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Disgust elevates core body temperature and up-regulates certain oral immune markers

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ABSTRACT

Recent findings suggest that disgust can activate particular aspects of the immune system. In this study we examine whether disgust can also elevate core body temperature (BT), a further feature of an immune response to disease. In addition, we also examined whether food based disgust – a core eliciting stimulus – may be a more potent immune stimulus than non-food based disgust. Healthy males were randomly assigned to view one of four sets of images – food disgust, non-food disgust, food control and negative emotion control. Measures of BT, salivary immune and related markers, and self-report data, were collected before, and at two time points after image viewing. Disgust elevated BT relative to the negative emotion control condition, as did food images. Different mechanisms appeared to account for these effects on BT, with higher *initial* levels of Tumor Necrosis Factor alpha (TNF-a) *and* disgust, predictive of BT increases in the disgust conditions. Disgust also increased TNF-a, and albumin levels, relative to the control conditions. Type of disgust exerted little effect. These findings further support the idea that disgust impacts upon immune function, and that disgust serves primarily a disease avoidance function.

1. Introduction

It has been suggested that disgust functions to protect us from infectious disease (e.g. Curtis et al., 2004; Oaten et al., 2009; Rozin et al., 2000). If this account is correct, we might expect disgust to work synergistically with other bodily systems that share the same functional goal – the most notable of which would be the immune system. That there may be a functional relationship between the immune system and disgust, and also more broadly with other psychological processes involved in disease avoidance, has been suggested by several authors (Rubio-Godoy et al., 2007; Oaten et al., 2009). However, there are now more substantial reasons – as we review below – to suspect that disgust interacts with immune function (e.g. Miller and Maner, 2011; Schaller et al., 2010; Stevenson et al., 2011). The aim of the study reported here is to further examine the nature of disgust-immune links, by addressing two questions. The first concerns whether experiencing disgust can raise core body temperature, which would facilitate an immune response to possible pathogen attack. This question has not been investigated before and would provide new evidence of a link between disgust and the immune system. The second question concerns whether food-related disgust cues are especially effective at generating a preparatory immune response, based upon the idea that disgust may form part of a broader neuro-gut-immune axis (Stevenson et al., 2011).

One reason to suspect that disgust-immune interactions could occur would be if there were potential neural links to mediate them. The brain has several interfaces with the immune system (Steinman, 2004), as well as numerous regions associated with processing immune related signals (Dantzer et al., 2008; Maier and Watkins, 1998), one of which is the insular cortex (Pacheco-Lopez and Bermudez-Rattoni, 2011). The insular has links to the immune system via the hypothalamic–pituitary–adrenal axis, and the insular appears instrumental in mediating conditioned immune responses in animals (e.g. Ramirez-Amaya et al., 1996; Riether et al., 2008). The insular is also implicated in mediating the emotion of disgust (e.g. Heining, 2006). Damage to the insular can impair disgust perception (Phillips et al., 1997), and the experience of this emotion while leaving knowledge about it intact (e.g. Hayes et al., 2007). While this neural overlap is no more than suggestive, it does demonstrate potential connectivity between brain areas involved in disgust processing and brain areas known to modulate immune function.

A further reason to suspect that disgust and the immune system may interact concerns their common functional goals. It is in an organism's interest to avoid infection. Being sick redirects

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significant amounts of energy away from other goals such as reproduction, towards supporting an activated immune system (e.g. Pacheco-Lopez and Bermudez-Rattoni, 2011; Straub et al., 2010). On this basis any cue, which might act to reduce the costs associated with an active infection, including mounting a preparatory response to prevent this occurring, would be energetically worthwhile.

While disgust-immune links may be largely unexplored, one further reason to suggest they may exist comes from the far more extensively studied interaction between stress and the immune system (e.g. Segerstrom and Miller, 2004). When an organism experiences significant stress, that is from the activation of the fight or flight response, this acts to stimulate several aspects of the immune system, including certain inflammatory cytokines, and other components of the acute phase response, such as increased body temperature (Maier and Watkins, 1998). Maier and Watkins suggest that this close yoking between stress and the immune systems acts to prepare an organism for physical injury, which might result from fight or flight. Using a parallel line of argument, one might then suggest that detecting cues that signal disease, and which induce disgust, *might* also lead to a similar preparatory outcome.

Two recent bodies of work now suggest that interactions between the immune system and disgust – and other psychological components relating to disease avoidance – do occur. One line of evidence comes from findings indicating that immune suppression is associated with behaviors, including disgust, that act to compensate for this deficit by promoting disease avoidance. For example, it has been shown that mothers during the first trimester of pregnancy, where immune-suppression may occur, demonstrate greater ingestive selectivity, heightened nausea and greater disgust, than at other times during pregnancy (e.g. Navarrete et al., 2007; Fessler, 2002). Conceptually similar findings have been documented with other forms of immune suppression, such as that which occurs at the end of a period of illness. This is associated with enhanced vigilance for disease cues (Miller and Maner, 2011).

Two studies have examined the effect of disgust or disease cues on various immune parameters. Schaller et al., 2010 exposed one group of participants to pictures of sick people and another to emotionally negative images. Viewing pictures of sick people led to a preparatory immune response, in that stimulation of blood with bacterial lipopolysaccharide resulted in enhanced levels of the inflammatory cytokine Il-6, relative to the group viewing the negative images. This suggests that disease cues, which were found not to induce disgust, can result in a preparatory up-regulation of immune markers. In a second study, Stevenson et al., 2011, exposed participants either to disgusting, emotionally negative or neutral images, and then examined whether these groups differed on two immune parameters, salivary IgA secretion rate and in TNF-a (and albumin) following the manipulation (salivary cortisol was also obtained). We found that TNF-a (and albumin) levels increased after exposure to disgusting images, but not to negative or neutral images, suggesting a preparatory immune response. However, IgA secretion was reduced in the disgust group, relative to the two control groups, and we hypothesized that this might have occurred because this emotion evolved to remove poisons – bitter things – from the mouth (Rozin et al., 2000). Excess salivation, which can aid flushing out poisons from the mouth, would lead to the wastage of IgA, and this we suggested accounted for the observed reduction.

The present study builds on these initial findings by addressing two issues. The first was to determine whether body temperature would be affected by a disgust induction. As we noted above, stress in animals (Maier and Watkins, 1998) and also in humans (Marazziti et al., 1992; Renbourn, 1960), can result in a rise in core body temperature. Increased body temperature, even by quite modest amounts, can facilitate the immune system's capacity to deal with pathogens as well as slowing microbial reproduction (Kluger, 1979). If then disgust does prepare the body for possible pathogen attack, one further way in which this could occur would be via a rise in core body temperature. Not only would this be a novel finding, it would also provide further support for the idea of a link between disgust and the immune system.

Second, we wanted to investigate whether different types of disgust cue could evoke different patterns of immune response. While the literature suggests a number of possible ways in which the cues that generate disgust can be organized (e.g. Rozin et al., 2000), we focused on a difference that we believed would test an idea developed in our earlier paper (Stevenson et al., 2011). We argued that disgust might form part of a broader neuro-gut-immune axis. This was suggested by evidence from the conditioned taste aversion literature (Garcia et al., 1985; Pacheco-Lopez et al., 2009), the probable evolutionary origins of disgust in the avoidance of cues that will or have resulted in gastrointestinal illness (Rozin et al., 2000), and the fact that responsiveness to cues relating to food-based disgust appear early in development and occur in many species (Steiner et al., 2001; Stevenson et al., 2010). If there is a neuro-gut-immune axis, then food based cues to illness would be expected to be more potent triggers of this system than non-food based cues. Thus, we examined whether inducing disgust using food and related gastrointestinal cues (i.e. rotting and contaminated food and its consequences [nausea, vomiting, diarrhea]) would be more effective at reducing salivary IgA secretion and at promoting increased TNF-a (and albumin) levels, than a disgust manipulation relying upon cues unrelated to food and the gastrointestinal system (i.e. body envelope violations, death, disease, sexual and socio-moral cues).

To address these aims, we compared four groups of participants – two disgust groups, one with food related disgusts and the other with non-food related disgusts, against two control groups, one of whom received cues matched to the disgust food condition – pictures of pleasant food, drink etc., and as we used before a negative emotional control group (Stevenson et al., 2011). This last mentioned group was included so as to determine whether any effects were disgust specific or just a consequence of experiencing a negative emotional state. In our previous study, we did not find any differences in immune or cortisol responses between the negative emotion condition and a neutral picture control group. It was for this reason that we did not include this additional neutral control condition here.

For dependent variables, we utilized the same set of oral immune markers as in our previous study, namely IgA and TNF-a, as well as albumin, which we found to be closely correlated to oral TNF-a levels. Both of these immune markers are primarily components of the innate immune system, with its fast but non-specific mode of action. Salivary cortisol concentration was also assayed to assess for any stress response. Core body temperature was obtained via infrared aural thermometry, with four readings being measured at each recording time point (two per ear) to increase reliability. All of these dependent variables were measured before and at two time points after the manipulation. Finally, as before, we only tested healthy young males, so as to eliminate variation in immune function, cortisol, and body temperature, associated with the menstrual cycle.

We predicted, first, that food-based disgust would be more effective at inducing a reduction in IgA secretion rate and elevating TNF-a and albumin than non-food based disgust. Second, that core body temperature would rise more in the two disgust groups relative to controls. Third, that based upon our previous findings, both disgust conditions would elevate TNF-a and albumin, and depress IgA secretion more than controls.