks (also beyond facial expressions, see Schindler et al., 2021; Baum & Abdel Rahman, 2021). The subsequent EPN index early salience detection and thus might share features with other similar negativities of early attention-related components, such as the Visual Awareness Negativity (VAN, Koivisto & Revonsuo,

2010) or the N2PC (e.g., see Eimer & Kiss, 2007). Differential processing at the EPN stage might be a prerequisite for additional, emotion-related, evaluative, and elaborate stimulus processing during later processing stages (LPP), recently leading to the notion of the EPN as a bottleneck for emotional awareness of stimuli and further selective attention processes (e.g., see Schindler, Caldarone, et al., 2020).

We identified that variations in the stimulus presentation duration best discriminate between studies reporting present or absent emotional EPN or LPP differences. All of the studies discussed above that report neither EPN nor LPP emotion effects presented faces very briefly (100 msec) during the perceptual distraction task (Schindler, Bruchmann, et al., 2020; Schindler et al., 2021; Schindler, Caldarone, et al., 2020; Schindler et al., 2021). A study using an exposure time of 150 msec reports EPN but no LPP emotion effects (Müller-Bardorff et al., 2016). Studies using 300–500 msec report either EPN or LPP, or even both ERPs to be increased for emotional expressions (Frühholz et al., 2011a; Valdés-Conroy et al., 2014; Wu et al., 2019). Finally, a 2,000 msec face presentation study reported relatively large emotion differences during the LPP window (MacNamara et al., 2012). Therefore, we suggest another factor to be relevant: The duration of stimuli being presented, enabling different perceptions and processing of emotion-related features of the face. Here, Nobre and van Ede (2018) highlighted the importance of temporal expectation. Temporal expectation, especially for the stimulus onset and the stimulus duration, can lead to the enhanced processing of specific features, in this case, emotional features of the anticipated stimuli presented. We suggest that when participants expect presentation duration to be short, attention will be focused to the task-relevant feature to resolve the task at hand. When the presentation duration exceeds the time necessary to resolve the task, processing resources become available for the processing of emotional features, not necessary in serial order (i.e., when participants are aware that a perceptual task can be solved even when attending to facial features, these might be processed already at stimulus onset). The latter point might be crucial in also explaining the heterogeneity of reported emotion effects during distraction tasks, as switches between the task and emotion-related stimulus features are likely divergent and depend further on the task difficulty.

Following our idea that face presentation duration is critical to observe conflicting emotion effects during the EPN and LPP time window, we aim to test if the increasing duration of face presentation is the critical factor of EPN and LPP amplitude enlargements for fearful faces. We choose the four most commonly used presentation durations (100 msec, 300 msec, 1,000 msec, and 2,000 msec, see Schindler & Bublatzky, 2020) to investigate whether this affects emotional differences during the EPN and LPP window. Participants will be presented with fearful and neutral faces and instructed to respond to thin lines displayed above the faces. This task has been shown to effectively abolish EPN and LPP emotional modulations for a presentation duration of 100 msec (Schindler, Bruchmann, et al., 2020; Steinweg, Schindler, Bruchmann, Moeck, & Straube, 2021). Crucially, fearful-neutral differences are expected to interact with the presentation duration for the EPN and LPP (see Table 1).

Precisely, we expected increasing emotion effects with increasing presentation duration, while block-order was counterbalanced across conditions. As secondary analyses, we tested presentation duration and emotion interactions for the N170 for completeness. Here, we did not expect interactions. We included further control and explorative analyses. First, we tested for interactions between emotion and presentation duration for accuracy and reaction times. Secondly, we used an online evaluation of eye gaze behavior. The experimental presentation stopped whenever participants' gaze deviated more than 3° at a radius around the fixation mark. Finally, we carried out explorative analyses and used group ICAs to explore possible different processes during the late positive potential and compared these findings to unrestricted ERP component analyses. The approved Stage 1 manuscript associated with this Registered Report may be accessed at https://osf.io/ry5s6.

2. Methods

2.1. Participants

In total, the data sampling plan was designed to examine 48 participants, for which power calculations using G*Power 3.1.7 (Faul et al., 2009) show a power of >95% to detect the smallest effect size of interest in our pilot study ($\eta_p^2 = .038$). Fifty-nine participants were examined, from which 11 participants were excluded due to the EEG exclusion criteria of the number of bad electrodes or rejected trials. Participants were given written informed consent and received 10 Euros per hour for participation. The remaining 48 participants (36 female, 11 male, 1 diverse) were 18 to 34 years old ($M = 23.67$, $SD = 3.93$), had normal or corrected-to-normal vision, were right-handed, and with no reported history of neurological or psychiatric disorders. Exclusion criteria concerning EEG data were defined as more than two interpolated electrodes within the sensor clusters of interest for main analyses (i.e., EPN, LPP) or more than ten interpolated sensors in total. Further EEG exclusion criteria were less than 50% kept trials in a single condition, ensuring sufficient trials for ERP analyses. Behavioral exclusion criteria were a mean performance lower than 80% correct responses, ensuring that participants followed the task instructions.

2.2. Stimuli

The facial stimuli were taken from the Radboud Faces Database (Langner et al., 2010) and from the Jena3D face database (J3DFD, see Itz, Golle, Luttmann, Schweinberger, & Kaufmann, 2017). Greyscale photographs of 16 males and 16 females from the Radboud and from the J3DFD database with cropped hair, ears, and neck were used (see Fig. 1), depicting 64 different identities (32 male and 32 female) with either neutral or fearful expressions. This reduced stimulus repetition effects that are reported to elicit habituation in the amygdala from fMRI (Breiter et al., 1996; Ishai, Pessoa, Bikle, & Ungerleider, 2004) and intracranial recordings (Guex et al., 2020). Luminance was matched for the face stimuli using the SHINE toolbox (Willenbockel et al., 2010). Each face stimulus had a

Table 1 – Research questions, hypotheses, analysis, and interpretation.

Question	Hypothesis	Sampling plan	Analysis Plan	Interpretation given different outcomes
Main analysis I: Does stimulus duration interact with mid-latency (EPN) emotional differentiation?	We predict that emotional ERP effects interact with presentation duration for the **EPN.** Emotion differences will increase with presentation duration.	Sampling of 48 results in >95% power to detect the interaction effect ($\eta p^2 = .038$)	Two (emotion: fearful, neutral) by four (presentation duration: 100 msec, 200 msec, 300 msec, 1000 msec) repeated measure ANOVA for the EPN ROI (see methods). In case of a significant interaction, we calculate post-hoc comparisons between fearful and neutral faces for each duration. To test increasing differences, we will calculate simple contrast of emotions differences (duration 1 *vs* 2, duration 1 *vs* 3, duration 1 *vs* 4).	No interaction of emotion and duration: This would imply no evidence for an interaction of presentation duration on fearful-neutral effects. This absence might be a power problem. However, if a power problem, we find it then unlikely that duration account for mixed findings in the literature. We expect other factors causing conflicting findings (e.g., the efficacy of perceptual distraction tasks; participants' adherence to instructions; differences in EEG preprocessing; type-I errors).
Main analysis II: Does stimulus duration interact with late (LPP) emotional differentiation?	We predict that emotional ERP effects interact with presentation duration for the **LPP.** Emotion differences will increase with presentation duration.	Sampling of 48 results in >95% power to detect the interaction effect ($\eta p^2 = .042$)	Two (emotion: fearful, neutral) by four (presentation duration: 100 msec, 200 msec, 300 msec, 1000 msec) repeated measure ANOVA for the LPP ROI (see methods). In case of a significant interaction, we calculate post-hoc comparisons between fearful and neutral faces for each duration. To test increasing differences, we will calculate simple contrast of emotions differences (duration 1 *vs* 2, duration 1 *vs* 3, duration 1 *vs* 4).	No interaction of emotion and duration: This would imply no evidence for an interaction of presentation duration on fearful-neutral effects. This absence might be a power problem. However, if a power problem, we find it then unlikely that duration account for mixed findings in the literature. We expect other factors causing conflicting findings (e.g., the efficacy of perceptual distraction tasks; participants' adherence to instructions; differences in EEG preprocessing; type-I errors).
Secondary analyses: Does stimulus duration interact with early (N170) emotional differentiation?	We predict no significant interactions of emotion and presentation duration for the **N170.** While this shows no evidence for absence, there are no large emotion differences across duration levels.	Sampling of 48 results in >95% power to detect a medium sized interaction effect ($\eta p^2 = .06$)	Two (emotion: fearful, neutral) by four (presentation duration: 100 msec, 200 msec, 300 msec, 1000 msec) repeated measure ANOVA for the N170 ROI (see methods). In case of a significant interaction, we calculate post-hoc comparisons between fearful and neutral faces for each duration.	Interaction of emotion and duration: This would indicate that presentation duration influence already stages of processing related to configural and structural face perception. In contrast to task demands, the exposure to a face allows a more elaborate sampling of face features, contributing to larger fearful-neutral differences.

Table 1 – (*continued*)

Question	Hypothesis	Sampling plan	Analysis Plan	Interpretation given different outcomes
Control analyses	We will control for possible interactions of emotion and presentation duration for the accuracy or reaction times. We will also carry out ANOVAs restricted to trials without gaze deviations from the fixation cross		Two (emotion: fearful, neutral) by four (presentation duration: 100 msec, 200 msec, 300 msec, 1000 msec) repeated measure ANCOVAs with accuracy or reaction time as a covariates. Two by four repeated measure ANOVAs limited to trials without gaze-deviations from the fixation cross	No interaction of emotion and duration when controlling for accuracy, reaction time, or eye-gaze behavior. If control analyses show that interactions become insignificant when including accuracy/reaction time as a covariate, or are insignificant when limiting trials only to those without gaze deviations, these differences in responding or gaze behavior could drive the observed ERP differences. While this would the cause of possible confounds, this would not question that differently used presentation durations lead to different ERP effects.

width (bizygomatic diameter) of 6.3 degrees of visual angle (deg) and a height of 8.3 deg. Faces were always displayed with an overlay of five horizontal or vertical thin lines within the boundaries of the face (horizontal lines 4.0 deg; vertical lines 5.2 deg; thickness .03 deg; centered around $x = .1$, $y = -.1$), which were overlaid to the faces during the presentation.

2.3. *Procedure*

The experiment was programmed and run with Matlab (Version R2019b; Mathworks Inc., Natick, MA; http://www.mathworks.com), the Psychophysics Toolbox (Version 3.0.15; Brainard, 1997; Kleiner, Brainard, & Pelli, 2007), and the Eyelink Toolbox (Cornelissen, Peters, & Palmer, 2002). Participants responded to a demographic questionnaire. Meanwhile, they were prepared for the EEG. The stimuli were presented on a Gamma-corrected display (Iiyama G-Master GB2488HSU), with a background displayed in medium grey (RGB 128, 128, 128) running at 60 Hz with a Michelson contrast of .9979 (L_{min} = .35 cd/m^2; L_{max} = 327.43 cd/m^2), while participants were seated 60 cm in front of the display. Participants always had to decide whether the lines above the stimuli were horizontal or vertical (see Fig. 1). The stimulus duration varied between blocks. We used eight different presentation orders, which were pseudo-randomized between participants (i.e., order will be A-B-C-D, D-A-B-C, C-D-A-B, B–C-D-A, D-C-B-A, A-D-C-B, B-A-D-C, C–B-A-D). The trial structure was the same in each block: First, a fixation cross was presented for 800–1000 msec. Then a face was shown for 100, 300, 1,000, or 2,000 msec followed by a fixation cross presented for 1,500 msec. Responses were recorded in this time window. Participants were instructed to respond by pushing either X or M (on a keyboard with QWERTZ-layout) for horizontal or vertical lines, using one finger of each hand. Response keys were counterbalanced between participants. Further, participants were instructed to reduce eye movements and movements during stimulus presentation as much as possible and constantly fixate the central fixation cross. Eye-gaze position was tracked using an eye tracker (see paragraph 2.5). Online evaluation of the gaze position was used to abort trials whenever the gaze fell out of a 3° radius around the fixation cross.[1] Moreover, participants were instructed to blink on the fixation cross and avoid blinking during stimulus presentation. Participants were instructed to respond as quickly and accurately as possible. Each face was shown in each presentation duration condition, leading to a total of 64 fearful and 64 neutral faces presented in each presentation duration, summing up to a total of 512 trials.

2.4. *EEG recording and preprocessing*

EEG data were recorded with a sampling rate of 512 Hz from 64 BioSemi active electrodes, which are aligned according to the 10–20 system. The Biosemi's Actiview software (www.biosemi.com) was used to record the EEG data. Biosemi uses two additional electrodes (CMS and DLR) as online references, while offline, the data were re-referenced to average reference. Further, four external eye-electrodes measured vertical and

[1] Initially, a 2° radius around the fixation cross was used but increased due to heavy trial losses and lengthened experimental procedures of the first six measured participants.

horizontal eye movements. EEG preprocessing was done using BESA (Ille, Berg, & Scherg, 2002). Eye movements and blinks were corrected using the automatic eye-artifact correction method implemented in BESA (Ille et al., 2002). Therefore, a predefined source model was applied to the data, combining three topographies accounting for EOG activities, consisting of horizontal and vertical eye movement and blinks (HEOG, VEOG, blink) with 12 regional sources modeling the different brain regions. A principal component analysis (PCA) was performed for segments where the correlation between data and artifact topography exceeded the HEOG (150 μV) or VEOG (250 μV) thresholds. All PCA components explaining more than the minimum variance were maintained. The recorded data was decomposed using all topographies into a linear combination of brain and artifact activities (Ille et al., 2002). EEG data were filtered offline with a low-cutoff filter of .01 (6 dB/oct) and a 40 Hz low-pass zero-phase filter (24 dB/oct). The remaining artifacts were rejected based on an absolute threshold (>120 μV), signal gradient (>75 μV/∂T), and low signal (i.e., the *SD* of the gradient, <.01 μV/∂T). Thereby, 50 percent of trials per condition had to be accepted, otherwise, the data-set was excluded. Noisy EEG sensors were interpolated using a spline interpolation procedure. Due to the delay of the LCD screen for stimulus presentation of 29 msec, measured with a photodiode, stimulus timing were corrected during epoching. Filtered data were segmented from 200 msec before stimulus onset until 1000 msec after stimulus presentation. A baseline correction was performed using inhouse Matlab functions and will subtract the average voltage of the 200 msec before stimulus onset from the epoch. Further, trials during which recording stopped due to gaze deviations and trials with incorrect responses were excluded from ERP analyses.

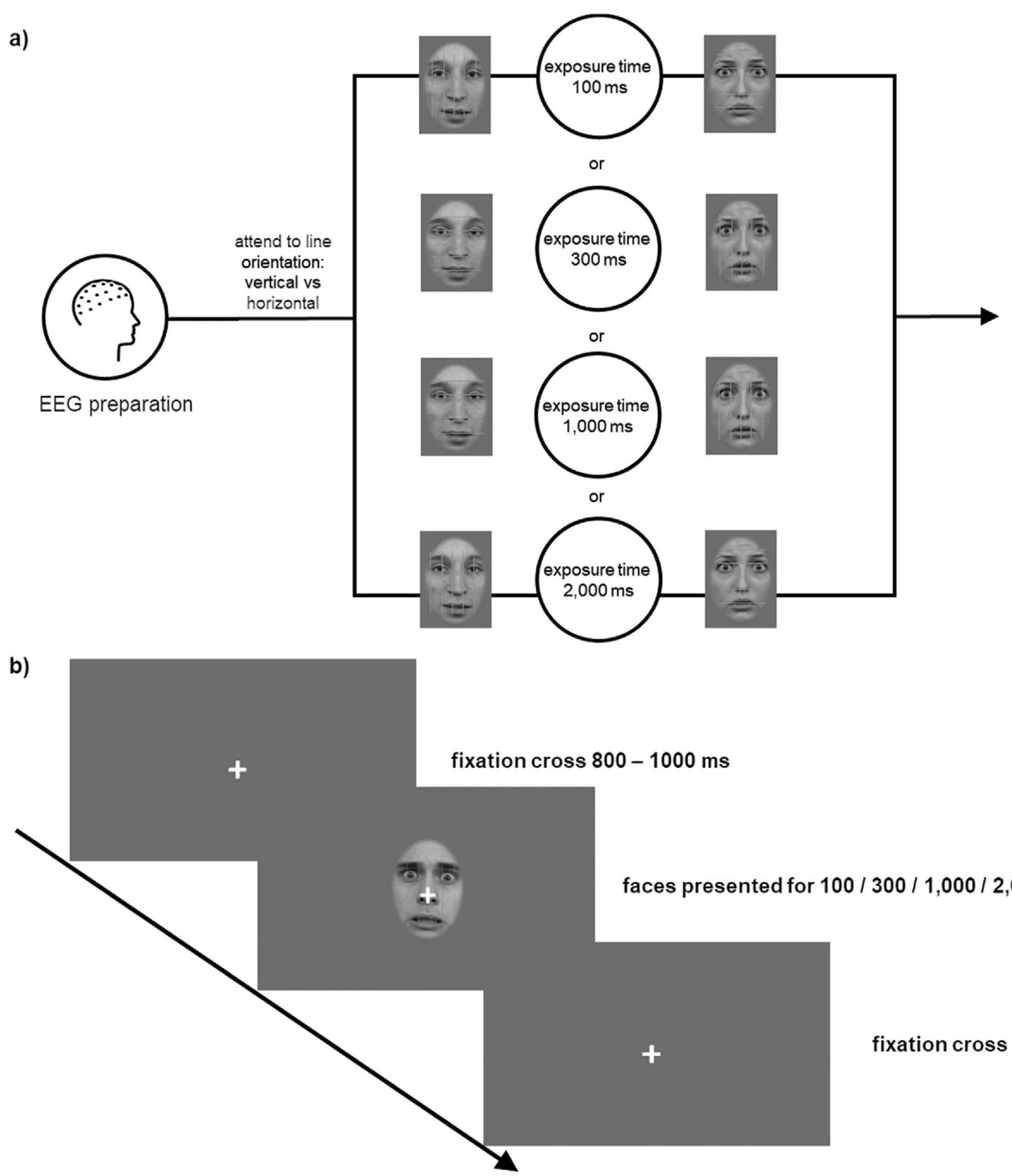

Fig. 1 — Schematic overview of a) the used four presentation durations and b) the attention task. Participants performed line orientation discrimination in four blocks with different face presentation durations. Line orientation were randomly overlaid to fearful and neutral facial expressions. Stimulus properties are manipulated to increase visibility.

2.5. Eye-tracking recording

We used an eye-tracker to explore differences in eye movement patterns for fearful and neutral faces. We used the Eyelink 1000 eye-tracker from SR research to track eye-gaze behavior (EyeLink 1000, SR Research Ltd., Mississauga, Canada). Participants were asked to place their heads on a chin rest, and the right eye was recorded. Recording sampling rate was 1000 Hz. Before each presentation duration block, an eye-tracker calibration procedure was automatically initiated using a nine-point calibration procedure. Gaze position was tracked continuously during the experiment and online evaluated, stopping experimental presentation whenever the gaze deviated more than 3° at a radius around the fixation mark. These trials were discarded from further analyses.

2.6. Data analyses

2.6.1. Main analyses

We examined interactions of emotion and presentation duration for the EPN and LPP components. To this end, we used two (emotion: fearful, neutral) by four (presentation duration: 100 msec, 300 msec, 1000 msec, 2000 msec) repeated measure ANOVAs. Statistical analyses for ERP and behavioral data will be done using JASP (Love et al., 2019). JASP is an open-source statistic software based on the programming languages R and C++. JASP allows calculations of frequentist and Bayesian statistics (Love et al., 2019). The effect size were indicated by using Partial eta-squared (η_P^2) and Cohen's *d*. Greenhouse-Geisser correction of degrees of freedom were done when a violation of Mauchly's test of Sphericity was detected. We calculated post-hoc comparisons between fearful and neutral faces for each duration for significant interaction effects using the Bonferroni-Holm correction. Further, simple contrasts for differences tested the expected increase of fearful-neutral differences. We identified the time windows and electrodes by visually inspecting the collapsed ERPs of the pilot data (see Luck & Gaspelin, 2017) and on previous studies using similar tasks and stimuli (e.g., see Schindler, Bruchmann, et al., 2020). To this end, using the pilot data, we collapsed ERPs across all fearful compared to all neutral faces to identify the EPN and LPP components. According to this identification approach based on the pilot data, time windows were segmented from 200 to 350 msec to investigate EPN effects and from 400 to 1000 msec to investigate LPP effects. The analysis used the average amplitudes across all sensors over the full-time windows. We measured the EPN component from a symmetrical occipital cluster (P9, P7, PO7, O1, P10, P8, PO8, O2) and the LPP component from a centro-parietal cluster (CP3, CP1, CPz, CP2, CP4, P3, P1, Pz, P2, P4). For ERPs, we displayed confidence intervals generated via the bootstrap method (Efron & Tibshirani, 1994). To this end, for N subjects, ERPs were calculated, resulting in an N-by-T (time points) matrix. Randomly drawing N times with replacement, a new N-by-T matrix were generated. The matrix was then averaged across the subject dimension. This procedure was repeated 1000 times, resulting in a 1000-by-T matrix. For each sample, the 2.5- and 97.5-percentile was calculated, resulting in a 95% confidence interval around the mean ERP. The same procedure were applied to differential ERPs, i.e., the initial N-by-T matrix consists of fearful−neutral difference ERPs.

2.6.2. Secondary analyses

We examined emotion and presentation duration interactions for the N170 component using the above-described repeated measure ANOVAs. Based on the pilot data, we identified the N170 time windows and electrodes by visual inspection of the collapsed ERPs across all conditions. We segmented time windows from 120 to 170 msec and averaged from a symmetrical occipital cluster (P9, P7, PO7, P10, P8, PO8).

2.6.3. Control analyses

For behavioral data, the accuracy and reaction times were examined as control variables. We considered correct responses during trials with reaction times between 200 and 1,500 msec. We tested for significant interactions in accuracy or reaction times between presentation duration and emotion. Given that there no significant interactions were observed, we did not perform Analyses of Covariance (ANCOVAs) with reaction times, or accuracy, as a covariate. We tested if the average absolute activity of the HEOG and VEOG channels differs between conditions using above-described repeated measure ANOVAs.

2.6.4. Explorative analyses

Finally, we explored if separate different subcomponents of the late positivity can be separated by using an Independent Component Analysis (ICA) at the group level. To this end, we used the group ICA toolbox EEGIFT (V1.0; Eichele, Rachakonda, Brakedal, Eikeland, & Calhoun, 2011). For this purpose, single-trial data were sorted by experimental condition for each subject. A principal component analysis (PCA) was applied first to reduce the data to 20 components, as the top 20 components were suggested to typically explain more than 95% of the variance (Eichele et al., 2011). Then ICA was performed using the Infomax algorithm and the default settings as implemented in EEGIFT. From the resulting 20 components, we selected two components by visual inspection, given that we typically observe a clear differentiation between noisy and clean components. We uploaded all component identification results to the OSF framework. For each of these components and for each duration, we compared fearful and neutral conditions using cluster-based permutation tests (Maris & Oostenveld, 2007) using the complete post-stimulus interval and correcting for multiple testing.

Further, we performed unregistered exploratory post-hoc comparisons for each duration for the examined ERPs and ICs. All recorded data, paradigm, and participant information were uploaded to the Open Science Framework project (https://osf.io/ax297/).

3. Results

3.1. Main ERP results

A main effect of emotion was found for the EPN ($F_{(1,47)} = 8.493$, $p = .005$ $\eta_P^2 = .153$) with greater amplitudes for fearful than neutral faces (see Fig. 2). The interaction of emotion and presentation duration was insignificant ($F_{(3,\ 141)} = .854$, $p = .467$, $\eta_P^2 = .018$).

Unregistered exploratory tests showed that EPN effects were absent during the presentation durations of 100 msec ($t_{(47)} = -.63$, $p = .534$), 300 msec ($t_{(47)} = -1.36$, $p = .181$) or 1000 msec ($t_{(47)} = -.54$, $p = .593$), but present during the long presentation duration of 2000 msec ($t_{(47)} = -2.95$, $p = .005$).

For the LPP a main effect of emotion was observed ($F_{(1,47)} = 7.322$, $p = .009$, $\eta_P^2 = .135$). Here, fearful faces showed a higher positivity than neutral faces (see Fig. 3). The interaction of emotion and presentation duration was insignificant ($F_{(3,141)} = .758$, $p = .520$, $\eta_P^2 = .016$).

Unregistered exploratory tests showed that LPP effects were absent during the brief presentation durations of 100 msec ($t_{(47)} = .90$, $p = .371$) and 300 msec ($t_{(47)} = .34$, $p = .737$), but present for the long durations of 1000 msec ($t_{(47)} = 2.49$, $p = .016$) and 2000 msec ($t_{(47)} = 2.40$, $p = .022$).

3.2. *Secondary ERP results*

A main effect of emotion was found for the N170 ($F_{(1,47)} = 44.309$, $p < .001$, $\eta_P^2 = .485$) with higher negativity for fearful than neutral faces (see Fig. 4). The interaction between emotion and duration was insignificant ($F_{(3,\ 141)} = .148$, $p = .931$, $\eta_P^2 = .003$).

Unregistered exploratory tests showed that N170 effects were present during all durations: For the 100 msec ($t_{(47)} = -3.09$, $p = .003$), 300 msec ($t_{(47)} = -3.61$, $p < .001$), 1000 msec ($t_{(47)} = -2.97$, $p = .005$), and 2000 msec duration ($t_{(47)} = -3.35$, $p = .002$).

3.3. *Planned explorative tests: group ICA results for different subcomponents of the late positive potential*

The group ICA algorithm relies on complete data sets, and for four participants, ICA failed since recordings were split or single trials were missed due to eye-tracking recalibration throughout the course of the experiment. Therefore, we performed a group ICA for 44 participants. We identified 2 ICs with very distinct time courses and topographies that reflected the late positivity component of interest (see Fig. 5). IC 5 showed a remarkably stable positivity over trials from approximately 300 to 600 msec. IC 17 showed a more variable positivity from 600 to 900 msec. All other ICs were characterized by markedly worse signal-to-noise ratios and topographies without discernible positive or negative poles. For IC 5, no main effect of emotion was observed ($F_{(1,43)} = .58$, $p = .450$, $\eta_P^2 = .013$). The interaction of emotion and presentation duration was significant ($F_{(3,129)} = 3.59$, $p = .015$, $\eta_P^2 = .077$). Post-hoc comparisons showed a larger positivity for fearful faces for the 100 msec presentation duration condition ($t = 2.16$, $p = .036$, Cohen's $d = .326$), while in the other presentation durations, no emotion effect occurred ($ts < 1.50$, $ps > .140$; see Fig. 5). For IC 17, a main effect of

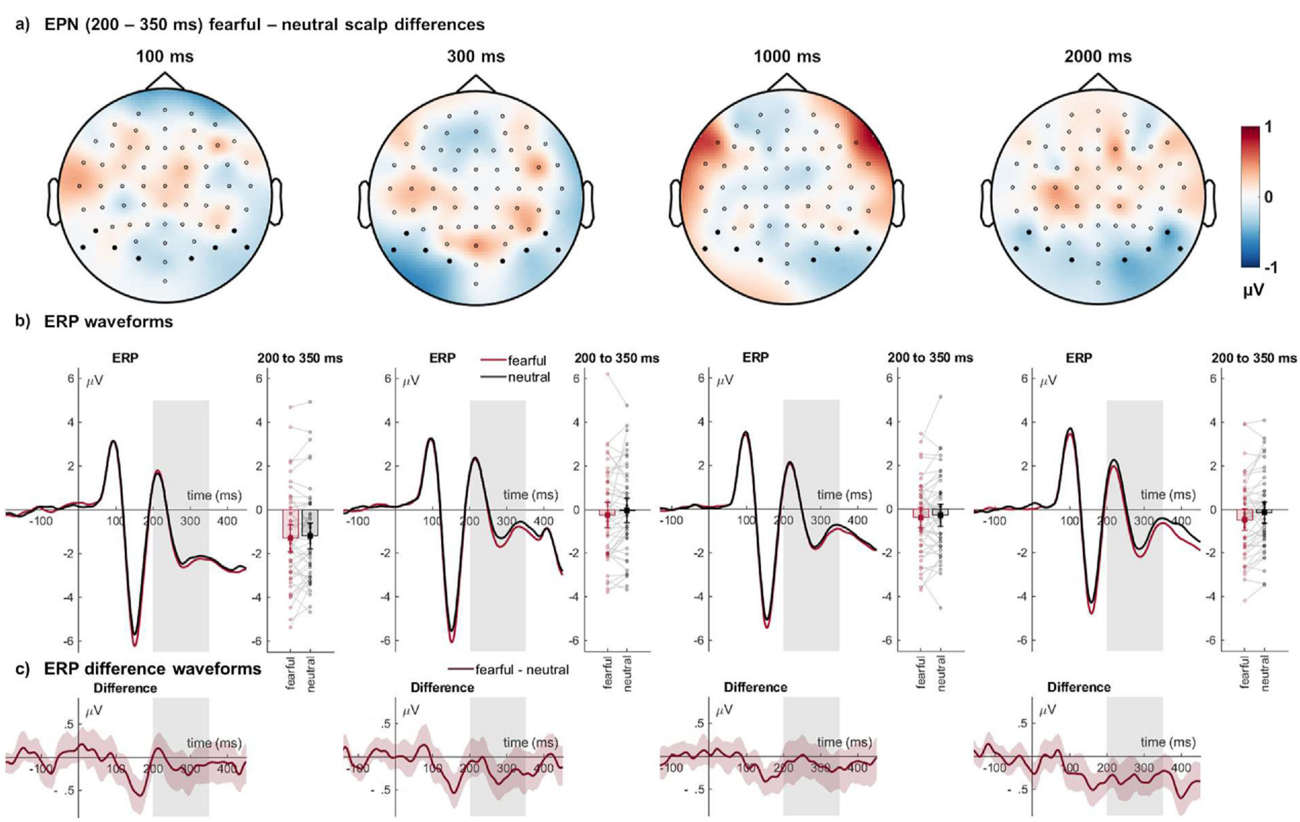

Fig. 2 — Effect of presentation duration on emotion differences for the EPN. a) Scalp topographies depict the differences between fearful and neutral faces. b) ERP waveforms show the time course over highlighted left and right sensors. Bar plots display the mean microvolt value for the highlighted interval. Error bars show 95% confidence intervals of the mean. c) Respective difference plots contain 95% bootstrap confidence intervals of intra-individual differences.

emotion was observed ($F_{(1,43)} = 4.611$, $p = .037$, $\eta_P^2 = .097$). Here, fearful faces showed a higher positivity than neutral faces (see Fig. 5). The interaction of emotion and presentation duration was insignificant ($F_{(3,129)} = .85$, $p = .472$, $\eta_P^2 = .019$). Exploratory post-hoc tests showed a similar pattern as observed during the LPP. For the 100 msec duration ($t_{(43)} = .33$, $p = .746$), the 300 msec duration ($t_{(43)} = .80$, $p = .429$), and the 1000 msec duration ($t_{(43)} = 1.56$, $p = .126$), no differences were observed, while an increased positivity for fearful faces was observed for the duration of 2000 msec ($t_{(43)} = 2.35$, $p = .023$).

3.4. *Behavioural results*

Neither a main effect of emotion ($F_{(1,47)} = .033$, $p = .857$, $\eta_P^2 = .001$), nor an interaction of presentation duration and emotion ($F_{(2.438,\ 114.571)} = 2.259$, $p = .098$, $\eta_P^2 = .046$) occurred for the accuracy (see Table 2). Regarding reaction times, no main effect of emotion ($F_{(1,47)} = .607$, $p = .440$, $\eta_P^2 = .013$) and no interaction was found ($F_{(2.037,\ 95.724)} = .301$, $p = .745$, $\eta_P^2 = .006$).

3.5. *Control analyses*

Control analyses tested differences between conditions for horizontal or vertical eye-related activity. There were no significant effects of emotion, duration, and no interaction between emotion and duration for all examined time windows for ERPs of interest (see Table 3).

4. Discussion

In this registered report, we investigated the influence of the presentation duration on emotional differences during a perceptual distraction task. We presented fearful and neutral faces with four commonly used presentation durations, while participants were instructed to respond to overlying lines only. In addition, we used an eye tracker to ensure that participants fixated on the center of the face. We expected an influence of the presentation duration on EPN and LPP differences, namely, that longer exposure time would lead to larger fearful-neutral differentiation.

Our registered analyses showed main effects of emotion for the EPN and LPP components, yet no significant interaction between duration and emotion occurred. The overall accuracy was very high, showing that participants were able to perform the task as requested. Our results align with theories that argue emotional processing is automatic and independent of available processing resources (Vuilleumier & Huang, 2009). This assumption is supported by studies with presentation durations from 300 msec to 2,000 msec, which found emotional modulation of mid-latency (EPN) and late (LPP) ERPs even when attention was directed to a different perceptual or working memory task (Durston & Itier, 2021; Frühholz, Jellinghaus, & Herrmann, 2011b; MacNamara et al., 2012; Valdés-Conroy et al., 2014; Wu et al., 2019). However, our ERP findings are in contrast to our expectations based on recent findings, showing

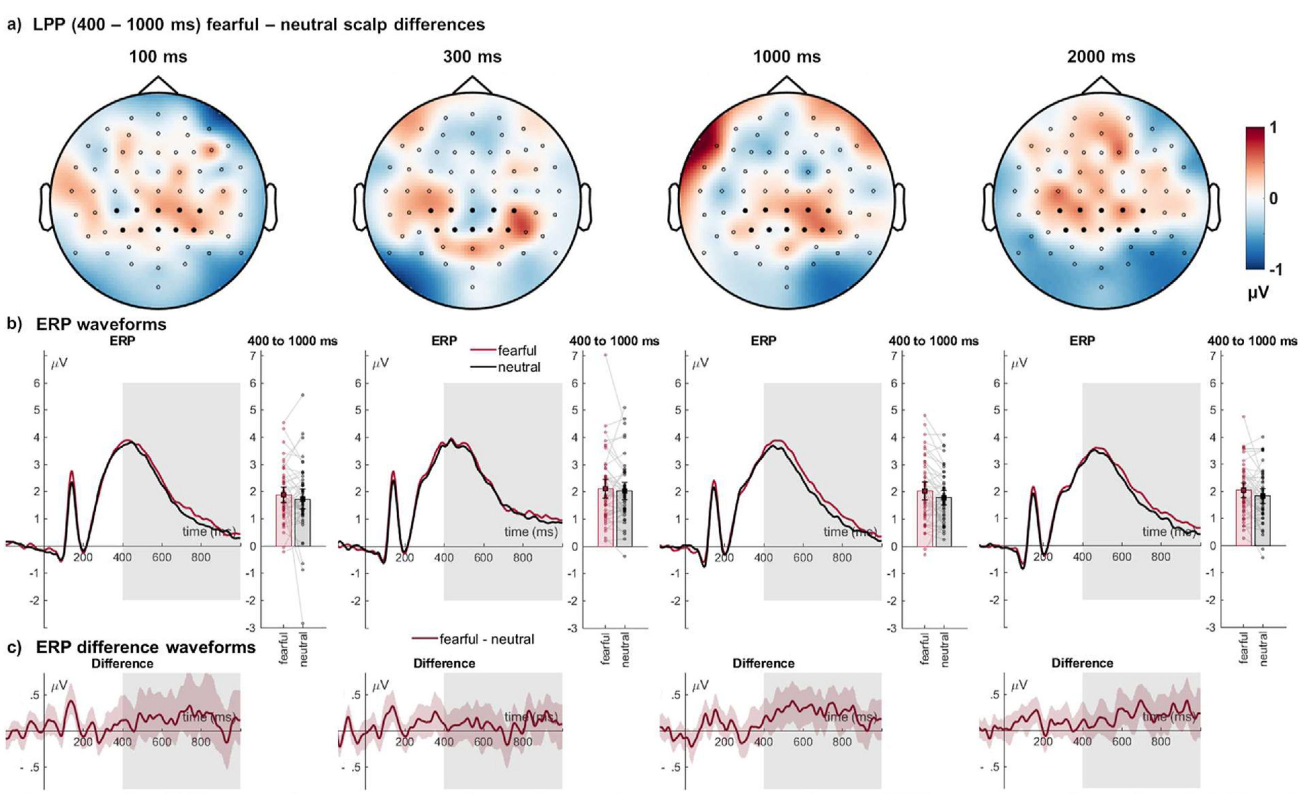

Fig. 3 – Effect of presentation duration on emotion differences for the LPP. a) Scalp topographies depict the differences between fearful and neutral faces. b) ERP waveforms show the time course over highlighted sensors. Bar plots display the mean microvolt value for the highlighted interval. Error bars show 95% confidence intervals of the mean. c) Respective difference plots contain 95% bootstrap confidence intervals of intra-individual differences.

an absence of emotional modulations of the EPN and LPP components under distraction with presentation durations varying between 50 and 100 msec (Schindler, Bruchmann, et al., 2020; Schindler et al., 2021; Schindler, Caldarone, et al., 2020; Schindler et al., 2021). These previous studies follow theoretical accounts which argue that emotional stimuli have a processing advantage but depend on available attentional resources (Pessoa, 2009). Because of these contrary findings, we suggested presentation duration to be a relevant factor in explaining the absence or presence of emotion effects under distraction. Since emotional stimuli are known to modulate attention (Frischen, Eastwood, & Smilek, 2008; Öhman, Flykt, & Esteves, 2001) it was expected that an interaction of emotion and presentation duration in the EPN and the LPP leading to enhanced amplitudes for fearful faces only when presentation duration was extended to 1,000 msec and 2,000 msec, allowing participants to process emotional information while completing the perceptual task. To this end, we performed unregistered exploratory post-hoc comparisons for each presentation duration separately. These tests showed that during shorter durations, no significant differences between fearful faces and neutral faces were observed (100, 300, and 1000 msec for the EPN; 100 and 300 msec for the LPP), but during long stimulus intervals, significant differences were seen.

Thus, our explorative data may suggest that, indeed, shorter presentation times lead to a lower probability of significant emotion effects in accordance with the hypothesis. Both, lower perception and inhibition of distracting information might explain this outcome. On the one hand, longer presentation durations enhance the ability to perceive irrelevant information. On the other hand, this may also lead to a collapse of inhibitory processes (e.g., due to ironic processes, see Wegner, 1994). The relative frontal positivity in the 1,000 msec duration condition might show (unsuccessful) inhibitory attempts (see Schindler & Kissler, 2018), while this is less pronounced in the 2,000 msec condition (see Figs. 2–3). This weak threshold effect, however, does not lead to a significant interaction. Thus, our sample size and the within-subject design might be unsuited to reveal statistically relevant interactions between presentation duration and emotion effects. Future studies have to test this assumption and confirm whether differences between duration conditions remain insignificant and if absent and present effects depend on duration conditions. Future studies might further investigate differences between analytic strategies.

The insignificant interaction effects might also be explained by some design changes from the initial pilot data, on which power analyses were based. We used eye-tracking gaze control to avoid differences in gaze exploration behavior. Gaze control might have had a strong impact, as gaze deviations stopped the experiment and recalibration procedures, leading to longer testing times. Trials with gaze deviations were rejected, which led to a rather high trial rejection rate (28 percent) and fewer trial numbers per

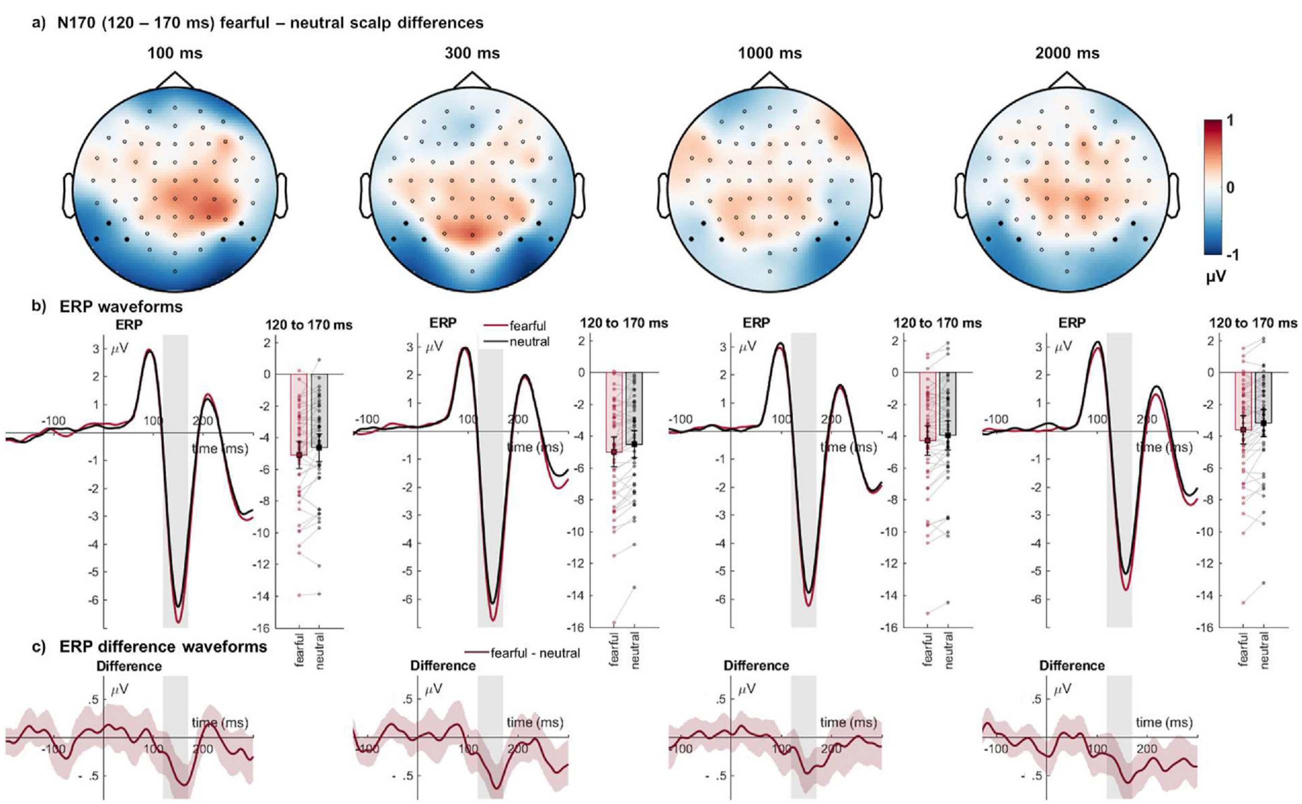

Fig. 4 – Effect of presentation duration on emotion differences for the N170. a) Scalp topographies depict the differences between fearful and neutral faces. b) ERP waveforms show the time course over highlighted left and right sensors. Bar plots display the mean microvolt value for the highlighted interval. Error bars show 95% confidence intervals of the mean. c) Respective difference plots contain 95% bootstrap confidence intervals of intra-individual differences.

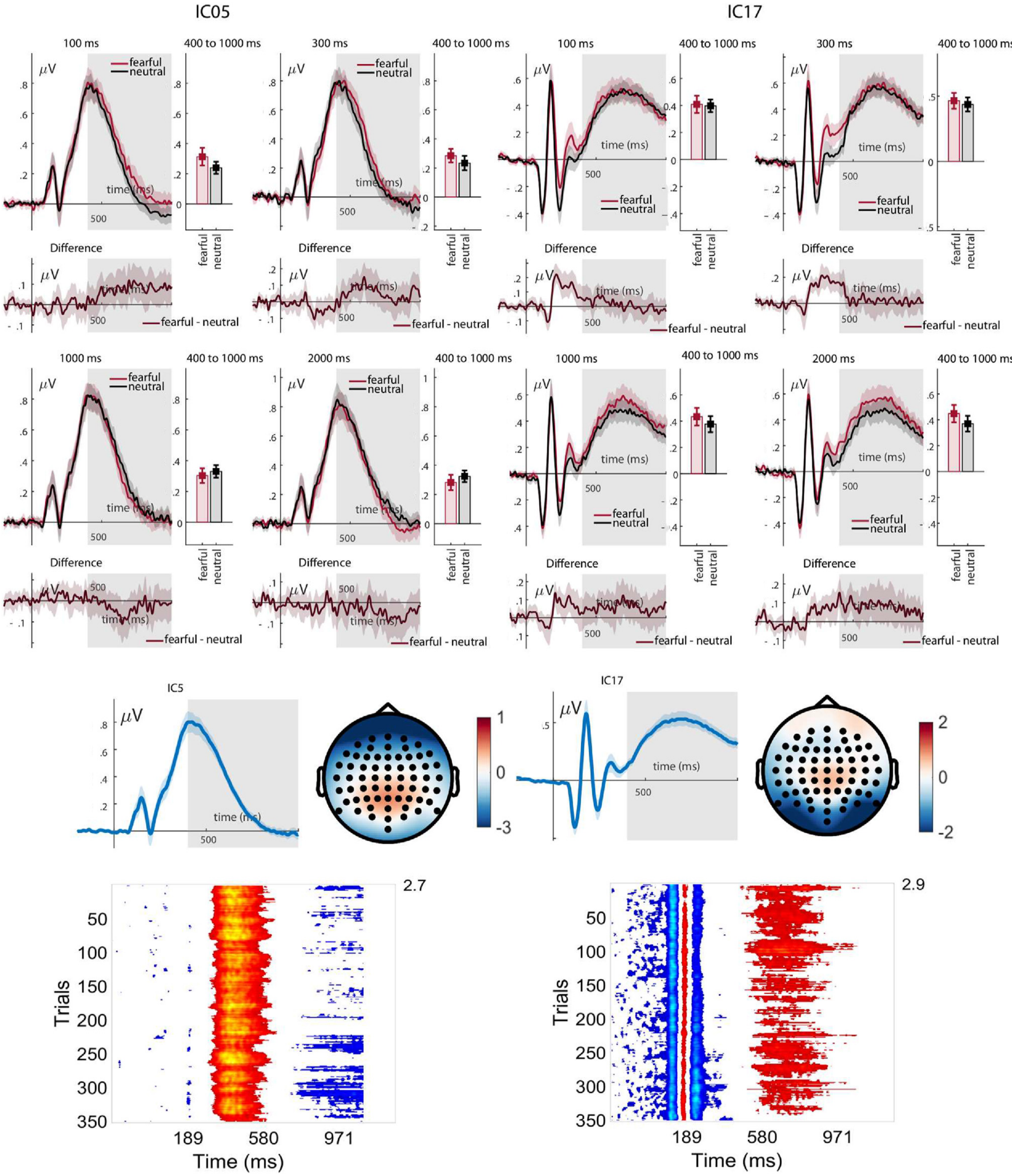

Fig. 5 – Results of the Independent Component Analysis, showing for IC 5 and IC 17 the effects of emotion and the interaction between emotion and presentation duration. Scalp topographies depict the grand average of each IC. ERP waveforms show the time course. Shaded intervals around waveforms display 95% confidence intervals around means. Bar plots display the mean microvolt value for the highlighted interval. Error bars show 95% confidence intervals of the mean. Respective difference plots contain 95% bootstrap confidence intervals of intra-individual differences.

Table 2 – Accuracy and reaction time for all presentation duration conditions.

	duration 100 msec		duration 300 msec		duration 1000 msec		duration 2000 msec	
	fearful	neutral	Fearful	neutral	fearful	neutral	fearful	neutral
accuracy in percent (*SD*)	95.6 *(4.5)*	94.9 *(4.9)*	95 *(6.3)*	95.8 *(4.4)*	97.9 *(2)*	97.5 *(2.5)*	98.1 *(2.9)*	98.6 *(1.6)*
reaction time in msec (*SD*)	552 *(82)*	552 *(86)*	562 *(101)*	562 *(101)*	601 *(69)*	601 *(81)*	653 *(95)*	649 *(94)*

Notes. Hits are displayed in percent correct. Reaction times are rounded to milliseconds. Standard deviations are presented below means in brackets and italic. For each presentation duration condition, line discrimination accuracy and reaction time is displayed per emotional expression.

Table 3 – Results from 2 × 4 repeated measures ANOVAs for HEOG and VEOG activity.

ERP component	Effect	ANOVA Results			
		DF	F	*p*	η_P^2
N170 HEOG	emotion	1, 47	1.73	.195	.035
	duration	2, 141	.32	.808	.007
	emotion x duration	2, 141	1.41	.244	.029
N170 VEOG	emotion	1, 47	.03	.874	.001
	duration	2, 141	.35	.789	.007
	emotion x duration	2, 141	2.08	.105	.043
EPN HEOG	emotion	1, 47	.72	.400	.015
	duration	2, 141	.30	.826	.006
	emotion x duration	2, 141	.50	.686	.010
EPN VEOG	emotion	1, 47	.15	.701	.003
	duration	2, 141	.46	.714	.010
	emotion x duration	2, 141	1.42	.238	.029
LPP HEOG	emotion	1, 47	.24	.629	.004
	duration	2, 141	.45	.719	.009
	emotion x duration	2, 141	.21	.889	.004
LPP VEOG	emotion	1, 47	.31	.582	.007
	duration	2, 141	.13	.942	.003
	emotion x duration	2, 141	1.92	.129	.039

participant, and therefore, most excluded participants were excluded due to the trial number criteria. These changes made to the design were intended to avoid confounding and contamination of our ERP data. The use of online gaze control was important to prevent differences in gaze behavior (i.e., more exploration of more salient fearful faces), particularly when faces were presented for longer durations. Indeed, registered control analyses confirmed that horizontal and vertical EOG activity did not differ between duration and emotion conditions. Therefore, slight differences in exploration behavior between conditions during the longer presentation durations might have led to bigger differences in our pilot sample. To our knowledge, only a few studies that examine emotional face processing report measures of participants' gaze behavior and/or try to control or prevent differences between conditions.

We also explored whether different late positivities could be separated from each other by means of a group ICA. Indeed, two components with a stable late positive signature over parietal regions could be identified. An earlier IC (IC 5) showed a remarkably stable positivity over trials from approximately 300 to 600 msec. This IC could relate to a parietal P3 and index the detection and response to the target face. A significant interaction also showed a significantly larger positivity for fearful faces during the shortest duration (100 msec). This might be an advantage in detecting and/or processing fearful expressions during short stimulus exposure. Nevertheless, this did not transfer into a reaction time advantage for these faces. IC 17 showed a more variable positivity from 600 to 900 msec. This seems in line with ideas about the late positive potential relation to controlled attentional processes and stimulus evaluation (Hajcak, Dunning, & Foti, 2009a; Schupp, Flaisch, Stockburger, & Junghofer, 2006), particularly when the appraisal of affective meaning is involved (Schupp, Flaisch, Stockburger, & Junghofer, 2006; Wessing, Rehbein, Postert, Fürniss, & Junghöfer, 2013). This advantage for emotional visual stimuli has been repeatedly observed (e.g., see reviews from Compton, 2003; Schindler & Bublatzky, 2020; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). The higher variability of IC 17 compared to IC 5 might reflect trial-by-trial differences in the activation of occipito-parietal regions, subcortical areas, and fronto-parietal attention networks, which are suggested to contribute to LPP effects (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012; Pourtois, Schettino, & Vuilleumier, 2013; Sabatinelli, Lang, Keil, & Bradley, 2007, 2014). Of note, similar to the main LPP findings, for IC 17, fearful-neutral differences increased descriptively with increasing presentation duration, and separate *t*-tests per duration conditions showed a similar pattern of absent differences during the presentation durations.

Finally, we replicated the frequently observed increased N170 for emotional facial expressions independent of distracting tasks (Schindler & Bublatzky, 2020). For instance, a meta-analysis showed emotional modulation of the N170 in direct and indirect tasks that might reflect a highly automatic encoding of emotional expressions (Hinojosa et al., 2015). This enhancement of the N170 for emotional expression might be due to perceptual differences between emotional and neutral facial expressions. However, increased N170 amplitudes have been observed for neutral faces associated with negative information, suggesting that at least some emotional association is processed during the N170 stage (Baum & Abdel Rahman, 2021; Schindler et al., 2021). Explorative tests showed larger N170 amplitudes for fearful than neutral expressions in all duration conditions. This is in line with the relative insensitivity of the N170 emotion differentiation to a variety of tasks, stimulus modifications, or attention manipulations (Schindler et al., 2021; Schindler, Bruchmann, Bublatzky, & Straube, 2019, 2022).

Some limitations have to be mentioned. We controlled for task difficulty by having a task that could be solved easily. However, only one specific task was used, so we could not test whether greater task difficulty would prevent emotion effects.

Also, task-relevant and irrelevant information was presented simultaneously at the same location. Differences in the face-distractor temporal or spatial onset relative to the task-relevant stimuli might lead to smaller or absent EPN or LPP effects. Further, repetition effects were reduced but could not be fully excluded since each face was presented four times in the experiment. However, we counterbalanced the order of presentation duration, and therefore, this is highly unlikely to influence the results systematically.

In summary, we observed main effects of emotion for the EPN and LPP, but no interactions of emotion with the duration of presented faces. These findings suggest that the duration of the presented face stimulus is not a major factor explaining the variability of reported emotion effects in perceptual distraction tasks, at least for the given experimental and analytical setup and when eye-gaze is strictly controlled.

Author contributions

All authors contributed to the study design. LM and RV piloted the experiment. RV, MB, and SS analyzed the data. RV and SS visualized the data. RV wrote and revised the manuscript under the supervision of SS. All authors read and approved the final version.

Open practices

The study in this article earned Open Data, Open Materials and Preregistered badges for transparent practices. Data and Materials for the study are available at: https://osf.io/ax297.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cortex.2022.12.011.

REFERENCES

Bar-Haim, Y., Lamy, D., & Glickman, S. (2005). Attentional bias in anxiety: A behavioral and ERP study. *Brain and Cognition, 59*(1), 11–22. https://doi.org/10.1016/j.bandc.2005.03.005

Baum, J., & Abdel Rahman, R. (2021). Negative news dominates fast and slow brain responses and social judgments even after source credibility evaluation. *Neuroimage, 244*, Article 118572. https://doi.org/10.1016/j.neuroimage.2021.118572

Brainard, D. H. (1997). The Psychophysics toolbox. *Spatial Vision, 10*(4), 433–436.

Breiter, H. C., Etcoff, N. L., Whalen, P. J., Kennedy, W. A., Rauch, S. L., Buckner, R. L., et al. (1996). Response and habituation of the human amygdala during visual processing of facial expression. *Neuron, 17*(5), 875–887. https://doi.org/10.1016/S0896-6273(00)80219-6

Brosch, T., & Wieser, M. J. (2011). The (Non)Automaticity of amygdala responses to threat: On the issue of fast signals and slow measures. *Journal of Neuroscience, 31*(41), 14451–14452. https://doi.org/10.1523/JNEUROSCI.4089-11.2011

Carretié, L. (2014). Exogenous (automatic) attention to emotional stimuli: A review. *Cognitive, Affective & Behavioral Neuroscience, 14*(4), 1228–1258. https://doi.org/10.3758/s13415-014-0270-2

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30*(2), 203–216. https://doi.org/10.1016/j.cpr.2009.11.003

Compton, R. J. (2003). The interface between emotion and attention: A review of evidence from psychology and neuroscience. *Behavioral and Cognitive Neuroscience Reviews, 2*(2), 115–129. https://doi.org/10.1177/1534582303002002003

Cornelissen, F. W., Peters, E. M., & Palmer, J. (2002). The Eyelink toolbox: Eye tracking with MATLAB and the Psychophysics toolbox. *Behavior Research Methods, Instruments, & Computers, 34*(4), 613–617. https://doi.org/10.3758/BF03195489

Durston, A. J., & Itier, R. J. (2021). The early processing of fearful and happy facial expressions is independent of task demands – support from mass univariate analyses. *Brain Research, 1765*, Article 147505. https://doi.org/10.1016/j.brainres.2021.147505

Efron, B., & Tibshirani, R. J. (1994). *An introduction to the bootstrap*. CRC Press.

Eichele, T., Rachakonda, S., Brakedal, B., Eikeland, R., & Calhoun, V. D. (2011). Eegift: Group independent component analysis for event-related EEG data. *Computational Intelligence and Neuroscience*. , Article 129365. https://doi.org/10.1155/2011/129365, 2011.

Eimer, M. (2011). The face-sensitive N170 component of the event-related brain potential. In G. Rhodes, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 329–344). USA: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199559053.013.0017.

Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. *Neuropsychologia, 45*(1), 15–31. https://doi.org/10.1016/j.neuropsychologia.2006.04.022

Eimer, M., & Kiss, M. (2007). Attentional capture by task-irrelevant fearful faces is revealed by the N2pc component. *Biological Psychology, 74*(1), 108–112. https://doi.org/10.1016/j.biopsycho.2006.06.008

Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological Bulletin, 134*(5), 662–676. https://doi.org/10.1037/0033-2909.134.5.662

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), 1–13. https://doi.org/10.1016/j.ijpsycho.2009.05.010

Frühholz, S., Jellinghaus, A., & Herrmann, M. (2011a). Time course of implicit processing and explicit processing of emotional faces and emotional words. *Biological Psychology, 87*(2), 265–274. https://doi.org/10.1016/j.biopsycho.2011.03.008

Frühholz, S., Jellinghaus, A., & Herrmann, M. (2011b). Time course of implicit processing and explicit processing of emotional faces and emotional words. *Biological Psychology, 87*(2), 265–274. https://doi.org/10.1016/j.biopsycho.2011.03.008

Guex, R., Méndez-Bértolo, C., Moratti, S., Strange, B. A., Spinelli, L., Murray, R. J., et al. (2020). Temporal dynamics of amygdala response to emotion- and action-relevance. *Scientific Reports, 10*(1), Article 11138. https://doi.org/10.1038/s41598-020-67862-1

Hajcak, G., Dunning, J. P., & Foti, D. (2009a). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology, 120*(3), 505–510. https://doi.org/10.1016/j.clinph.2008.11.028

Hajcak, G., Dunning, J. P., & Foti, D. (2009b). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology, 120*(3), 505—510. https://doi.org/10.1016/j.clinph.2008.11.028

Hinojosa, J. A., Mercado, F., & Carretié, L. (2015). N170 sensitivity to facial expression: A meta-analysis. *Neuroscience and Biobehavioral Reviews, 55*, 498—509. https://doi.org/10.1016/j.neubiorev.2015.06.002

Hudson, A., Durston, A. J., McCrackin, S. D., & Itier, R. J. (2021). Emotion, gender and gaze discrimination tasks do not differentially impact the neural processing of angry or happy facial expressions—a mass univariate ERP analysis. *Brain Topography*. https://doi.org/10.1007/s10548-021-00873-x

Ille, N., Berg, P., & Scherg, M. (2002). Artifact correction of the ongoing EEG using spatial filters based on artifact and brain signal topographies. *Journal of Clinical Neurophysiology, 19*(2), 113—124.

Ishai, A., Pessoa, L., Bikle, P. C., & Ungerleider, L. G. (2004). Repetition suppression of faces is modulated by emotion. *Proceedings of the National Academy of Sciences, 101*(26), 9827—9832. https://doi.org/10.1073/pnas.0403559101

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. https://doi.org/10.1016/j.brainres.2017.03.013

Itz, M. L., Golle, J., Luttmann, S., Schweinberger, S. R., & Kaufmann, J. M. (2017). Dominance of texture over shape in facial identity processing is modulated by individual abilities. *British Journal of Psychology, 108*(2), 369—396.

Junghöfer, M., Bradley, M. M., Elbert, T. R., & Lang, P. J. (2001). Fleeting images: A new look at early emotion discrimination. *Psychophysiology, 38*(2), 175—178. https://doi.org/10.1111/1469-8986.3820175

Kleiner, M., Brainard, D. H., & Pelli, D. G. (2007). What's new in Psychtoolbox-3? *Perception, 36*, 14.

Koivisto, M., & Revonsuo, A. (2010). Event-related brain potential correlates of visual awareness. *Neuroscience and Biobehavioral Reviews, 34*(6), 922—934. https://doi.org/10.1016/j.neubiorev.2009.12.002

Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences, 9*(2), 75—82. https://doi.org/10.1016/j.tics.2004.12.004

Lavie, N., Beck, D. M., & Konstantinou, N. (2014). Blinded by the load: Attention, awareness and the role of perceptual load. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*(1641), Article 20130205. https://doi.org/10.1098/rstb.2013.0205

Lim, S.-L., Padmala, S., & Pessoa, L. (2008). Affective learning modulates spatial competition during low-load attentional conditions. *Neuropsychologia, 46*(5), 1267—1278. https://doi.org/10.1016/j.neuropsychologia.2007.12.003

Liu, Y., Huang, H., McGinnis-Deweese, M., Keil, A., & Ding, M. (2012). Neural substrate of the late positive potential in emotional processing. *The Journal of Neuroscience, 32*(42), 14563—14572. https://doi.org/10.1523/JNEUROSCI.3109-12.2012

Love, J., Selker, R., Marsman, M., Jamil, T., Dropmann, D., Verhagen, J., et al. (2019). Jasp: Graphical statistical software for common statistical designs. *Journal of Statistical Software, 88*(2), 1—17. https://doi.org/10.18637/jss.v088.i02

Luck, S. J., & Gaspelin, N. (2017). How to get statistically significant effects in any ERP experiment (and why you shouldn't). *Psychophysiology, 54*(1), 146—157. https://doi.org/10.1111/psyp.12639

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*(3), 349—356. https://doi.org/10.1016/j.biopsycho.2012.08.005

Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods, 164*(1), 177—190. https://doi.org/10.1016/j.jneumeth.2007.03.024

Müller-Bardorff, M., Schulz, C., Peterburs, J., Bruchmann, M., Mothes-Lasch, M., Miltner, W., et al. (2016). Effects of emotional intensity under perceptual load: An event-related potentials (ERPs) study. *Biological Psychology, 117*, 141—149. https://doi.org/10.1016/j.biopsycho.2016.03.006

Neath-Tavares, K. N., & Itier, R. J. (2016). Neural processing of fearful and happy facial expressions during emotion-relevant and emotion-irrelevant tasks: A fixation-to-feature approach. *Biological Psychology, 119*, 122—140. https://doi.org/10.1016/j.biopsycho.2016.07.013

Nobre, A. C., & van Ede, F. (2018). Anticipated moments: Temporal structure in attention. *Nature Reviews Neuroscience, 19*(1), 34—48. https://doi.org/10.1038/nrn.2017.141

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology. General, 130*(3), 466—478. https://doi.org/10.1037/0096-3445.130.3.466

Pegna, A. J., Landis, T., & Khateb, A. (2008). Electrophysiological evidence for early non-conscious processing of fearful facial expressions. *International Journal of Psychophysiology, 70*(2), 127—136. https://doi.org/10.1016/j.ijpsycho.2008.08.007

Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences, 13*(4), 160—166. https://doi.org/10.1016/j.tics.2009.01.006

Pessoa, L., Oliveira, L., & Pereira, M. (2013). Top-down attention and processing of emotional stimuli. *The Cambridge Handbook of Affective Neuroscience*, 357—374.

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: What is magic and what is not. *Biological Psychology, 92*(3), 492—512. https://doi.org/10.1016/j.biopsycho.2012.02.007

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. https://doi.org/10.1016/j.biopsycho.2012.02.002

Rellecke, J., Sommer, W., & Schacht, A. (2013). Emotion effects on the N170: A question of reference? *Brain Topography, 26*(1), 62—71. https://doi.org/10.1007/s10548-012-0261-y

Sabatinelli, D., Frank, D. W., Wanger, T. J., Dhamala, M., Adhikari, B. M., & Li, X. (2014). The timing and directional connectivity of human frontoparietal and ventral visual attention networks in emotional scene perception. *Neuroscience, 277*, 229—238. https://doi.org/10.1016/j.neuroscience.2014.07.005

Sabatinelli, D., Lang, P. J., Keil, A., & Bradley, M. M. (2007). Emotional perception: Correlation of functional MRI and event-related potentials. *Cerebral Cortex, 17*, 1085—1091. https://doi.org/10.1093/cercor/bhl017. Epub 2006 Jun. 12.

Santos, I. M., Iglesias, J., Olivares, E. I., & Young, A. W. (2008). Differential effects of object-based attention on evoked potentials to fearful and disgusted faces. *Neuropsychologia, 46*(5), 1468—1479. https://doi.org/10.1016/j.neuropsychologia.2007.12.024

Schindler, S., Bruchmann, M., Bublatzky, F., & Straube, T. (2019). Modulation of face- and emotion-selective ERPs by the three most common types of face image manipulations. *Social Cognitive and Affective Neuroscience Electronic Resource, 14*(5), 493—503. https://doi.org/10.1093/scan/nsz027

Schindler, S., Bruchmann, M., Gathmann, B., Moeck, R., & Straube, T. (2021). Effects of low-level visual information and perceptual load on P1 and N170 responses to emotional expressions. *Cortex; a Journal Devoted To the Study of the Nervous System and Behavior, 136*, 14—27. https://doi.org/10.1016/j.cortex.2020.12.011

Schindler, S., Bruchmann, M., Krasowski, C., Moeck, R., & Straube, T. (2021). Charged with a crime: The neuronal signature of processing negatively evaluated faces under different attentional conditions. *Psychological Science*. https://doi.org/10.1177/0956797621996667

Schindler, S., Bruchmann, M., Steinweg, A.-L., Moeck, R., & Straube, T. (2020). Attentional conditions differentially affect early, intermediate and late neural responses to fearful and neutral faces. *Social Cognitive and Affective Neuroscience Electronic Resource, 15*(7), 765–774. https://doi.org/10.1093/scan/nsaa098

Schindler, S., & Bublatzky, F. (2020). Attention and emotion: An integrative review of emotional face processing as a function of attention. *Cortex; a Journal Devoted To the Study of the Nervous System and Behavior, 130*, 362–386. https://doi.org/10.1016/j.cortex.2020.06.010

Schindler, S., Caldarone, F., Bruchmann, M., Moeck, R., & Straube, T. (2020). Time-dependent effects of perceptual load on processing fearful and neutral faces. *Neuropsychologia, 146*, Article 107529. https://doi.org/10.1016/j.neuropsychologia.2020.107529

Schindler, S., & Kissler, J. (2018). Too hard to forget? ERPs to remember, forget, and uninformative cues in the encoding phase of item-method directed forgetting. *Psychophysiology, 55*(10), Article e13207. https://doi.org/10.1111/psyp.13207

Schindler, S., Richter, T. S., Bruchmann, M., Busch, N. A., & Straube, T. (2022). Effects of task load, spatial attention, and trait anxiety on neuronal responses to fearful and neutral faces. *Psychophysiology*. https://doi.org/10.1111/psyp.14114. e14114.

Schindler, S., Tirloni, C., Bruchmann, M., & Straube, T. (2021). Face and emotional expression processing under continuous perceptual load tasks: An ERP study. *Biological Psychology*. , Article 108056. https://doi.org/10.1016/j.biopsycho.2021.108056

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Chapter 2 Emotion and attention: Event-related brain potential studies. *Progress in Brain Research, 156*, 31–51. https://doi.org/10.1016/S0079-6123(06)56002-9

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghofer, M. (2006). Emotion and attention: Event-related brain potential studies. *Progress in Brain Research, 156*, 31–51. https://doi.org/10.1016/S0079-6123(06)56002-9

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *The Journal of Neuroscience, 27*, 1082–1089. https://doi.org/10.1523/JNEUROSCI.3223-06.2007

Smith, M. L. (2012). Rapid processing of emotional expressions without conscious awareness. *Cerebral Cortex, 22*(8), 1748–1760. https://doi.org/10.1093/cercor/bhr250

Steinweg, A.-L., Schindler, S., Bruchmann, M., Moeck, R., & Straube, T. (2021). Reduced early fearful face processing during perceptual distraction in high trait anxious participants. *Psychophysiology, 58*(6), Article e13819. https://doi.org/10.1111/psyp.13819

Straube, T., Mothes-Lasch, M., & Miltner, W. H. R. (2011). Neural mechanisms of the automatic processing of emotional information from faces and voices. *British Journal of Psychology, 102*(4), 830–848. https://doi.org/10.1111/j.2044-8295.2011.02056.x

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*(2), 59–66. https://doi.org/10.1016/j.ijpsycho.2014.02.005

Vuilleumier, P., & Huang, Y.-M. (2009). Emotional attention: Uncovering the mechanisms of affective biases in perception. *Current Directions in Psychological Science, 18*(3), 148–152. https://doi.org/10.1111/j.1467-8721.2009.01626.x

Walentowska, W., & Wronka, E. (2012). Trait anxiety and involuntary processing of facial emotions. *International Journal of Psychophysiology, 85*(1), 27–36. https://doi.org/10.1016/j.ijpsycho.2011.12.004

Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review, 101*(1), 34–52. https://doi.org/10.1037/0033-295X.101.1.34

Wessing, I., Rehbein, M. A., Postert, C., Fürniss, T., & Junghöfer, M. (2013). The neural basis of cognitive change: Reappraisal of emotional faces modulates neural source activity in a frontoparietal attention network. *Neuroimage, 81*, 15–25. https://doi.org/10.1016/j.neuroimage.2013.04.117

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods, 42*(3), 671–684. https://doi.org/10.3758/BRM.42.3.671

Wu, L., Müller, H. J., Zhou, X., & Wei, P. (2019). Differential modulations of reward expectation on implicit facial emotion processing: ERP evidence. *Psychophysiology, 56*(3), Article e13304. https://doi.org/10.1111/psyp.13304