



Core disgust and moral disgust are related to distinct spatiotemporal patterns of neural processing: An event-related potential study

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ABSTRACT

Core disgust is thought to rely more on sensory and perceptual processes, whereas moral disgust is thought to rely more on social evaluation processes. However, little is known about the neurocognitive mechanisms underlying these two types of disgust. We recorded event-related potentials (ERPs) from participants while they performed a lexical decision task in which core- and moral-disgust words were intermixed with neutral words and pseudowords. Lexical judgment was faster for core-disgust words and slower for moral-disgust words, relative to the neutral words. Core-disgust words, relative to neutral words, elicited a larger early posterior negative (EPN), a larger N320, a smaller N400, and a larger late positive component (LPC), whereas moral disgust words elicited a smaller N320 and a larger N400 than neutral words. These results suggest that the N320 and N400 components are particularly sensitive to the neurocognitive processes that overlap in processing both core and moral disgust, whereas the EPN and LPC may reflect processes that are particularly sensitive to core disgust.

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1. Introduction

Disgust is one of the most important human emotions, it helps us avoid biological pathogens, social and moral threats (Rozin, Haidt, & McCauley, 2008). It is thought to be a heterogeneous construct consisting of distinct psychological responses (Simpson, Carter, Anthony, & Overton, 2006). Initially, disgust was considered a negative emotion elicited by food, i.e., revulsion at the prospect of oral incorporation of offensive objects such as contaminated food or feces (Rozin & Fallon, 1987). The disgust reaction elicited by these kinds of physical materials is referred to as core disgust (Rozin, Haidt, & McCauley, 2000). Many subsequent studies, however, have established that there is also a strong link between the disgust reaction and immoral behavior. Immoral acts such as incest, theft and violent behavior can diminish our appetite, and can even induce nausea (Royzman, Leeman, & Sabini, 2008; Schnall, Haidt, Clore, and Jordan, 2008). This class of disgust is referred to as moral disgust (Chapman, Kim, Susskind, & Anderson, 2009; Rozin et al., 2000). Although there have been some studies concerning the facial expression signifying disgust (Gagnon, Gosselin, Hudon-ven der Buhs, Larocque, & Milliard, 2010; Phillips et al., 1998, 1997). There

has been limited research examining the difference between core disgust and moral disgust (Moll et al., 2005; Simpson et al., 2006). Investigating the difference between core and moral disgust not only help us distinguish two different types of disgust, but also help us understand how humans assess moral threats. The present study was directed toward investigating the degree to which these two different types of disgust involve the recruitment of distinct neural systems.

Core disgust is a basic emotion (Toronchuk & Ellis, 2007a, 2007b) that is elicited rapidly and automatically when ongoing affective and cognitive processes interact to activate adaptive behavioral and mental responses that encourage avoidance of the stimulus or event being appraised (Izard, 2007). It does not depend on complex appraisals or higher order cognition such as thought and judgment (Öhman, 2005). In contrast, moral disgust is associated with behaviors that violate human dignity (Rozin, Lowery, Imada, & Haidt, 1999), and in some case justice (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003), and is an emotion involving higher order cognition and complex appraisals (Clark, 2010; Roseman, 2004).

Converging evidence from recent studies underlines the appropriateness of distinguishing between core disgust and moral disgust (Borg, Lieberman, & Kiehl, 2008; Moll et al., 2005; Simpson et al., 2006). For example, when subjects were asked to provide a rating of their emotional response to core vs. moral disgust elicitors at three time points, disgust reactivity to core elicitors was reduced over time, whereas moral disgust reactivity intensified over time.

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Thus, different emotional response patterns are activated by stimuli eliciting core vs. moral disgust (Simpson et al., 2006).

Several recent neuroimaging studies have suggested that core disgust and moral disgust activate distinct brain networks. Some have suggested that processing of core disgust (e.g., disgusting foods, bad smells) is associated with activity in the insula, basal ganglia, thalamus, and amygdala (Calder, Keane, Manes, Antoun, & Young, 2000; Phillips et al., 1997), whereas processing of moral disgust is mainly associated with activity in the medial prefrontal cortex, bilateral temporal–parietal junction, temporal poles and the precuneus (Greene & Haidt, 2002). Moll et al. (2005) asked participants to read emotional sentences that provoked either core or moral disgust. They found that relative to moral disgust, core disgust was more associated with activation of the medial orbital frontal cortex (OFC), an area linked to visceromotor, multiple sensory, and emotional–motor processing (Schacht & Sommer, 2009; Zatorre, Jones-Gotman, Evans, & Meyer, 1992). In contrast, moral disgust was more associated with activation of the anterior OFC, the left piriform cortex, the anterior superior frontal gyrus (SFG) and the right anterior inferior temporal gyrus (ITG). These regions are linked to the regulation of social behavior (Moll et al., 2005). Using a similar approach, Borg et al. (2008) showed that core disgust is associated with activation of the occipital lobes, left fusiform gyrus and bilateral lingual gyrus, in addition to the frontal and temporal areas, moral disgust is associated more with medial prefrontal cortex and bilateral temporo-parietal junction.

In addition there is evidence indicating that processing different characteristics of the facial expression signifying disgust (e.g., nose wrinkle, tongue extrusion) involves distinct brain areas (von dem Hagen et al., 2009): Some aspects of the disgust facial reaction are more associated with core disgust, such as a gaping mouth, whereas others are more associated with moral disgust, such as the upper lip curl (Rozin, Lowery, & Ebert, 1994). von dem Hagen et al. (2009) demonstrated that the primary visual cortex, parietal cortex and left fusiform gyrus are activated when participants view facial expressions associated with core disgust, whereas the dorsal medial prefrontal cortex, temporal–parietal junction and superior temporal sulcus are activated when participants view expressions associated with moral disgust.

In sum, these neuroimaging studies suggest that core disgust is associated with salience networks encompassing the primary visual and parietal cortices, basal ganglia, thalamus, amygdala and insula. On the other hand, moral disgust is associated with the brain networks involved in appraisal and emotion regulation such as superior and medial frontal cortex, temporal–parietal junction, ventral anterior cingulate and orbital prefrontal cortex. However, previous behavioral and fMRI studies have typically not been able to dissociate between importantly different individual cognitive sub-processes (e.g., semantic access, semantic integration and syntax processing in a sentence). Due to the fact that these processes are closely linked in time, it is difficult to determine in which cognitive sub-process differences between core and moral disgust arise using fMRI and behavioral methods. Event-related potential recordings provide a continuous measure of cognitive processing in milliseconds thereby allow us to disentangle nuanced neurocognitive processes. Therefore we conducted an ERP study to disentangle the temporal dynamics of the neural processes associated with core vs. moral. Participants performed a lexical decision task while their electroencephalogram (EEG) was recorded. The task included neutral words, words related to core disgust, words related to moral disgust and pseudowords. We used words because emotional words have been shown to reliably evoke an emotional reaction in a lexical decision task (Carretié et al., 2008; Kanske & Kotz, 2007).

ERP research demonstrates that emotion modulates word processing from early lexical access to late semantic integration

(Keil, Ihssen, & Heim, 2006). For example, the early posterior negative (EPN), a negative deflection in the ERP occurring at occipital–temporal sites, is an early component sensitive to emotional words (Herbert, Junghofer, & Kissler, 2008; Scott, O'Donnell, Leuthold, & Sereno, 2009). Emotional words trigger a larger EPN than neutral words (Herbert et al., 2008), and this effect is thought to reflect selective attention to emotional stimuli (Schupp, Stockburger, Codispoti, et al., 2007). The N400 is a later ERP component associated with semantic integration (Kutas & Federmeier, 2000) that may also be impacted by emotion, though some of the evidence for this is inconsistent: Some studies have shown that emotional words elicit a smaller N400 than neutral words in a lexical decision task suggesting that semantic integration is facilitated by an emotional connotation (Herbert et al., 2008; Kanske & Kotz, 2007), whereas others found no reliable effect of emotion on the N400 (Kissler & Koessler, 2011). The late positive component (LPC) is another late component involved in word processing that is impacted by emotion (Herbert, Kissler, Junghöfer, Peyk, & Rockstroh, 2006; Kanske & Kotz, 2007; Williamson, Harpur, & Hare, 1991). Emotional words elicit a larger amplitude LPC than neutral words in a lexical decision task (Williamson et al., 1991), and in a naming task (Pauli, Amrhein, Mühlberger, Dengler, & Wiedemann, 2005). An enhanced LPC has been claimed to indicate more sustained processing (e.g., attention capture, evaluation, or memory encoding) of emotional words relative to neutral words (Kissler, Assadollahi, & Herbert, 2006; Olofsson, Nordin, Sequeira, & Polich, 2008).

We hypothesized that core disgust, because it is a rapid process that recruits salience networks, should enhance the EPN in the brain, and through this increased salience should facilitate semantic integration, reducing the N400. Furthermore, sustained processing of the core disgust words should result in an enhanced LPC. In contrast, the formation of moral disgust takes more time, involves complex appraisals and judgments, and activates brain areas responsible of social evaluation. Therefore, moral disgust should affect word processing after the integration of word connotation, showing no effect on the EPN, but impacting later components such as the N400 and LPC. Further, the N400 should be enhanced by moral disgust, because semantic integration of words that induce moral disgust may be more difficult than semantic integration of neutral words, due to an inherent level of incomprehensibility associated with morally disgusting concepts. According to previous study (Van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009), the moral value processing of moral disgust words should also result in an enhanced LPC.

2. Methods

2.1. Participants

Twenty healthy undergraduate students (10 females, 22.45 ± 2.16 years, ranging from 20 to 28 years) participated in the experiment. All participants were right-handed native Chinese speakers, with normal or corrected-to-normal vision. None of them reported any mental illness or chronic physical illness. The local ethics committee approved the study and written informed consent was obtained from all subjects. Participants were paid ¥30 for their participation.

2.2. Stimuli

The neutral words and the disgust words were carefully selected in two separate pilot studies. First, using the Self-Assessment Manikin (SAM) method, thirty one participants were asked to assess arousal (from very calm to very exciting), valence (from very unpleasant to very pleasant), and familiarity (from very unfamiliar to very familiar) of 512 Chinese words on a 9-point Likert-type scale. They were then placed into different emotional categories including happy, fear, sad, disgust, surprise, anger, and neutral. In the second pilot study, another twenty one participants were asked to assess imaginability (from very unimaginable to very imaginable) of these words on a 9-point Likert-type scale. Thereafter, 30 core disgust words (e.g., feces, maggot), 30 moral disgust words (e.g., spy, blackmail) and 30 neutral words (e.g., glass, paper) were selected according to the following criteria: (1) to be considered

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