Individual differences in processing emotional images after reading disgusting and neutral sentences

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Abstract

The present study examined the extent to which Event Related Potentials (ERPs) evoked by disgusting, threatening and neutral photographic images were influenced by disgust propensity, disgust sensitivity and attentional control following exposure to disgusting information. Emotional cognition was manipulated by instructing participants to remember either disgusting or neutral sentences; participants in both groups then viewed emotional images while ERPs were recorded. Disgust propensity was associated with a reduced Late Positive Potential (LPP) gap between threatening and neutral stimuli (an effect driven by a rise in the LPP for neutral images) but only amongst individuals who were exposed to disgusting sentences. The typical LPP increase for disgust over neutral was reduced by attentional shifting capacity but only for individuals who were not previously exposed to disgust. There was also a persistent occipital shifted late positivity that was enhanced for disgust for the entire LPP window and was independent of exposure. Results suggest that emotion specific ERP effects can emerge within the broad unpleasant emotional category in conjunction with individual differences and prior emotional exposure. These results have important implications for the ways in which the perception of emotion is impacted by short term cognitive influences and longer term individual differences.

Keywords: Disgust; Emotion; Exposure; ERP; LPP; Priming

1. Introduction

Prior emotional exposure is associated with a wide range of behavioural and psychological outcomes. This exposure can take the form of mood manipulations (Forgas, 1998a, 1998b; Forgas & Koch, 2013) which tend to result in emotionally congruent (to the mood induction) subsequent behaviours, but there is also an extensive literature on emotional priming which tends to find similar emotional congruence effects, but with effects that bias perceptual processing (Murphy & Zajonc, 1993; Neumann & Lozo, 2012; Rohr et al., 2012; Rohr & Wentura, 2014). A clear example of consequential emotional exposure comes from research on disgust in which there has been a substantial amount of research over the last decade that suggests that exposing individuals to disgust has a number of significant short-term psychological effects. Most notable is the link between disgust and morality, where a great deal of research appears to demonstrate that exposure to disgust is associated with individuals rendering more punitive moral judgements (Horberg et al., 2009; Moretti & di Pellegrino, 2010; Schnall et al., 2008; van Dillen et al., 2012), an association that is in accordance with other research that has discovered a link between disgust sensitivity and political beliefs (Brenner & Inbar, 2014; Crawford et al., 2014; Herzog & Golden, 2009; Inbar et al., 2009, 2012; Iyer et al., 2012; Terrizzi et al., 2010).

However, disgusting stimuli has also been demonstrated to have a disrupting influence on processing such that perceptual tasks (such as probe detection paradigms) become more difficult (van Hooff et al., 2013, 2014). A key finding of these studies is that the disrupting influence of disgust has a slower onset to that of other negative emotions, but the resulting perceptual biases are longer lasting. Physiologically, disgust is unusual among the other typically studied basic negative emotions in that it stimulates both the sympathetic and parasympathetic nervous system (de Jong et al., 2011) and manifests with decreased cardiac activity (Rohrmann & Hopp, 2008) unlike emotions such as fear and anger (Sinha et al., 1992). It is also associated with hyper-vigilance and metabolic suppression (Schneiderman & McCabe, 1989) which could explain the longer lasting disruption to ongoing processes as a result of feeling disgusted. Disgust exposure appears to have a number of behavioural and perceptual consequences and can influence spheres as disparate as product evaluation (Argo et al., 2006; Morales & Fitzsimons, 2007) and the ability to detect shades of grey (Sherman et al., 2012). Thus, disgust seems to have consequences on both perceptual and cognitive assessments. However, there has been little research on the extent to which prior disgust exposure can influence the processing of subsequent emotional information in the environment. Given that physical disgust is often conceptualised as a disease avoidance mechanism that insulates the individual from harm (Curtis et al., 2004; Fessler & Haley, 2006; Rozin et al., 1995; Susskind et al., 2008; Tyber et al., 2013), it is possible to hypothesise that it will result in a hyper-vigilance to aversive stimuli – either by expanding the range of stimuli that provoke an aversive response or by allocating more attentional resources to processing such aversive stimuli.

Electroencephalography (EEG) provides a good means for examining the perceptual influences of prior emotional exposure. Event Related Potential (ERP) studies enable one to examine the extent to which such exposure can influence the time-course processing of subsequent stimuli. By providing an electrophysiological marker of participants' reaction to emotional images, their automatic response (prior to classification or evaluation) can be examined – thus resulting in a good marker of emotion processing following emotional exposure. Possibly the best ERP markers of emotional perception are the Early Posterior Negativity (EPN) and the Late Positive Potential (LPP). There is

some suggestion that other early components (such as the P1, N1, P2 and the N2 family) are also modulated by emotion (see Carretié et al., 2004; Keil et al., 2002; Kiss & Eimer, 2008), but these components are more generally associated with other (non-emotional) processes (such as stimulus detection and spatial attention) which emotion has the potential to disrupt (rather than reflecting emotional processing per se).

The EPN is a negative going deflection that occurs between 250-300 ms after stimulus presentation over occipital sites that is enhanced for emotional compared to non-emotional stimuli (Foti et al., 2009; Schupp et al., 2003, 2004b, 2006) and is thought to reflect the tagging of emotional stimuli for the recruitment of attentional resources (Schupp et al., 2006). As the component itself is often defined and represented as the point in the waveform where emotional and non-emotional stimuli diverge, it is almost a marker of emotion processing by definition. Research has suggested that while other early emotionally sensitive components can interact with other processes, the EPN does remain largely independently sensitive to emotion (for example see Bublatzky & Schupp, 2012). However, there are studies that have suggested that it is further enhanced by highly arousing images (Junghöfer et al., 2001; Schupp et al., 2004a). There is also some suggestion that it is a component that is sensitive to valence, with some studies finding an enhancement for pleasant over unpleasant images (Schupp et al., 2006; Schupp et al., 2004a; Pastor et al., 2007; Weinberg & Hajcak, 2010). The EPN has also been speculated to be a marker of a task-independent automatic process as it is observable for emotional stimuli in passive viewing paradigms and even when attention is diverted to another task (Schupp et al., 2003).

The LPP typically refers to the positive drift that occurs across centro-parietal regions after 400 ms post-stimulus onset (Brown et al., 2012; Schupp et al., 2006) but it has been observed from as early as 200 ms for a period lasting for as long as several seconds (Cuthbert et al., 2000). However, this late positivity has also been observed across frontal (Hauswald et al., 2011; Leutgeb et al., 2012) and occipital areas (Bublatzky & Schupp, 2012; Foti et al., 2009). Principal Component Analysis (PCA) has suggested that the LPP actually represents numerous overlapping components with a variety of functions (Foti et al., 2009; MacNamara et al., 2009; Weinberg & Hajcak, 2011) but the LPP as it is commonly examined is a component that is clearly enhanced for emotional over non-emotional stimuli (Cuthbert et al., 2000; Foti et al., 2009; Keil et al., 2002; Pastor et al., 2007; Schupp et al., 2000). In addition to this emotional enhancement, the LPP is also influenced by consciously directed top-down processes, with the later phase (approximately 600 ms or later) generally seeing an enhanced contribution from these influences (Moser et al., 2006, 2009, 2010; Olofsson et al., 2008; Weinberg & Hajcak, 2011; Weinberg et al., 2012) along with the influence of contextual manipulations (Foti & Hajcak, 2008; Kisley et al., 2011; MacNamara et al., 2011b). As with the EPN, there is still some debate over whether the LPP is sensitive to valence, as many studies have reported greater positivity for negative stimuli rather than typical broad emotional enhancement (Carretié et al., 2001; Delplanque et al., 2005; Foti et al., 2009; Hajcak & Olvet, 2008; Huang & Luo, 2006; Ito et al., 1998). Weinberg and Hajcak (2010) suggested that such discrepancies likely resulted from LPP differences within sub-categories of stimuli, though there is some evidence that the nature of the task (and presentation strategy) itself influences this LPP *negativity bias* (Hilgard et al., 2014). For examining the influence of prior emotional exposure, the LPP (particularly in the later phase) could represent the point in processing that is most relevant – where both the emotional properties of the stimuli and contextual factors exert an influence.

The LPP (particularly in its early portion) has been speculated to represent increased allocation of attentional resources to motivationally salient stimuli (which emotional images are inherently exemplars of; Ferrari et al., 2008; Weinberg et al., 2012), although it may alternatively reflect global inhibition of visual cortex activity following emotion processing (Brown et al., 2012). Given what is known about the LPP, there is no reason to believe that semantic information about the basic emotional categories is indexed by the component (that is to say that there is no reason to believe that there should be divergent LPPs for different emotions that are equally motivationally salient). Thus, emotion-specific modulation of the LPP as a result of emotional exposure is likely to represent enhanced attentional resources towards a specific category of emotional stimuli.

Prior research has suggested that inducing disgust in participants can influence the LPP when processing disgusted but not angry expressions, but only when participants are engaged in emotional evaluation (Hartigan & Richards, 2016). However, ERP research (particularly on the emotional effects in the LPP) tends to use emotional photographic images. While expressions provide easily matched and controllable stimuli that clearly embody specific emotional categories, the structural similarities between specific exemplars of each emotion could potentially reduce the task into a classification exercise (particularly when an explicit emotion identification task is used). This is especially true for disgust, where behavioural data has shown that classification of disgusted expressions is dependent on the relative inclusion of anger within the stimuli selection (Pochedly et al., 2012). However, the differences between emotional scene images of the same emotional category (each typically embodying a unique event – even if certain emotional elicitors remain similar) may require a more complex assessment that relies less on simple structural elements. A meta-analysis by Sabatinelli et al. (2011) revealed that although the processing of facial expressions and emotional scenes stimulates a substantial degree of neural overlap, scene images were associated with increased activation in occipital areas associated with the perception of objects. With regard to function, the role of facial expressions as a social communication tool signalling rejection or disapproval (Blair, 2003; Roelofs et al., 2010; van Dillen et al., 2017) likely stimulates a different neural and psychological response in the perceiver. The expression of disgust also appears to have an extremely specific role in avoiding the uptake of contaminants through the eyes, nose and mouth (Fessler & Haley, 2006; Rozin et al., 1995; Susskind et al., 2008) and perception of such an expression may serve as a communicative signal of a hazardous environment. Emotional scenes may be a better category of stimuli to actually evoke the specific emotional response (generating the physiology and behavioural tendencies associated with the emotion) and thus there is good reason to examine how perception of both is impacted by recent emotional experience.

The present study examined the extent to which prior disgust exposure can influence subsequent emotional processing as represented by activation of the EPN and LPP. Participants were instructed to remember a series of sentences, describing disgusting or neutral scenarios, before viewing a series of emotional scene images that represented either disgusting, threatening (or fear-inducing) or neutral emotional content. The experiment aimed to examine whether this exposure had the potential to enhance the LPP either broadly (simply increasing it for each stimuli category), with general emotional modulation (enhancing it for both disgusting and threatening images) or at the level of the specific emotional category (enhancing the LPP for disgusting stimuli specifically). Many studies have found that individual differences in psychological variables such as anxiety can influence both the EPN (Holmes et al., 2008; Mühlberger et al., 2009; Wieser et al., 2010) and LPP (MacNamara et al., 2011a; MacNamara & Hajcak, 2009, 2010; Mocaiber et al., 2009; Moser et al.,

2008; Weinberg & Hajcak, 2011), with the LPP also susceptive to influences such as interoceptive sensitivity (Herbert et al., 2007; Pollatos et al., 2005). Thus, measures of individual differences judged relevant to the specific task were taken from each participant. Given that many studies have found trait disgust to be a modulating influence in the effectiveness of disgust induction (Armstrong et al., 2014; Cisler et al., 2009; Olatunji et al., 2013; Sherman et al., 2012), markers of both disgust sensitivity (the visceral unpleasantness associated with experiencing disgust) and disgust propensity (the tendency to ascribe a disgust response to a wider range of elicitors) were used. As the experiment required participants to memorise the sentences for later recognition before engaging in an emotional assessment task (thus resulting in a task that could require the reallocation of attentional resources), and also due to the prevailing interpretation of the LPP as a marker of attentional allocation, measures of both attentional focus and attentional shifting were taken and examined in the analysis.

In sum, this experiment aimed to examine whether prior disgust exposure could modulate the LPP and EPN for stimuli of discrepant emotional content, and whether this modulation was contingent on either trait disgust or attentional control. Given the contextual and top-down sensitivity of the LPP, if disgust exposure has the capacity to influence subsequent emotional perception (and if this influence can be reflected electrophysiologically), this component was hypothesised to be the one most likely to manifest such influences. However, given the prevailing theory that the EPN indexes *automatic* attentional capture of emotionally salient stimuli (prior to further processing), this component should not be impacted by prior disgust exposure (see Hartigan & Richards, 2016). Given that the LPP reflects attentional allocation, and is sensitive to attentional manipulations (MacNamara et al., 2011a, van Dillen & Derks, 2012), individual differences in attentional control may play an important role in moderating emotional responses to task stimuli. With regard to prior disgust exposure, it has been found that higher levels of attentional control (including self reported attentional control) can override the influence of a disgust manipulation on a subsequent task by facilitating disengagement (van Dillen et al., 2012). In a task such as the one presented here – where disgusting sentences are necessarily actively held in working memory – the ability to control attention (and, in particular, the ability to shift attention to a task that requires an emotional assessment of images) could facilitate a greater ability to override such disgust influences and suppress an increased affective response to disgusting or threatening images. As individual differences in disgust have been found to mediate disgust priming and conditioning influences, the consequences of disgust exposure may be expected to increase with levels of disgust propensity (or sensitivity) – resulting in a greater affective response to subsequent emotional stimuli (though it is difficult to predict the specificity with which such effects may emerge). These hypotheses were investigated.

2. Method

2.1. Participants

Forty participants, with a mean age of 28.98 (*SD* = 9.34), took part in this study (15 male; 38 right handed). Ethical approval was granted by the Birkbeck College ethics board in the Department of Psychological Sciences.

2.2. Stimuli

A total of 90 images were used in this experiment (30 each of disgusting, threatening and neutral). Images were initially drawn from the International Affective Picture Database (IAPS; Lang et al., 2008), but additional images were found elsewhere online to supplement emotional categories. All images were 1024 x 768 resolution, and none were windowboxed (i.e. none included black borders). Disgusting images included depictions of mud, faeces, vomit and animal entrails. Threatening images included images of aggressive dogs, snakes, alligators, sharks and guns. Neutral images depicted simple objects (e.g. cups and plates). Due to the known influences on emotional ERP components from picture complexity (Wiens et al., 2011), all images were of a simple composition depicting only a single central entity against a background. The images were selected to provoke automatic affective responses (of either disgust or fear) without requiring the integration of information from multiple parts of the image to understand the scene. Images did not include clear depictions of humans, and while some had sections of a human hand (holding the object central to the picture), none included human faces (or human figures in their entirety). All images were rated (on a 7-point scale) after the experiment for the level of disgust and threat, with disgusting images being more disgusting, and threatening images more threatening than both the other categories according to paired *t* tests (all *p*s < .001). Disgust images were rated with means of 6.0 for disgust and 2.8 for threat; threatening images were rated at 2.4 for disgust and 5.4 for threat; neutral images were rated 1.1 for disgust and 1.2 for threat. Images were also rated for how pleasant they were with ratings of 4.3 (*SD* = 1.8) for neutral, 2.5 (*SD* = 1.4) for threatening, and 1.4 (*SD* = .5) for disgust, with all differences significant by *t* tests (*p*s < .001).

In total, 24 each of disgusting and neutral sentences were created. The disgusting sentences were adapted from other studies (van Dillen et al., 2012), but some were also adapted from the disgusting scenarios outlined in disgust propensity questionnaires not used in this study (mainly the DS-R; Olatunji et al., 2007; see appendix for the complete list of sentences used). Each sentence was phrased in the second person and described a disgusting experience happening to the reader. The sentences each contained one of twelve unique elicitors (with two sentences being created for each elicitor). The elicitors included ant infestations, cockroaches, used condoms, lice, maggots, mould, mucus, rats, slugs, skin spots, urine and filthy water. None of the disgust elicitors were represented in the disgusting images in order to ensure that results were not merely based on familiarity effects with the specific exemplars. For each disgust sentence, a corresponding neutral sentence was also created (that was matched for the number of syllables) but with the disgust elicitor being replaced by a neutral alternative – for example, a scenario depicting stepping in a puddle of urine is replaced by a scenario depicting stepping on a sunken paving stone. After the experiment, all 48 sentences were rated by participants for how disgusting they found the scenarios to be; on average, the disgust

sentences were rated as considerably more disgusting than the neutral sentences (5.6 vs. 1.6; $p < .001$).

2.3. Design and Procedure

Prior to arrival, participants were assigned at random to either the disgust exposure or neutral exposure groups (n = 20 for each condition). After being fitted with the EEG skullcap, participants completed the experimental task. The image task consisted of four blocks of trials, which all included a single presentation of each of the 90 images in a random order (with the emotion categories of the stimuli mixed in each block). Before each block, participants were presented on screen with three sentences and were instructed to remember each one as they would be tested on their ability to do so after the block of images. In the disgust exposure condition, each sentence participants were instructed to remember had a unique disgust elicitor.

For the sentence recognition task (which took place after each block), participants were presented (individually and sequentially) with six sentences, three of which were the familiar sentences and three of which were unfamiliar (but, in the case of the disgust sentences, contained the same elicitor so that participants could not recognise the disgust sentences by simply remembering the elicitor). As each disgust elicitor was associated with two unique sentences, whether each sentence appeared as a sentence to remember or as an unfamiliar sentence in the recognition task was counterbalanced between participants (such that each sentence was remembered by half the participants in the disgust group). In this recognition task, the six sentences were presented in a random order and participants simply had to indicate whether each one was familiar or not by way of a left or right response key. For the neutral exposure condition, the matched neutrals were used with the same counterbalance as the disgust condition (so that each unique sentence was remembered by half the participants in the group). After the recognition task, three additional (unique) sentences were presented for participants to remember prior to the next block (and before each subsequent block). Thus, a total of twelve sentences were presented to each participant over the course of the experiment. After each recognition task, participants took a short break before the next three sentences were presented to remember. The purpose of this task was not actually to test participants' memory of these sentences, but simply to ensure that participants were ruminating on disgusting scenarios (in the disgust exposure condition); success in this task was extremely high (with 98% correct assignment of familiar and unfamiliar sentences across both conditions) but this was not subject to further analysis.

For the trials in the image task blocks, participants initially saw a fixation cross for 1000 ms, followed by a target image for 1000 ms and then a 50 ms blank screen. An SOA that varied between 1110 and 1400 ms was used between trials. After each trial (prior to the SOA), there was a 10% chance that participants would be prompted to decide whether the image they had just seen was unpleasant or not (using a left or right response key that was counterbalanced between participants). This procedure was used in order to ensure that participants were fully engaged with processing the images, rather than simply trying to remember the sentences; participants were informed, in instructions prior to the task, that they would be prompted to respond after some images.

Following the fourth image block (and final recognition task), participants were presented again with each of the images once and asked to rate each image for how pleasant, threatening and disgusting

each was. Finally, participants completed the revised Disgust Propensity and Sensitivity Scale (DPSS-R; van Overveld et al., 2006) and the Attentional Control Scale (ACS; Derryberry & Reed, 2002).

2.4. EEG recording

EEG data were sampled with a digitization rate of 500 Hz using a synamp amplifier (Neuroscan) and a 100 Hz low-pass filter (with a 50 Hz notch filter enabled). Data was DC-recorded and used a linked-earlobe reference. Signals were recorded from 26 electrodes (FP1, FP2, F7, F3, Fz, F4, F8, FC5, FC1, FCz, FC2, FC6, O2,C3, Cz, C4, O1, CP5, CP1, CP2, CP6, P7, P3, Pz, P4 and P8 according to the international 10-20 system). Horizontal eye movements (HEOG) were measured from two electrodes placed at the outer canthi of the eyes. Impedances on all electrodes were kept below 5 kΩ. Independent Component Analysis (ICA) was used to identify and eliminate eye blinks, eye movements, and muscle activity from the data (see section 2.5). The EEG data were epoched using a pre-stimulus base-line of 100 ms and a window that continued until 1000 ms after stimulus presentation. Data were filtered offline using a bandpass filter of .01-40 Hz.

2.5. Artefact correction

Prior to the ICA, highly anomalous portions of data (containing clearly identifiable visual noise not indicative of either common brain components or artefacts) were excluded for each participant. An initial ICA was performed using the extended runica EEGLAB function, and was run on data segmented into epochs identical to those used in the analysis. This first ICA run was used to identify trials with anomalous data for deletion – based on statistical thresholding strategies (identifying potentially anomalous segments as a result of standard deviation, linear drifts, kurtosis and abnormal spectra). All epochs flagged by these measures were also examined manually prior to removal, and only those representing clear deviations (rather than simply higher amplitude deflections in the typical regular component activity) were excluded. The average number of trials excluded was 28 (representing 8% of the total data).

Following this, a second ICA (using the same algorithm) was run on the pruned data in order to identify common artefacts that would be corrected in the data. Twenty-eight components were examined (and subtracted components were predominantly in early positions of the decomposition array). The components that were corrected almost exclusively conformed to the pattern representing eye blinks and lateral eye movements, although some participants also had vertical eye movements or (clearly identifiable) pulse artefacts corrected. The average number of corrected components was 2.1 (with only one participant having greater than three components removed). All analyses were conducted on the corrected data.

2.6. EEG data analysis

ERP components were identified using a mean amplitude measure for clusters of electrodes across particular time periods that were defined prior to analysis. These time periods and electrodes were based primarily on intervals identified in previous research (see Hartigan & Richards, 2016; Richards et al., 2013; Langeslag & van Strien, 2009), though the EPN was partially identified from observing the negative-going deflection in the average wave form after the second peak (collapsed across condition and emotion). The EPN component was measured over occipito-parietal electrodes, P7, P8, O1 and O2 across a time window from 200-280 ms after stimulus. The LPP was measured from

centro-parietal electrodes (P3, Pz, P4, Cz, CP1 and CP2) from 400-1000 ms after stimulus – which was divided into early (400-700 ms) and late (700-1000 ms) windows which were analysed separately.

The primary analysis was conducted using linear mixed effects ANOVA with R statistics software (http://www.r-project.org/). Disgusting, threatening and neutral data were initially analysed in the same model. For each ERP component a preliminary 3 (emotion) x 2 (exposure group) mixed effect analysis was conducted to examine main experimental effects. Following significant emotion effects, further analysis was conducted on both disgusting and threatening trials separately (against a contrast of the neutral trials). Markers of disgust sensitivity and disgust propensity (from the DPSS-R) as well as attentional control and attentional focus (from the ACS) were derived from the completed questionnaires. These four variables were entered separately as fixed effect continuous variables (thus comparing the four individual measures separately) to the basic 3 x 2 ANOVA model. *Orthogonal contrasts* were used (see Singmann & Kellen, *in press*) and only effects related to the individual difference measures were analysed with only the highest order interaction reported. For all comparisons, participants were entered as a random effect. Following significant individual difference effects, correlations were examined post hoc to elucidate the findings.

3. Results

3.1. EPN

Average scores for the EPN (and centro-parietal LPP) components for each condition are reported in Table 1 (and see Figure 1 for grand average ERPs for the EPN window, and Figure 3 for topographic maps). There were no significant effects or interaction (all Fs < 1.14, all ps > .33).

3.2. Centro-Parietal LPP (400-700 ms)

There was a main effect of emotion ($F(1, 38) = 15.77$, $p < .001$). Figure 2 reveals that the LPP for disgust and threat trials was enhanced over neutral (and see Table 1 for centro-parietal LPP means). There was no exposure group effect or interaction (Fs < .99, ps > .46). With disgust propensity entered into the analysis, there were no significant effects (Fs < .72, ps >.49). There were also no effects associated with disgust sensitivity (all Fs < 1.24, ps > .27) or attentional focus (Fs < 1.55, ps > .22). With attentional shifting entered into the model, there was a significant emotion x exposure x attentional shifting interaction ($F(1, 38) = 4.94$, $p = .010$).

To explore the shifting effect in more detail, the LPP for both disgusting and threatening images was compared with the neutral LPP individually in two separate models (both of which included attentional shifting as a continuous variable). For the disgust and neutral comparison, there was an interaction between emotion, exposure and attentional shifting ($F(1, 38) = 8.17$, $p = .007$). In order to further elucidate this finding, a difference score was created by subtracting the average LPP for neutral stimuli from the average LPP for disgusting stimuli (thus creating a value representing the increased LPP for disgust over neutral) and this was correlated with attentional shifting in both exposure groups. There was a significant negative correlation between these two variables in the neutral exposure group ($r(18) = -.53$, $p = .016$; see Figure 4) that was not present in the disgust exposure group ($p = .23$).

For the comparison between threatening and neutral (with attentional shifting as a continuous variable), there was a borderline non-significant interaction between emotion, exposure group and attentional shifting ($F(1, 38) = 4.02$, $p = .052$). Similarly to the disgust and neutral comparison, this appeared to be driven by a correlation (though the effect was substantially weaker) between the index representing the difference between threatening and neutral LPP (threatening minus neutral) and attentional shifting in the neutral exposure group ($r(18) = -.44$, $p = .051$), but not in the disgust exposure group (p = .81).

3.3. Centro-Parietal LPP (700-1000 ms)

As with the earlier window, there was a significant main effect of emotion ($F(1, 38) = 9.98$, $p < .001$) but no exposure effect or interaction (*F*s < .45, *p*s > .64). There was a borderline non-significant interaction between exposure group, emotion and disgust propensity ($F(1, 38) = 3.02$, $p = .055$). The contribution of disgust propensity to the LPP augmentation of both disgust and threat over neutral was examined by comparing both emotions against a neutral contrast separately. For the comparison between disgust and neutral (with disgust propensity entered as a continuous variable), there were no significant effects (all *F*s < 1.30, *p*s > .26). For the model contrasting threatening and neutral, there was an interaction between exposure group, emotion and disgust propensity ($F(1, 38) = 5.67$, $p = .023$). A difference index was created by subtracting the neutral LPP from the threatening LPP and this value was significantly negatively correlated with disgust propensity in the disgust exposure group ($r(18) = -.63$, $p = .003$; see Figure 5) but there was no significant correlation in the neutral exposure group ($p = .55$). Rather than representing a reduction in LPP for threatening stimuli, this correlation appeared to predominantly represent an *increase* in LPP to neutral stimuli with increasing disgust propensity – a finding supported by a significant positive correlation with disgust propensity and neutral LPP ($r(18) = .46$, $p = .040$), but no correlation with threat LPP ($p = .57$).

There were no effects associated with disgust sensitivity (all *F*s < .27, *p*s > .76) or attentional focus (all *F*s < 1.37, *p*s > .26). As with the previous window, there was an interaction between emotion, exposure group and attentional shifting ($F(1, 38) = 4.08$, $p = .021$). As with the previous window, this was explored in more detail by comparing disgust and neutral LPP individually in two separate analyses (both including attentional shifting as a continuous variable). For the disgust and neutral comparison, there was a significant interaction between emotion, exposure group and attentional shifting ($F(1, 38) = 8.67$, $p = .006$). As with the earlier window, this was driven by a significant negative correlation between the index representing the LPP difference between disgust and neutral (disgust minus neutral) and attentional shifting in the neutral exposure group ($r(18) = -.54$, $p = .015$), but not in the disgust exposure group ($p = .44$). For the threatening and neutral comparison, there were no significant effects (the 3-way interaction was no longer significant: $F = 2.78$, $p = .10$; all other *F*s < 3.68, all other *p*s > .063).

3.4. Occipital LPP

The data in this study failed to find the EPN typical of other studies; however, a clearly visibly enhanced *positivity* for both disgust and threat over neutral was visible for this time period (see Figure 1; means are reported in Table 2). There was also a visible enhancement for disgust over threat. This component is concordant with the (emotion sensitive) *occipital LPP* present and analyzed in some studies (Bublatzky & Schupp, 2012; Foti et al., 2009; Pastor et al., 2007). As this positivity could represent a meaningful discrepancy in an ERP component explored in previous

research, this occipital positivity was analyzed post-hoc (subject to the same 3 x 2 basic mixed ANOVA, with participants as a random effect, for three time periods (200-400 ms, 400-700 ms, and 700-1000 ms). These latter two windows represented the ones used in the main analysis, but the initial 200-400 period was also examined as it was the first point at which this positivity appeared to emerge, and because this period overlapped with the window used for the EPN analysis. Following significant emotion effects, paired t tests were used to test the differences between the three stimuli categories.

For the early 200-400 ms window, there was a significant main effect of emotion ($F(1, 38) = 5.73$, $p = .005$) but no exposure effect or interaction (Fs < .64, ps > .53). In order to examine the differences between emotions, individual t tests were performed comparing each of the three emotions; given the lack of exposure effects, this comparison was performed collapsed across exposure groups. Threat was enhanced over neutral ($t(39) = 4.95$, $p < .001$) and disgust was enhanced over both neutral ($t(39) = 10.30$, $p < .001$) and threatening ($t(39) = 5.58$, $p < .001$).

As with the previous window, there was a significant main effect of emotion in the 400-700 ms window ($F(1, 38) = 14.39$, $p < .001$) but no exposure effect or interaction (Fs < .26, ps > .77). As with the previous window, this was investigated further using paired t tests (collapsed across exposure group). Mirroring the previous window, threatening trials were enhanced over neutral ($t(39) = 6.82$, $p < .001$) and disgust was enhanced over both neutral ($t(39) = 17.11$, $p < .001$) and threatening ($t(39) = 10.48$, $p < .001$).

There remained a significant main effect of emotion in the 700-1000 ms window ($F(1, 38) = 10.52$, $p < .001$) but no exposure effect of interaction (Fs < .21, ps > .81). The subsequent t tests revealed that disgust was enhanced over both neutral ($t(39) = 12.29$, $p < .001$) and threatening images ($t(39) = 9.32$, $p < .001$), but there was no significant difference between fear and neutral in this window ($p = .11$).

3.5. Post-hoc trait disgust rating analysis

As there was a significant modulation of the LPP for the threatening and neutral comparison in the disgust exposure group, further analysis was conducted in order to explore whether disgust propensity influenced explicit appraisal of either stimuli or sentences. Disgust propensity was significantly positively correlated with disgust ratings for disgusting ($r(18) = .58$, $p = .007$) and threatening ($r(18) = .46$, $p = .042$), but not neutral ($p = .36$) stimuli in the disgust exposure group, but there were no significant correlations in the neutral exposure group (all ps > .25). The level of disgust experienced for the disgust over neutral sentences (derived through a difference score) was also positively correlated with disgust propensity in the disgust exposure condition ($r(18) = .53$, $p = .016$) but not the neutral exposure condition ($p = .15$). For comparison, disgust sensitivity did not correlate with any of these measures in either condition (ps > .14).

4. Discussion

This study examined the extent to which emotion processing (measured by ERPs) was impacted by prior exposure to disgusting stimuli across different levels of trait disgust and attentional control. Using a standard measure of the EPN (consistent with previous research), there was no significant emotional deflection in this task – there was a period of increased negativity for threatening stimuli, but this was not significant. Consistent with prior research, the LPP was enhanced across both windows for both disgusting and threatening stimuli regardless of exposure group. Disgust propensity modulated the contrast between threatening and neutral stimuli (in the disgust exposure group) and appeared to be driven by an increased LPP for neutral stimuli as propensity increased. Attentional shifting was a suppressive influence on the LPP for both disgusting and threatening stimuli (in the neutral exposure group), but this effect was much stronger for disgust and persisted to the later LPP window for disgusting stimuli exclusively. A post-hoc analysis revealed that there was also a significantly increased positivity for disgust over both threatening and neutral stimuli (irrespective of condition) in what is typically referred to as the *occipital LPP* that persisted from 200-1000 ms.

Disgust propensity appeared to modulate the LPP for the neutral stimuli within the disgust exposure condition. Although when all three emotions were entered into the same ANOVA, this effect was borderline significant, there appeared to be a modulation of neutral (relative to threatening) when the emotions were analysed separately against a neutral stimuli control. This finding is concordant with the description of disgust propensity (as it is represented by van Overveld et al., 2006) as a variable that increases the likelihood of individuals being disgusted. There were no effects related to disgust sensitivity, which is a variable that would arguably be more likely to be associated with reaction to stimuli that specifically evoked disgust (as it reflects an increased affective experience when in the presence of disgust). Within this experiment, disgust propensity was also the only disgust measure that correlated with the assessment of stimuli and sentences (and only did so for participants in the disgust exposure condition). Disgust propensity is speculated to be an influence on the affective reaction to stimuli that evoke substantial fear as well as disgust (as evidenced by the link between disgust propensity and spider phobia in van Overveld et al., 2006), thus it is not surprising that it was disgust propensity, rather than sensitivity, that underpinned these effects. The modulation of affective response in both electrophysiological and evaluative data as a result of disgust propensity was present only for participants in the disgust exposure condition – suggesting that higher disgust propensity does not simply increase emotional responses to disgusting stimuli, but also modulates future emotional experience after disgust has been processed. The ERP effects only emerged in the later LPP window, which is in accordance with previous LPP research which has highlighted the post 600 ms period as the point at which contextual and top-down influences play an enhanced role. Rather than specifically modulating the response to disgusting images, this finding could suggest that disgust propensity enhances emotional reaction more generally following priming with disgust. Under this interpretation, the emotional modulation of the LPP for emotional images is not affected by disgust propensity, but high propensity results in an increased allocation of attention to stimuli that would not normally augment the LPP after such prior exposure. It is also possible that there is a ceiling effect for the emotional response generated by aversive images that is not present for neutral stimuli, and thus this LPP enhancement represents a stimuli independent allocation of attentional resources in anticipation of emotional stimuli, following recent disgust exposure. It is not

clear whether these effects are contingent on the prior exposure being of a disgusting nature, and it is possible that manipulations that evoke other negative emotions may also be partially modulated by disgust propensity.

The ability to shift attention was associated with a lower LPP for negative stimuli in the early window but only among participants who were not previously exposed to disgusting sentences. Despite the very low difficulty of the memory component of the experiment, the image task (where participants were encouraged to cognitively appraise the emotional aspects of the stimuli) may have resulted in a task that would benefit from increased attentional shifting (as participants were also attempting to remember sentences). However, the modulation of the LPP for emotional stimuli only in the neutral exposure groups may be indicative of an attentional effect that is washed out with prior disgust exposure. Prior research on mood congruent cognitions suggests that emotional stimuli that match the content of an individual's current mood is subject to enhanced attention (Bower & Mayer, 1989; Siemer, 2005; Smallwood et al., 2009). In light of this, it is possible that attentional effects were only present in the neutral exposure group as the disgusting images did not match the working memory content of the manipulation (and were not representative of a task-relevant emotional category as a result) – thus enabling individuals with increased attentional control to exert a greater influence over the attentional resources allocated to these stimuli. Alternatively, as there is evidence suggesting that the LPP is influenced by working memory load (MacNamara et al., 2011a, van Dillen & Derks, 2012), it is possible that the emotional nature of the disgust sentences consumed more cognitive resources such that individual differences in attentional shifting were not able to exert a moderating role following such exposure. Under this interpretation, those higher in attentional control are able to suppress the affective LPP response (and the allocation of attentional resources it represents), but the ability to do so is limited when the scenarios in working memory (that are matched on other criteria – thus consuming similar working memory resources) necessitate increased emotional processing. Attentional shifting did not play a moderating role in the comparison between threatening and neutral after 700 ms (and only did so weakly for the early window), but continued to do so for disgusting stimuli until the end of the window. It is possible that due to the increased unpleasantness with which participants regarded the disgusting stimuli, attentional shifting continued to play a moderating role (after the emotional images were further down the processing stream) at the point in processing where top-down evaluations come to exert a greater influence (i.e. the late portion of the LPP).

There were no significant emotion-related EPN effects in the present experiment. This is unlikely to be a result of the specific research paradigm as a similar task was used in Hartigan and Richards (2016), where a clear EPN for disgust, angry and happy facial expressions was observed. Differences in stimuli selection are a more likely explanation for this discrepancy as this study did not use many of the sub-categories of stimuli included in other emotion LPP research (in particular: scenes with facial expressions and images of people more generally). It is worth noting that even other studies that have used more typical stimuli selections have failed to find a modulation of the EPN for unpleasant over neutral scene images; for example, although Pastor et al. (2007) found evidence of enhanced EPN for pleasant stimuli, there was no increased negative deflection for unpleasant (over neutral) stimuli (in fact, neutral was more negative). The lack of inclusion of a pleasant category in the current experiment meant that no emotional deflection was present at all in the data. The increased positivity for disgusting stimuli (over the occipital electrodes typically analysed in EPN data) that was observed in the data here began in a window that overlapped with the EPN, and this

enhanced positivity could have been partially responsible for the lack of EPN. This positive drift was enhanced for disgusting and threatening images over neutral in the first two windows (encompassing the 200-700 ms period), but disgust was enhanced over both threat and neutral for the duration of the window. The occipital LPP has been mostly studied in the context of development, where it has been speculated that the more maximally central LPP present in adults shifts over time from a more occipital distribution (Hajcak & Dennis, 2009; Kujawa et al., 2013) – a finding worth noting in light of the topographic maps in this experiment revealing an occipital shifted distribution for disgust, but a more central one for fear (see Figure 3). The occipital LPP has also been studied with adult participants (Bublatzky & Schupp, 2012), and the PCA analysis conducted by Foti et al. (2009) revealed this occipital positivity that was modulated by both emotion and valence. From the data in this experiment, this modulation seemingly reflected an emotional effect that was more pronounced for disgusting stimuli (we have also found this same pattern of results in the occipital LPP in a subsequent ERP experiment from our lab). It is not clear whether this modulation reflects an enhancement that is sensitive to the specific elements of disgusting scene images, the enhanced attentional resources required to process disgusting images, or whether it simply reflects the increased negativity generated by the disgust responses; however, it is clear that this modulation was independent of prior disgust exposure and should be investigated further.

This study demonstrated that disgust propensity was able to modulate the LPP amongst individuals who had been previously exposed to disgust, whereas attentional shifting exerted an influence only for individuals who had not experienced such prior emotional exposure. For individuals exposed to disgust, increasing disgust propensity resulted in an increased LPP neutral baseline, whereas high attentional shifting was associated with a reduced LPP for disgust stimuli only for those remembering sentences that were not disgusting (possibly as a result of attention not being directed to stimuli that matched working memory content). These results show that disgust exposure can influence subsequent emotion processing, but does so discrepantly between individuals with different trait characteristics. The clear and substantial modulation for disgusting over both threatening and neutral images in the occipital LPP has implications for the extent to which emotional sub-categories of aversive scene images can diverge electrophysiologically as well as in explicit classification. With regard to disgust exposure, these results add more evidence to the notion that as well as influencing higher cognitive processes, disgust can also have a considerable influence on emotional perception.

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Appendix

Disgust sentences

"As you start to fall asleep, you feel something tickling your lip and realise, too late, that a cockroach has crawled into your mouth."

"As you come home and walk through your front door, you notice a crackling noise as you step, you turn on the light and realise that the floor is covered with cockroaches."

"As you open your bin you notice that there are maggots crawling around inside."

"As you sit down on a bench in the park you notice a dead pigeon with maggots infesting the corpse."

"As you walk across your bathroom floor in bare feet you step on something, looking down you notice you have squashed a slug."

"As you are at a family birthday party, a relative's young child walks over to you with a squashed slug clenched in his fist."

"As you walk down an alley, you notice that you have stepped in a puddle of urine."

"As you are sitting beside a small child, they lose control of their bladder and urine spreads across the seat and into your clothes."

"As you are watching TV you notice something brushing against your ankle, you look down to see a rat running away."

"As you search in your loft for some tools, you disturb a nest of rats and they run away into a hole in the wall."

"As you sit across from someone on a train you notice that they have a spot on their face that has begun to leak."

"As a colleague goes to shake your hand you notice that they have a cluster of infected spots on two of their fingers."

"As you brush your hair the day after you help out on a school trip, you realise that it is full of head lice."

"As you sit down to have a haircut, you hear the hairdresser inform another customer that they are infested with head lice."

"As you finish mopping up a spill on your kitchen floor, you accidentally knock the bucket of dirty water over your feet and it soaks into your trousers."

"As you walk outside you accidentally drop your keys into a puddle of muddy stagnant water and have to reach in to get them."

"As you are talking to a friend they unexpectedly sneeze mucus in your face."

"As you are standing at a bus stop, a stranger loudly clears the mucus from his throat and spits it onto the floor."

"As you go into your living room one morning, you find that the sofa is covered with small ants."

"As you put your foot in your shoe, you notice that ants are crawling all over it."

"As you walk barefoot along a sandy beach, you accidentally step on a used condom."

"As you pick up some coins you dropped in the street, you accidentally pick up a used condom."

"As you wrap yourself in a towel after getting out of the shower, you realise that the towel has patches of mould all over it."

"As you look in the mirror whilst washing yourself, you notice that the flannel you are using is mouldy."

Neutral sentences

"As you start to fall asleep, you feel something tickling your mouth and realise, too late, that feathers have escaped from your pillow."

"As you come home and walk through your front door, you notice a crackling noise as you step, you turn on the light and realise that you have stepped on some new post."

"As you open your bin you notice that the lid has a large crack and needs replaced."

"As you sit down on a bench in the park you notice a white pigeon flap its wings fast and fly away."

"As you walk across your bathroom floor in bare feet you step on something, looking down you notice a hand towel underfoot."

"As you are at a family birthday party, a relative's young child walks over to you with a small toy clenched in his fist."

"As you walk down an alley, you notice that you have stepped on a sunken paving stone."

"As you are sitting beside a small child, they knock over their drink and water spreads across the seat and onto the floor below."

"As you are watching TV you notice something brushing against your ankle, you look down to see your cat running away."

"As you search in your loft for some tools, you disturb a pile of books and they fall and scatter to the floor by the wall."

"As you sit across from someone on a train you notice that they have blue ink on their face from a pen that has leaked."

"As a colleague goes to shake your hand you notice that they have a cluster of golden freckles on two of their fingers."

"As you brush your hair the day after you help out on a school trip, you realise that the sun has lightened it."

"As you sit down to have a haircut, you hear the hairdresser inform another customer that an offer is available."

"As you finish mopping up a spill on your kitchen floor, you accidentally drop a package of new cleaning cloths onto your feet and a few fall out and unfold."

"As you walk outside you accidentally drop your keys onto some grass that is scattered with autumn leaves and have to reach down to get them."

"As you are talking to a friend they unexpectedly start laughing as you speak."

“As you are standing at a bus stop, a stranger loudly starts humming and tapping one of his feet against the ground."

"As you go into your living room one morning, you find that the sofa is covered with cushions."

"As you put your foot in your shoe, you notice that the laces need to be replaced."

"As you walk barefoot along a sandy beach, you accidentally step on a small pebble."

"As you pick up some coins you dropped in the street, you accidentally pick up a used receipt."

"As you wrap yourself in a towel after getting out of the shower, you realise that the towel has some small loose threads all over it."

"As you look in the mirror whilst washing yourself, you notice that the flannel you are using is dripping."

Condition	EPN (200-280)	LPP (400-700)	LPP (700-1000)
Disgust Exposure Group			
Disgust	9.54 (6.18)	6.07 (3.75)	4.28 (2.12)
Fear	8.00 (5.80)	5.61 (3.19)	3.97 (2.77)
Neutral	8.51 (5.35)	1.63 (2.92)	0.67 (2.43)
Neutral Exposure Group			
Disgust	8.70 (3.25)	7.46 (6.19)	4.57 (3.99)
Fear	7.28 (3.61)	7.36 (5.41)	4.02 (3.46)
Neutral	7.80 (3.01)	2.46 (4.16)	0.24 (1.78)

Table 1. Means (and SD) for EPN and centro-parietal LPPs for each set of stimuli set in each condition at each time window.

Condition	Occipital LPP (200-400)	Occipital LPP (400-700)	Occipital LPP (700-1000)
Disgust Exposure Group			
Disgust	10.35 (5.47)	9.29 (3.62)	4.20 (2.72)
Fear	8.81 (5.02)	6.19 (3.37)	1.62 (2.28)
Neutral	7.82 (4.34)	4.66 (2.96)	1.23 (2.11)
Neutral Exposure Group			
Disgust	9.70 (2.82)	9.64 (3.70)	4.49 (2.61)
Fear	8.65 (3.07)	6.90 (2.83)	1.65 (2.04)
Neutral	7.20 (2.52)	5.06 (2.30)	1.19 (1.67)

Table 2. Means (and SD) for occipital LPPs for each set of stimuli set in each condition at each time window.

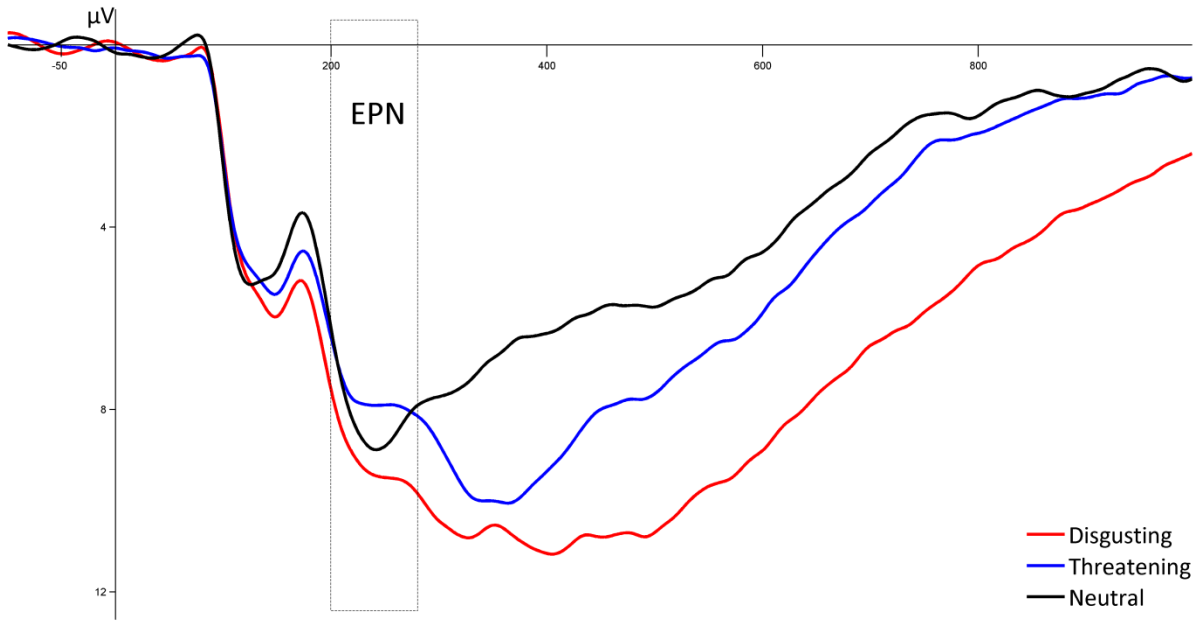

Figure 1. EPN and Occipital LPP (Electrodes P7, P8, 01 and 02) for disgusting, threatening and neutral images collapsed across conditions.

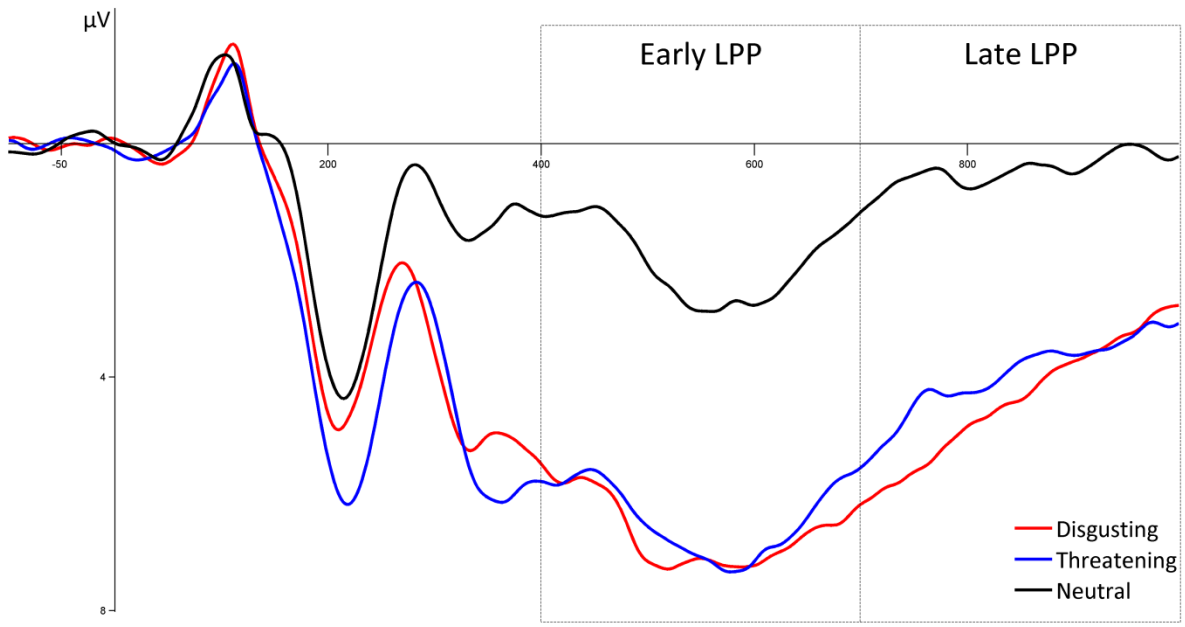

Figure 2. Centro-parietal LPP (electrodes P3, Pz, P4, Cz, CP1 and CP2) for both time windows for disgusting, threatening and neutral images collapsed across conditions.

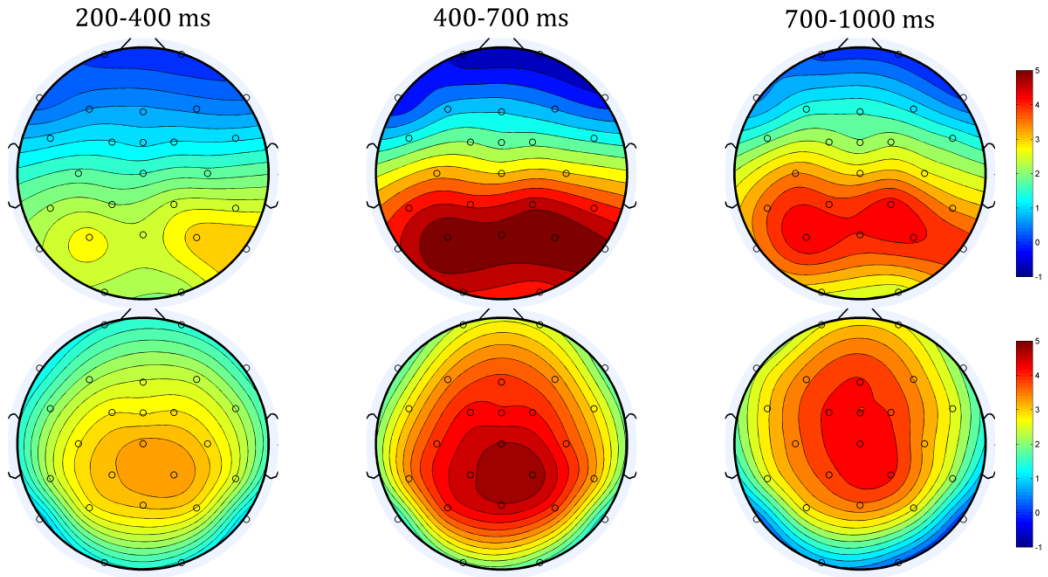

Figure 3. Topographic maps showing the mean amplitude (in µV) enhancement for disgust (top) and fear (bottom) over neutral at each LPP time window (collapsed across condition).

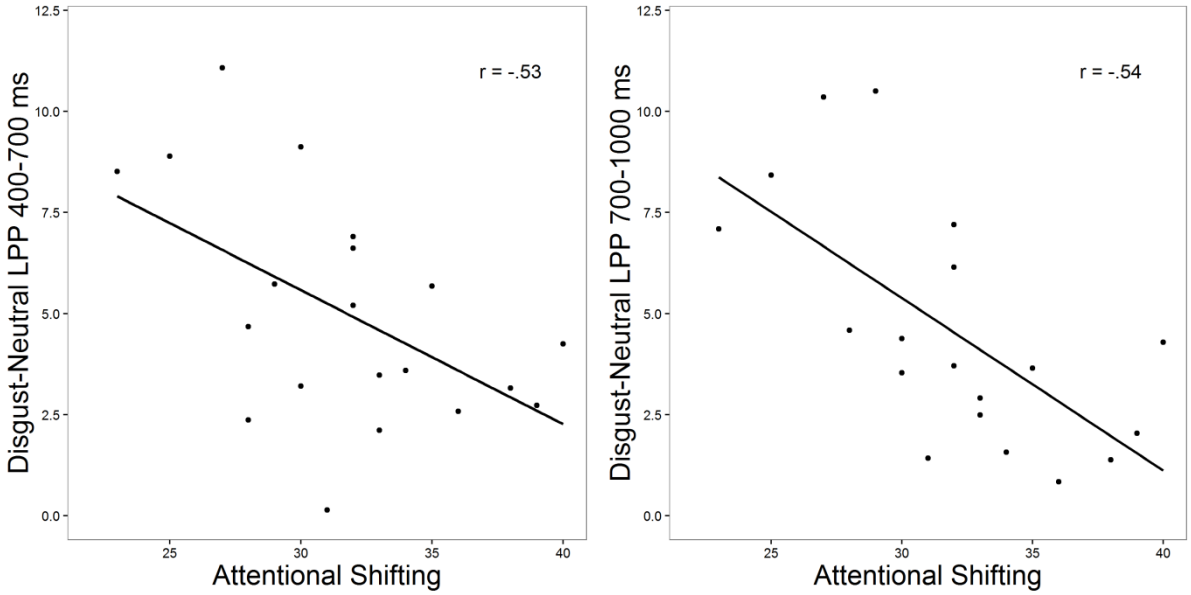

Figure 4. Correlations between the disgust-neutral LPP index and attentional shifting for the neutral exposure group for both centro-parietal LPP windows.

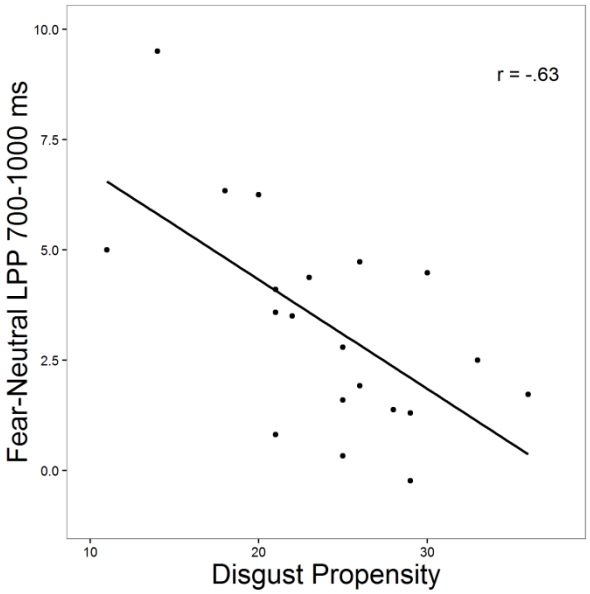

Figure 5. Correlation between the fear-neutral LPP index and disgust propensity for the disgust exposure group in the late centro-parietal LPP windows.