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Review article

Core, social and moral disgust are bounded: A review on behavioral and neural bases of repugnance in clinical disorders

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ABSTRACT

Disgust is a multifaceted experience that might affect several aspects of life. Here, we reviewed research on neurological and psychiatric disorders that are characterized by abnormal disgust processing to test the hypothesis of a shared neurocognitive architecture in the representation of three disgust domains: i) personal experience of ‘core disgust’; ii) social disgust, i.e., sensitivity to others’ expressions of disgust; iii) moral disgust, i.e., sensitivity to ethical violations. Our review provides some support to the shared neurocognitive hypothesis and suggests that the insula might be the “hub” structure linking the three domains of disgust sensitivity, while other brain regions may subserve specific facets of the multidimensional experience. Our review also suggests a role of serotonin core and moral disgust, supporting “neo-sentimentalist” theories of morality, which posit a causal role of affect in moral judgment.

1. Introduction

If we were asked to describe an autobiographical experience of disgust, we would probably talk about some unpleasant, poorly prepared food consumed in a bad restaurant. The link between disgust and food is probably the easiest to recall, given the relevance of feeding to our own survival and the extensive evidence that taste aversion learning is rapid across species (Gelperin, 1975; Darnauillac et al., 2004). But disgust is more than a mere gustatory matter: perceptions and judgments about disgust impact all aspects of life: disgust influences how we select our friends and our sexual partners, which social group we adhere to, the clothing we wear, the music we listen to and, probably, our concept of morality.

Although more than 140 years have elapsed since Charles Darwin published his influential work on emotions entitled *The Expression of the Emotions in Man and Animals* (Darwin, 1872), our understanding of the neural basis of disgust has progressed rapidly only in the last decades. We have acquired a framework for understanding the neural correlates of disgust, including an appreciation of the role of the insula and its interconnected circuits (Murphy et al., 2003; Wickers et al., 2003; Schäfer et al., 2005; Fusar-Poli et al., 2009; Kirby and Robinsons, 2015). Moreover, we are aware of the role played by genes in explaining inter-individual differences in experiencing disgust or aversion

to specific flavors and smells (e.g., Reed et al., 2006; Reed and Knaapila, 2010). Finally, we have a better understanding of neuro-functional relationships in different disgust-related experiences (Vicario et al., 2017), including the moral dimension of disgust (Chapman et al., 2009), and the importance of socio-cultural and educational factors in shaping aversion to certain sensorial and social outcomes (Curtis, 2011; Davey, 2011).

From a theoretical point of view, the *body-to-soul preadaptation* theory suggests that “*disgust, an originally food-related emotion, expanded, both in biological and in cultural evolution, to become a guardian of the body, the social order, and the soul*” (Rozin and Fallon, 1987; Rozin et al., 2008). From this perspective, disgust has evolved from the antecedent distaste response by a preadaptation process that allows a structure or system that originally evolved for one purpose to be reused in a new context. Accordingly, this theory conceives moral disgust as a phenomenon of preadaptation – the disgust response being expanded to serve functions for which it did not originally evolve. On the other hand, the *adaptationist* theory of Tybur et al. (2009, 2013) suggests that “*disgust evolved to motivate behavioral solutions to multiple distinct adaptive problems such as the avoidance of substances associated with disease-causing agents in ancestral environments; the avoidance of sexual partners and behaviors that would reduce one’s long-term reproductive success; the avoidance of individuals who inflict social costs on oneself or members of*

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one's social network" (Tybur et al., 2013). From this perspective, disgust has its roots in a phenomenon of adaptation that helps to avoid potential pathogens, but can be co-opted to support condemnation in the moral domain.

Both the above-mentioned theories conceive disgust as a defensive mechanism that has evolved to protect against illness, disease and contamination by promoting withdrawal from and avoidance of spoiled foods or other contaminants. Thus, disgust is an emotion critical not only for regulating one's own ingestive behavior, but also for social interactions. Moreover, both these theories provide an account of how disgust might be linked to moral judgment. This reveals the *neo-sentimentalist* or *intuitionist*¹ nature (Haidt, 2001) of these theories, as they argue for a causal role of affect in moral judgment. By contrast, there are other theories (e.g., Royzman et al., 2011; Royzman et al., 2009) that have placed particular emphasis on *rationalist* (or, more broadly, cognitive) inputs to moral judgment. From their perspective, disgust and morality are separate although some theorists (e.g., Kohlberg, 1971) did not deny the role of affect in moral judgment.

Overall, although the existing literature provides a framework for understanding how the brain processes certain aspects of disgust, the general picture is still fragmented. This might be due to the complex nature of disgust as an object of study, as it is a multifaceted emotion that is potentially influenced by a wide range of factors.

At least three lines of research addressing different aspects of disgust can be identified in neuroscience and psychology research. The first line of research has focused on *core disgust* – a very basic subjective experience of aversion that is triggered by potentially toxic visual, gustatory or olfactory stimuli (i.e., rotten foods, excrement) that could contaminate the body, as well as other unpleasant experiences not related to ingestion, but to mutilation, sex, and pathogens (Rozin et al., 2008, 2000; Toronchuk and Ellis, 2007). Another line of research has focused on the ability to recognize disgust in others (Frith, 2009; Wicker et al., 2003). Current theoretical models of disgust fail to consider this socio-emotional ability as a constituent of the disgust experience (Rozin and Fallon, 1987; Rozin et al., 2008; Tybur et al., 2009, 2013). However, one research tradition has shown that observing others' motor and vocal emotional expressions activate mechanisms that are responsible for the generation of the same emotion in oneself (Goldman and Sripada, 2005; Gallese et al., 2004; Niedenthal, 2007; Keysers and Gazzola, 2009; Paracampo et al., 2016; Vicario et al., 2017; Vicario et al., in press). This idea has found support in seminal studies addressing the first-person experience of disgust and the recognition of disgust in others (e.g., Calder et al., 2000; Wicker et al., 2003). Considering this line of research, we refer to *social disgust* as a relevant aspect of the disgust experience with important socio-communicative implications. Finally, the third line of research has focused on *moral disgust*, that is, the subjective sensitivity to, and negative evaluations of, moral transgressions and socially inappropriate people and behaviors, some of which involve an inappropriate use of the body (e.g., cannibalism, pedophilia, torture), while others do not (e.g., hypocrisy, fawning, betrayal; Chapman et al., 2009; Rozin et al., 2000; Haidt et al., 1997; Jones, 2007).

Whether and how these three domains of disgust are linked at behavioral and neural levels is still a matter of debate and controversy. From the neural point of view, some research suggests the existence of a shared representation of different disgust components. For instance, Wicker et al. (2003) have shown that the personal experience of smelling unpleasant scents (core disgust) and the observation of faces expressing disgust (social disgust) activate the same sites in the anterior insula (AI) and the anterior cingulate cortex (ACC). Similar results have been reported by Jabbi et al. (2008), who found corresponding regions of activation in the AI when experiencing disgust (i.e., bad tastants), when viewing someone else experiencing disgust and when imagining

the experience of gustatory disgust. This suggests that one's own experience of disgust and perception of disgust in others may tap into similar neural resources (Calder et al., 2000; Keysers and Gazzola, 2009; Rizzolatti and Sinigaglia, 2016). However, it should be noted that the study of Jabbi et al. (2008) also showed distinct patterns of insular connectivity while observing, imagining and experiencing disgust, indicating that partially different functional networks are recruited in the three tasks. Interestingly, insular and cingulate regions are also active when experiencing moral disgust related to an unfair monetary offer in the ultimatum game (Sanfey et al., 2003) and to social norm violations (Spitzer et al., 2007; Hutcherson et al., 2015; see also Vicario, 2016 for a discussion). Other brain regions, such as the medial prefrontal cortex (mPFC), might also take part in moral cognition (see Sevinc and Spreng, 2014; for a systematic review), possibly because of their involvement in decision-making and processing others mental states.

While the above evidence supports the view of shared disgust representations in the brain, it should be noted that insular and cingulate cortices are also active in a wide variety of tasks involving subjective awareness of both positive and negative feelings (Menon and Uddin, 2010; Ibañez et al., 2010; Cauda et al., 2012; Tamietto et al., 2015), and are believed to play a domain-general role in identifying the most salient among several internal and extrapersonal stimuli in order to guide behavior. Therefore, insular and cingulate involvement in the different dimensions of disgust may reflect the emotional and homeostatic salience of disgust stimuli, rather than a disgust-specific mechanism. On the other hand, direct stimulation of the insula in awake monkeys and human neurosurgery patients can elicit core disgust sensations (e.g., nausea, unpleasant tastes and sensations in the mouth and stomach) and related vegetative and oral motor responses (Ostrowsky et al., 2000; Penfield and Faulk, 1955; Selimbeyoglu and Parvizi, 2010; Caruana et al., 2011). Remarkably, a recent study also demonstrated that electrical stimulation of the AI induces a selective impairment in social disgust sensitivity (Papagno et al., 2016), thus providing causal evidence for a critical role of the AI in both core disgust and social disgust.

Behavioral investigations in healthy individuals also provide support for the hypothesis of a common system for processing core and moral disgust. A seminal study showed that similar facial reactions are evoked by core disgust – elicited by gustatory distaste or the observation of contaminants – and moral disgust – elicited by unfair treatment in an economic game (Chapman et al., 2009). Additionally, studies have reported interactions between core disgust and moral disgust. For example, a personal experience of disgust evoked by consumption of bitter liquids increased moral disapproval ratings of ethical violations (Eskine et al., 2011). Conversely, thinking about moral transgressions or virtues, relative to neutral control events, led participants to perceive a neutral-tasting beverage as disgusting or delicious, respectively (Eskine et al., 2012). Evoking core disgust experimentally renders moral judgments and behaviors more severe (Moretti and di Pellegrino, 2010; Chapman and Anderson, 2013). Moreover, disgust sensitivity predicts conservative attitudes toward abortion and gay marriage (Inbar et al., 2009). By contrast, a recent analysis by Landy and Goodwin (2015) challenges this link between core and moral disgust by showing that the modest effect of disgust on moral judgment found in the literature might be due to publication bias (but see Schnall et al., 2015 for different conclusions).

Despite evidence that the experience of disgust can be altered in several neurological and psychiatric diseases, clinical disorders have been mostly neglected by theories of disgust. Thus, the main goal of this review is to establish the behavioral and neural bases of core, social and moral disgust through an analysis of clinical disorders characterized by abnormal disgust processing in at least one of the three examined domains. Studies addressing clinical disorders are extremely important for understanding the mechanisms of disgust, and present two main advantages. First, instead of providing correlational information about the brain regions that are active when processing core, social or moral

¹ In his review, Haidt uses the terms "intuition" and "emotion" interchangeably.

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