Effects of body ownership illusion during exposure to disgusting stimuli

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ABSTRACT

Background: The Rubber Hand Illusion (RHI) refers to the feeling of ownership of a rubber hand by synchronously stroking the rubber hand and the own hand of a person. Previous research has shown that RHI can be used to simulate skin contact with a disgust-eliciting stimulus. We used a primary disgust elicitor (a living maggot) to replicate this finding and to gather data on disgust habituation during RHI, and effects on in-vivo exposure.

Methods: A total of 82 healthy participants (25 males, 57 females) were randomly assigned to one of two conditions; synchronous stroking or asynchronous stroking (control condition) of the rubber/own hand. Subsequently, a maggot was placed on the rubber hand for five minutes. Participants rated experienced disgust at the beginning and end of the exposure. They were also asked if the maggot could be placed on their own hand.

Results: Synchronous stroking successfully elicited RHI, which was associated with higher disgust ratings for the maggot at the beginning of exposure compared to asynchronous stroking. The two conditions did not differ in disgust habituation and the willingness to expose the own hand to the maggot.

Conclusion: RHI successfully simulated skin contact with a disgust stimulus. Future studies should apply longer exposure intervals and test individuals with higher disgust propensity to detect possible RHI effects on disgust habituation.

1. Introduction

Disgust is a basic emotion that motivates avoidance and rejection of potential disease elicitors (Davey, 2011). Spoiled food, certain animals (e.g., maggots, cockroaches), and body secretions (e.g., feces, blood) represent primary disgust triggers due to their contaminating properties (Schienle et al., 2003). According to evolutionary approaches, the emotion of disgust is a central component of the behavioral immune system that aims to protect the health of an individual (Schaller & Duncan, 2007).

Given this disease-protection function, disgust learning usually happens very quickly. For example, in the context of conditioned aversions, single-trial learning is possible (Rozin, 1986). Once disgust responses are acquired, these responses are difficult to extinguish (e.g., Bosman et al., 2016). Moreover, responses to unconditioned disgust stimuli are characterized by prolonged habituation. It has been shown that habituation of disgust occurs at a slower rate than habituation of fear (e.g., Olatunji et al., 2007; Olatunji et al., 2009).

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Nevertheless, disgust reactions can be changed. A study by Rozin (2008) demonstrated that repeated exposure with a primary disgust elicitor (a cadaver) reduced reported disgust in medical students. In the clinical context, exposure therapy is the treatment of choice for excessive disgust responses (e.g. in patients with obsessive–compulsive disorder (OCD), specific phobias; see Wolitzky-Taylor et al., 2008; Abramowitz, 2006). Exposure therapy is based on the premise that the controlled confrontation with the disorder-relevant stimulus without showing avoidance/flight and without engaging in disorder-specific behaviors (e.g., washing compulsions), reduces the intensity of negative emotions and arousal (Abramowitz, 2006). This process is conceptualized as habituation.

Exposure interventions involve several challenges. One difficulty refers to the generalization of habituation effects. Exposure-induced habituation to a specific disgust elicitor can sometimes not be transferred to another (similar) disgust stimulus or another context (Tsao & McKay, 2019). Additionally, exposure interventions are often undermined by compliance problems. People do not want to confront themselves with disgust elicitors that prompt avoidance and rejection as natural responses (Davey, 2011). Clinical studies estimated that approximately 30% of OCD patients refuse exposure therapy, and 20–30% drop out prematurely (Franklin & Foa, 2002; Olatunji, Cisler, & Deacon, 2010; Abramowitz, 2006). Therefore, approaches that improve the willingness to engage in disgust exposure are urgently needed. The present investigation tested a new additional treatment component during exposure with a primary disgust elicitor (a maggot). The new intervention consisted of the Rubber Hand Illusion (RHI).

RHI is a multisensory perception phenomenon including vision, touch, and proprioception that allows the investigation of changes in body image and body perception (Botvinick & Cohen, 1998). The simultaneous tactile stimulation of a person’s hand and a rubber hand creates the illusion that the rubber hand is part of one’s body. This approach was used for the first time to investigate disgust processing in a study by Jalal et al. (2015). The healthy participants of this study (n = 14) were exposed to fake disgust stimuli (fake feces, blood, vomit) after synchronous and asynchronous stroking of their hands and a rubber hand for five minutes. The participants reported a more intense RHI in the synchronous condition, which was associated with increased disgust ratings. This finding was replicated by Nitta et al. (2018) with a large sample of 133 healthy participants. In a subsequent study, Jalal et al. (2020) used the RHI as part of a ‘multisensory stimulation therapy’ for OCD patients. The patients’ hidden real hand and visible fake hand were stroked either synchronously (n = 16) or asynchronously (n = 13). After the tactile stimulation, the rubber hand was contaminated with fake feces. At the end of the 5-minute exposure time, the two groups did not differ in reported disgust and urge to wash their hands. However, the proportion of participants who exhibited a facial expression of disgust was higher in the synchronous condition.

The aims of the present study were threefold: First, we attempted to replicate the finding that RHI can be used to simulate skin contact with a disgust-eliciting stimulus. We predicted that placing a living maggot on a rubber hand elicits stronger disgust feelings during RHI as compared to asynchronous stroking. Second, we examined habituation effects. We investigated whether the decline in reported disgust for the maggot from the beginning to the end of the exposure interval would differ between the conditions with vs. without RHI. Third, we tested the generalizability of the exposure effects by asking the participants whether they would be willing to place the living maggot on their own hand after the exposure procedure with the rubber hand.

2. Method

We conducted a power analysis with G*Power (version 3.1.9.2; Faul, Erdfelder, Lang & Buchner, 2007), indicating that with an effect size of $d = 0.541$ (e.g., Jalal et al., 2015) together with a power of 0.95 and $\alpha = 0.05$, a total sample size of $N = 48$ would be needed for a repeated-measures ANOVA with two conditions (synchronous vs. asynchronous stroking). To account for possible drop-out, we recruited 85 participants.

2.1. Sample

A total of 85 university students completed an internet-based survey that screened for exclusion criteria (reported somatic/mental problems as assessed with the Brief Symptom Inventory (BSI); Derogatis & Melisaratos, 1983). The URL for the survey had been posted at the university. One participant dropped out of the study; two participants could not participate due to exclusion criteria. The final sample consisted of 82 participants (25 males, 57 females; mean age = 23 years; SD = 5.57).

| Group | Mean | SD  | t(80) | p    |
|-------|------|-----|-------|------|
| Mean age (years) | asynchronous | 22.54 | 6.29 | -0.896 | 0.37 |
| Disgust by maggots | synchronous | 23.64 | 4.67 | -0.184 | 0.86 |
| | asynchronous | 4.88 | 2.99 | 0.602 | 0.55 |
| | synchronous | 4.51 | 2.54 | -0.184 | 0.86 |
| QADP | asynchronous | 2.43 | 0.71 | 1.184 | 0.24 |
| | synchronous | 2.61 | 0.71 | -0.032 | 0.98 |
| BSI | asynchronous | 0.52 | 0.44 | 0.156 | 0.88 |
| | synchronous | 0.52 | 0.44 | 0.156 | 0.88 |
| MAIA | asynchronous | 22.82 | 4.17 | 0.53 | 0.88 |
| | synchronous | 22.65 | 5.30 | 0.53 | 0.88 |

Footnote: QADP (Questionnaire for the Assessment of Disgust Propensity; BSI (Brief Symptom Inventory); MAIA (Multidimensional Assessment of Interoceptive Awareness).
The participants were randomly assigned to one of two groups: AS (asynchronous stroking condition; 14 males, 29 females), or S (synchronous stroking condition; 11 males, 28 females). The two groups did not differ in mean age, the total BSI score, general disgust propensity (Schienle et al., 2020), and reported interoceptive awareness (MAIA-2; Mehling et al., 2018). They also did not differ in their reported disgust by maggots (Table 1). The participants were presented with a container with living maggots and rated experienced disgust (10-point Likert scale, 1: “not disgusting at all”; 10: “extremely disgusting”).

Written informed consent was obtained after a full explanation of the testing procedure. The study was conducted following the Declaration of Helsinki and had been approved by the ethics committee of the University.

2.2. Procedure

The investigation was divided into two parts: the online survey and the exposure session. At the beginning of the exposure session, the participants were randomly assigned to either the AS or the S group. The participant’s right hand was placed behind a divider panel and covered with a cloth from the participant’s shoulder onwards (so it was not visible anymore), the left hand remained visible. The silicone hand was placed on the left side of the divider panel (Fig. 1).

The participants were asked to look at the silicone hand for one minute, then they completed the Embodiment Questionnaire (EQ; Longo et al., 2008), which is a self-measure that assesses embodiment with 10 statements on a 7-point scale (+3 “strongly agree”, −3 “strongly disagree”, 0 “neither agree nor disagree”). It consists of 3 subscales: ownership, location, and agency; in the present study, we assessed the sense of ownership of the rubber hand (ownership) and the causation between seen and felt touches on the rubber hand and real hand (location). Cronbach’s alpha ranged between 0.91 (T1) and 0.93 (T2).

For the baseline disgust rating (Likert scale: 1–10), a maggot was placed on the rubber hand. After the rating, the maggot was removed.

Then the hands were continuously brushed for 5 min. The brushing was done manually by the female experimenter, with a timer assuring a consistent frequency of one brushstroke every 2 s, lasting 1 s each. In the AS condition, the silicone hand and the own right hand of the participant were being stroked asynchronously in time (alternating rubber hand/real hand) and location (e.g. from the wrist down to one finger of the rubber hand, while stroking from one finger up to the wrist of the real hand). In the S condition, the silicone hand and the participant’s right hand were stimulated synchronously in time (coupled stimulation of rubber hand/real hand) and location (corresponding parts of rubber hand/real hand). After the 5-minute brushing, subjects indicated how much the rubber hand felt like their own hand (feeling-of-ownership) on a 10-point Likert scale ranging from 1 (“not at all”) to 10 (“exactly like my hand”).

Directly after the feeling-of-ownership rating, a maggot was placed on the silicone hand, followed by a disgust rating (beginning of exposure). The synchronous/asynchronous stimulation was continued with the maggot placed on the silicone hand for 5 min. After 5 min of stimulation, a second disgust rating was obtained (end of exposure). Finally, participants indicated their willingness to place the maggot on their own hand (yes/no), followed by a disgust rating. At the end of the experiment, participants filled out the EQ (T2) again.

2.3. Statistical analyses

We computed a mixed analysis of variance (ANOVA) to test the effects of Group (AS, S) and Time (beginning vs. end of stroking) on embodiment. To rule out possible effects of gender on disgust ratings we tested the effects of Gender (male, female), Group (AS, S), and Time (baseline, beginning of exposure, end of exposure) on reported disgust during the exposure procedure with the rubber hand using...
a mixed ANOVA. Post-hoc t-tests were computed to follow up on significant effects. Independent t-tests were used for comparing illusion intensity and experienced disgust during exposure of the own hand. A binomial Chi²-test was computed to compare the proportion of participants that agreed to engage in in-vivo exposure. Cohen’s d and η² (partial eta squared) were used as effect size measures. Greenhouse-Geisser correction was used if sphericity was violated. Data were analyzed in SPSS (version 26) and JAMOVI (version 1.8.1).

2.4. Data availability

Data are available on the Open Science Framework (https://osf.io/bq9k6/).

3. Results

3.1. Embodiment and rubber hand illusion intensity

Embodiment: The S group showed a slightly enhanced embodiment before (mean difference: 0.66) and a strong embodiment after the stroking (mean difference: −1.86) relative to the AS group. The interaction between Group × Time was statistically significant (F(1,80) = 17.6, p < .001, η² = 0.18; Table 2). Moreover the main effects Group (F(1,80) = 25.5, p < .001, η² = 0.241) and Time (F(1,80) = 58.9, p < .001, η² = 0.424) were significant.

Illusion Intensity: The S group showed stronger illusion intensity (M: 7.23, SD: 1.56) than the AS group (M: 3.84, SD: 2.14; t(80) = 8.13, p < .001, Cohen’s d: −1.80).

3.2. Exposure: Rubber hand

In the S group, disgust significantly increased from baseline to the beginning of exposure (t(78) = −5.004, p < .001, d = −0.517). In the AS group, there was no change in disgust ratings (t(78) = −0.362, p = .719, d = −0.034) indicated by a significant interaction Time X Group (F(1,64,129.291) = 5.07, p = .012, η² = 0.061; Fig. 2). The two groups did not differ in their disgust ratings for the maggot placed on the rubber hand at baseline (t(78) = 0.344, p = .732, d = 0.125) and at the beginning of exposure (t(78) = −1.628, p = .108, d = 0.359). There was no interaction between Gender × Time and Gender × Group (all ps > 0.61).

Neither the AS group (t(78) = 1.799, p = .076, d = 0.218) nor the S group (t(78) = 1.793, p = .077, d = 0.188) showed a statistically significant reduction of reported disgust (beginning vs. end of exposure). Both groups did not differ in their disgust ratings at the end of exposure (t(78) = −1.581, p = .118, d = −0.392).

There was no effect of gender on the exposure procedure (F(1,64,129.61) = 0.082, p = .887).

3.3. Exposure of one’s hand

A binomial Chi²-test showed no significant group differences in participants’ compliance to engage in in-vivo exposure (X²(1) = 1.7, p = .19). A total of 84% of the participants from the AS and 72% from the S group were willing to place a living maggot on their hands.

The groups did not differ in reported disgust during in-vivo exposure (M_AS = 5.03, SD = 2.76; M_S = 4.46, SD = 2.77; t(62) = 0.809, p = .42, d = −0.206).

4. Discussion

The present study investigated the effects of the rubber hand illusion (RHI) on experienced disgust during exposure to a primary disgust elicitor and the willingness to engage in vivo-exposure. We found, that participants experiencing RHI reported more intense disgust when a living maggot was placed on the rubber hand than without RHI. This replicates findings from previous research (Jalal et al., 2015; Nitta et al., 2018), where synchronous stroking for five minutes was sufficient to evoke elevated disgust to repulsive stimuli (fake feces, blood, vomit). Thus, the illusion of hand ownership created similar exposure effects as ‘real contamination’ even without skin contact with the disgust stimulus (maggot).

The type of stroking did not affect disgust habituation. In both groups, disgust ratings were lower at the end of the exposure interval compared to the beginning, with a slightly greater reduction in the AS group. In general, the decrease in reported disgust intensity was very small in both groups (M_AS = 0.58, M_S = 0.51; scale 1–10). This is in line with previous research indicating that disgust

Table 2
Means for the S and AS group for embodiment ratings.

| Group     | Time | Mean  | SD    | T(80) | P      | Cohen’s d |
|-----------|------|-------|-------|-------|--------|-----------|
| asynchronous | 1    | 0.66  | 1.47  | 2.17  | 0.033  | −0.48     |
| synchronous | 1    | 0.00  | 1.24  |       |        |           |
| asynchronous | 2    | −0.16 | 1.51  | 6.83  | <0.001 | 1.51      |
| synchronous | 2    | 1.71  | 0.82  |       |        |           |
habituation is prolonged compared to other aversive emotions (e.g., fear) (Olatunji et al., 2007; Olatunji et al., 2009; De Houwer, Thomas, & Baeyens, 2001).

Finally, the RHI did not influence the compliance to in-vivo exposure. Jalal et al. (2020) suggested, that RHI might offer a tolerable alternative to exposure as it does not include direct skin contact with highly aversive stimuli. However, for the clinical application of RHI, it would be important that the exposure experience with the rubber hand could be generalized to a real-life situation. Patients who

Fig. 2. Disgust ratings in the synchronous/asynchronous stroking condition during the exposure procedure with the rubber hand.
undergo exposure therapy need to learn how to endure ‘real’ contact with a disgust stimulus. In the present study, RHI did not desensitize participants so that they would be more willing to touch a living maggot. Different factors may account for this finding. First, the participants did not show within-session habituation during the rubber hand illusion. Moreover, the studied sample was characterized by average overall disgust propensity and disgust by maggots, which may have increased the compliance to engage in vivo exposure. In the present study, 78% of the participants agreed that the maggot was placed on their hands.

We need to mention the following limitations of the study. The current study sought to minimize carry-over effects between conditions using a between-subjects design. Future studies might include stimulation (synchronous/ asynchronous stroking) as a within-subjects factor due to the relatively strong intraindividual consistency of RHI effects and a lower interindividual consistency. Further, the exposure procedure of five minutes did not lead to sufficient within-session habituation. As other single-session exposure protocols (in healthy participants) varied between 30 and 40 min (Adams, Willems & Bridges, 2011), future studies should expand the time of exposure. Moreover, we tested a non-clinical sample. Future studies could focus on specific disorders (e.g. contamination-based OCD) and participants with high levels of disgust propensity.

In conclusion, we were able to demonstrate that a rubber hand can successfully be embodied so that its contamination elicits feelings of disgust. The clinical value of including RHI as a component of exposure therapy needs further investigation.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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