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Danger and disease: Electrocortical responses to threat- and disgust-eliciting images

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ABSTRACT

Previous research suggests facilitated processing of evolutionarily significant stimuli (e.g., depictions of erotica, mutilation, threat), as reflected by augmented event-related potentials (ERPs), including the early posterior negativity (EPN) and late positive potential (LPP). Evolutionary models suggest that images that evoke disgust should be high in motivational salience, but evidence that the EPN and LPP are enhanced by disgusting images is lacking. Prior studies have employed only a small number of disgusting images that were limited in the types of content depicted. In the current study, participants viewed larger sets of disgusting, threatening, and neutral images with more varied content while electroencephalography (EEG) was recorded. Results showed that disgusting and threatening images elicited equivalent LPPs, which were both significantly increased relative to LPPs elicited by neutral images. EPN amplitudes were augmented for both disgusting and threatening relative to neutral images, though significantly more for disgust. These findings offer initial evidence that the EPN and the LPP are sensitive to disgust-eliciting pictures and that these pictures may receive processing that is at least on par with that of threatening images. Limitations of the current study and implications for future research are discussed.

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1. Introduction

Evolutionary accounts suggest that stimuli relevant to survival (e.g., detection of food, mating partners and potential danger signals) should be particularly effective at capturing attention (Lang et al., 1997) and at motivating potentially adaptive physiological and behavioral changes (e.g., fighting, fleeing, procreating; Bradley, 2009). For example, erotic stimuli may signal an increased likelihood of procreation. Increased attention towards threatening stimuli can prioritize and potentiate escape-related behaviors (Hajcak et al., 2007). Similarly, disgust, an emotion characterized by revulsion in the face of noxious stimuli, may function to protect the individual from disease (Olatunji and Sawchuk, 2005). For example, bodily fluids and rotten food, which are strong disgust elicitors, are associated with the potential for infection and sickness (Rozin et al., 2000).

Laboratory studies of emotion processing have employed pictorial depictions of emotionally evocative contents, with electrophysiological measurement demonstrating increased event-related potential (ERP) components for emotional stimuli relative to neutral stimuli (Cacioppo et al., 1994; Cuthbert et al., 2000). Preferential processing of emotional stimuli has been demonstrated during both the early and later periods of attentional capture and processing, as demonstrated by specific ERP components. For example, in the early stages of attention capture, the early posterior negativity (EPN), an occipital negativity maximal at about 230 ms post picture presentation, has been found to be larger for emotional relative to neutral images (Foti et al., 2009; Schupp et al., 2003, 2006; Weinberg and Hajcak, 2010). During later stages of stimulus presentation, the late positive potential (LPP), a positive-going centro-parietal ERP beginning approximately 300 ms after stimulus onset, emerges as larger for emotional compared to neutral stimuli, reflecting sustained attention and the elaborated processing of stimulus meaning (Dillon et al., 2006; Hajcak and Olvet, 2008; Hajcak et al., 2011; Weinberg and Hajcak, 2010).

While initial affective ERP work focused on identifying and characterizing electrocortical indices that were reliably larger for emotional compared to non-emotional stimuli, more recent investigations have examined the effects of specific picture contents on ERPs. In line with motivational accounts of attention (Lang et al., 1997) these studies

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have generally found preferential processing of images that depict content relevant to biological imperatives — specifically, the need to reproduce and to fight/flee (Bradley et al., 2001; Briggs and Martin, 2009; Schupp et al., 2004; Weinberg and Hajcak, 2010). For example, erotic images elicit larger EPNs and LPPs compared to other pleasant emotional stimuli (Schupp et al., 2003, 2004; Weinberg and Hajcak, 2010). Similarly, for unpleasant images, both the EPN and LPP are most strongly elicited by depictions of mutilation and threat relative to those of grief or loss (Schupp et al., 2003, 2004; Weinberg and Hajcak, 2010).

The sensitivity of both the EPN and LPP to threatening images (e.g., individuals pointing weapons, venomous animals) has been interpreted as an adaptive allocation of attention to danger (Weinberg and Hajcak, 2010). Despite the fact that disgust may also function to signal danger, existing studies have not found disgusting images to strongly enhance either the EPN or the LPP. Importantly, however, these studies have tended to employ disgusting stimuli with a limited range of content (i.e., only "contamination" pictures) and have sometimes pooled these images with stimuli that may be perceived as less dangerous, such as images of grief and loss. For example, Schupp et al. (2003) recorded electroencephalographic (EEG) activity while participants viewed a large set (N = 700) of pictures drawn from the International Affective Picture System (IAPS; Lang et al., 2008). The authors did not specifically report on the EPN elicited by disgusting images, but instead assigned "contamination" images to a category of negative valenced pictures of low evolutionary significance (including grief and accidents) and reported that this category was associated with smaller EPNs than mutilation and threat-related pictures (Schupp et al., 2003).

In a subsequent report, Schupp et al. (2004) found that threatening images and images depicting mutilation were associated with larger LPPs compared to contamination images. Contamination images elicited LPPs that were equivalent in magnitude to those elicited by images of sadness and loss, which tend to be rated quite low in emotional intensity (Lang et al., 2008). In a more recent study, Weinberg and Hajcak (2010) expanded on Schupp et al.'s (2004) results by including a larger set of disgusting images (N = 15 disgusting pictures compared to N = 5 contamination images), as well as erotic, affiliative, threatening and mutilation pictures. Results showed that the largest LPPs were elicited by mutilation and erotic images, with threatening images also eliciting relatively large LPPs. In contrast, disgusting images elicited significantly smaller LPPs than erotic, mutilation and threatening images. Likewise, the EPN was also more strongly elicited by both mutilation and threat compared to disgusting images (Weinberg and Hajcak, 2010).

A limitation of the studies reviewed above is that they have used relatively small selections of disgusting images that contained pictures which may not have been especially strong disgust elicitors (e.g., images of used cigarette butts, a sickly looking kitten, a slice of pie with superimposed flies); moreover, prior work has relied on normative image ratings and did not collect subjective ratings of disgust for the stimuli employed. Therefore, it is possible that the stimuli used in prior studies were not strong disgust elicitors (or that these stimuli were combined with less evolutionarily significant images) and that more potent stimuli would have succeeded at strongly modulating ERP responses.

In the present study we therefore sought to further investigate the LPP and EPN elicited by disgusting images. We included a large number of disgusting images chosen for their depiction of disease-inducing agents. Some of these images were created in-house and were supplemented by images from the IAPS (Lang et al., 2008); participants viewed the pictures during a passive viewing task while EEG responses were recorded. In order to draw comparisons with prior work, and to better understand both early and later processing of specific picture contents (Weinberg and Hajcak, 2010), we measured both the EPN and the LPP elicited by disgusting, threatening and neutral pictures. We also asked participants to provide subjective ratings of the images in order to ensure that the disgusting pictures succeeded at being highly evocative of disgust. As a point of comparison, we employed threatening images, which should also be highly motivationally salient (e.g., Schupp et al., 2004), as well as neutral images.

2. Method

2.1. Participants

Twenty-eight undergraduate volunteers (16 female) took part in the study (age $M = 22.07$; $SD = 3.62$; range = 18–32 years). Participants had no history or signs of neurological, psychiatric or medical illness, as confirmed by a phone screen based on the Structured Clinical Interview for the DSM-IV (SCID; First et al., 1996). Potential participants who were taking psychotropic/psychoactive medications were excluded. The study was reviewed and approved by the University of Michigan Institutional Review Board and all participants provided written informed consent.

2.2. Visual stimuli

Ninety pictures were used: 30 threatening, 30 neutral and 30 disgusting. All picture categories contained a combination of images that had been created in-house and IAPS images (Lang et al., 2008)[2]. Disgusting images included several themes of disgusting content, including depictions of bodily secretions (vomit, excrement), infections (nasal, ear), and contaminated food; threatening images depicted animal and human threat (e.g., angry faces, weapons, lunging dogs) and neutral images depicted neutral people, landscapes and neutral animals (e.g., scenes of people working, computers, birds).

2.3. Procedure

After completing the informed consent procedure, EEG electrodes were attached and participants were oriented to the task. Visual stimuli were presented in color at the full size of the computer monitor (which measured 34 × 27 cm), using presentation software (Neurobehavioral Systems, Inc.; Albany, CA). Participants viewed four blocks of images; each consisting of 15 trials of each picture type (i.e., disgusting, threatening, neutral) intermixed in random order. Across the first two blocks each picture was shown once and then displayed for a second time across the last two blocks for a total of 180 trials. Each picture was presented for 1 s with a jittered inter-trial interval ranging from 500 ms–5000 ms, during which time a white fixation cross was shown on a black background.

After finishing the EEG recording, all participants rated the valence and arousal of each image. Participants also rated their emotional response to each image in terms of disgust ("How disgusting do you find this picture?") and perceived threat ("How threatening do you find this picture?"). Valence ratings used a 9-point scale from "unpleasant" to "pleasant." Arousal, disgust and threat ratings were made using a 9-point scale from "not at all" to "extremely."

2.4. Electroencephalographic recording and data processing

Continuous EEG recordings were collected using an elastic cap and the ActiveTwo BioSemi system (BioSemi, Amsterdam, Netherlands). Thirty-four electrode sites (standard 32 channel setup plus Iz and FCz)

[2] IAPS images in each picture category were as follows: disgusting — 7380, 9008, 9031, 9300, 9301, 9302, 9320, 9322, 9325, 9570; neutral — 1450, 1500, 1590, 2102, 2104, 2107, 2191, 2305, 2372, 7003, 7006, 7025, 7026, 7045, 7052, 7100, 7211; threatening — 1050, 1120, 1300, 1525, 1726, 1930, 2811, 3500, 6020, 6231, 6244, 6250, 6300, 6312, 6313, 6315, 6370, 6520, 6550, 6560, 6563, 6830, 6840. Twenty of the disgusting images, seven of the threatening images and thirteen of the neutral images were created in-house and are available upon request.