Evolutionary Psychological Science (2023) 9:121–134
https://doi.org/10.1007/s40806-022-00345-w

RESEARCH ARTICLE

Pseudo-Contamination and Memory: Is There a Memory Advantage for Objects Touched by "Morphologically Deviant People"?

Gaëtan Thiebaut[1] · **Alain Méot**[2] · **Arnaud Witt**[1] · **Pavol Prokop**[3,4] · **Patrick Bonin**[1]

Received: 14 February 2022 / Revised: 13 September 2022 / Accepted: 28 September 2022 / Published online: 22 October 2022

Abstract

Memory plays an important role in the behavioral immune system (BIS; Schaller in *The Handbook of Evolutionary Psychology* (2nd Edition), Vol. 1, (pp. 206-224). New York: Wiley, 2016), a proactive immune system whose ultimate function is to make organisms avoid sources of contamination. Indeed, it has been found that objects presented next to sick people are remembered better than objects shown next to healthy people—representing a contamination effect in memory. In the present studies, we investigated this memory effect in relation to "pseudo-contaminated" sources, that is to say, people exhibiting cues ultimately evoking the threat of contamination but objectively posing no such threat in terms of disease transmission. Common objects were shown next to photographs of people having three kinds of morphological deviations—obesity (study 1), scars and burns (study 2), strange eyes (study 3)—or no morphological deviation. Contrary to our expectations, we found that "pseudo-contaminated objects" were not remembered better than "non-contaminated objects," whereas discomfort ratings of the idea of touching the same objects were clearly higher with morphologically deviant people. Memory mechanisms do not seem to be mobilized by "pseudo-contamination" sources which are not directly related to infection risk.

Keywords Pseudo-contamination · Pathogens · Adaptive memory · Contamination · Behavioral immune system · Disgust

Introduction

The selective pressures imposed by pathogens have likely had a profound influence on human behavior (Schaller, 2011, 2016; Schaller & Murray, 2011). Pathogens have caused major diseases in the past and have been responsible for the greatest number of deaths in humans, more than all other causes put together (e.g., natural disasters, wars, accidents, violence) (Inhorn & Brown, 1990). Diseases are still present and potentially lethal (Troisi, 2020) and remain a major concern for our survival (Lesaffre, 2008; Moore, 2020).

The Behavioral Immune System

We are equipped with a biological immune system which helps fight off disease (Richtel, 2019; Sompayrac, 2016). Although relatively effective in combating diseases, this antiparasitic defense system is metabolically costly (Lochmiller & Deerenberg, 2000; Schaller & Duncan, 2007) and may incur additional costs (e.g., fevers can be deadly, and diarrhea can lead to dehydration). The biological immune system involves mechanisms that are activated predominantly after infection (Allen & Wynn, 2011). The behavioral immune system (BIS: Murray & Schaller, 2016; Schaller & Park, 2011; Shakhar, 2019; Thiebaut et al., 2021a) equips us with a second sophisticated set of mechanisms acting as the first line of defense. The ultimate function of the BIS is to inhibit contact with pathogens and to avoid infections. This system incurs costs as well as, for instance, withdrawal from social interactions (Dezecache et al., 2020). The activation of proactive processes depends on pathogens being detected in the immediate environment before they penetrate our natural barriers (Ackerman et al., 2018; Schaller, 2016). Thus, this system is particularly attuned to perceptual cues indicating the presence of contamination. Once a cue is detected, several types of response are generally triggered: emotional (e.g., disgust),

✉ Patrick Bonin
Patrick.Bonin@u-bourgogne.fr

[1] LEAD-CNRS UMR5022, Université de Bourgogne, Pôle AAFE - Esplanade Erasme, BP 26513, Dijon Cedex 21065, France

[2] LAPSCO-CNRS UMR6024, Université Clermont Auvergne, Clermont-Ferrand, France

[3] Department of Environmental Ecology and Landscape Management, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia

[4] Institute of Zoology, Slovak Academy of Sciences, Bratislava, Slovakia

cognitive (e.g., attention), and behavioral (e.g., avoidance) responses (Murray & Schaller, 2016; Schaller & Park, 2011). The biological and behavioral systems are complementary and interact in a complex and coordinated way to ensure our health (Díaz et al., 2020; Troisi, 2020).

Disgust is a central emotion in disease avoidance (Curtis & de Barra, 2018) and a core emotion of the BIS (Oaten et al., 2009; Schaller, 2014). The function of (pathogen) disgust is to activate and coordinate a set of mechanisms in order to avoid disease in cases where cues of disease are present in the immediate environment. Additionally, disgust should also make it possible to avoid things or situations posing a risk of disease *in the future* by activating memory mechanisms. The emotion of disgust can be easily triggered. For instance, Curtis et al. (2004) found that showing participants a photograph depicting a person with fever, who was spotty-faced, and sweaty, evoked disgust, whereas this was not the case for the same photograph shown without these symptoms. It has also been claimed that the functions of disgust are not limited to pathogens but extend to other domains such as the sexual or moral domain (e.g., Al-Shawaf et al., 2016; Chapman et al., 2009; Tybur et al., 2009).

Cues identified by the BIS as posing a potential risk of contamination often lead to avoidance behaviors, even when these cues do not represent real infection risks. Certain researchers assume that the BIS was not shaped by natural selection to reliably detect cues of contamination (Kurzban & Leary, 2001; Schaller, 2011; Schaller & Duncan, 2007). Indeed, the presence of pathogens does not always trigger the BIS, for instance in the case of a cooked hamburger infected by *Escherichia coli* bacteria. Instead, the BIS is sensitive to the probable presence of infectious cues in the environment and there are individual differences in the ability to detect pathogens and/or to avoid them (van Leeuwen & Jaeger, 2022). This, in turn, leads to individual differences in vulnerability to diseases (Duncan et al., 2009; Makhanova et al., 2022; Tybur et al., 2009). Framed within error management theory (Haselton & Buss, 2000), this system attempts to minimize “fatal errors.” The BIS is therefore prone to false-positive errors; that is to say, it can be readily activated by superficial signals of illness or by signs that are similar to those of illness, such as facial port-wine stains (Ryan et al., 2012). Thus, the BIS may “overgeneralize,” a behavior which is adaptive from an evolutionary point of view since it is more conducive to survival to issue an alarm in response to signals that do not have harmful consequences than the reverse. A smoke detector analogy (Nesse, 2005) is generally used to characterize the functioning of the BIS. In order to ensure safety, it is better to make smoke detectors that react to the smoke from a slice of bread in the toaster than detectors that react reluctantly even to major fires, enabling them to take hold and spread. However, false-positive errors such as perceiving a healthy person to be ill may cause a lost friendship or mating opportunities. People have to make trade-offs between the need for social contacts and the motivation to avoid disease (e.g., Sacco et al., 2014). Indeed, several studies have shown that people who deviate from “normality” on certain physical (or psychological) traits are identified by the BIS as posing a risk of contamination. Among the people who are categorized as posing a threat of contamination are obese (Crandall, 1994; Hebl & Mannix, 2003; Park et al., 2007) or disfigured individuals (Crandall & Moriarty, 1995; Shanmugarajah et al., 2012), elderly people (Duncan & Schaller, 2009), or individuals with facial port-wine stains (Ryan et al., 2012). In the Ryan et al. (2012) study, participants had to manipulate objects previously seen in a video depicting a healthy actor or an actor having facial cues representing birthmarks or indicating the presence of influenza. The findings indicated that the levels of behavioral avoidance and disgust were similar in the “influenza” and “birthmark” conditions but were higher in those two conditions than in the healthy (control) condition. Even though the participants in the experiment were explicitly aware that birthmarks are not contagious, they nevertheless treated them as disease-threatening, perhaps because of their superficial resemblance to cues of disease. People suffering from mental illness are also perceived as vectors of disease (Lund & Boggero, 2014). A recent study investigated the ability to perceive morphological deviation in faces and objects and compared this with levels of disgust sensitivity (Nussinson et al., 2018). It is worth stressing that disgust sensitivity is often taken as an index of BIS activation (e.g., Ryan et al., 2012). In Nussinson et al.’s (2018) first study, participants were asked to complete a questionnaire measuring their sensitivity to disgust. Next, they used a 9-point Likert scale to rate the regularity of photographs of faces, some of which were disfigured, while others were normal. Participants with a high level of disgust exhibited greater sensitivity to morphological deviance. In another study, participants primed with a slide show of pictures depicting pathogen threats scored higher on a task requiring them to differentiate between perfect and clearly imperfect geometrical shapes (e.g., circle, square, oval, rectangle) than participants primed with a slide show consisting of pictures of accidents (i.e., a negative condition not linked to pathogens). These findings suggest that a pathogenic threat or a personal sensitivity to pathogens increases sensitivity to morphological deviance, regardless of the nature of the stimuli (faces versus geometrical shapes).

The activation of the BIS brings about extremely negative social outcomes as these people are often stigmatized and ostracized. In effect, obese people report more discrimination in employment (Härkönen et al., 2011; Roe & Eickwort, 1976), even if their weight would not interfere with their ability to do their job. They are also victims of prejudices and are associated with a range of negative characteristics such as being sexually unattractive (Chen & Brown, 2005) and lacking in willpower, consequently being themselves responsible for being overweight (Cahnman, 1968; Vartanian, 2010). As predicted by the BIS, when individuals are more vulnerable to diseases

(Park et al., 2007), they tend to avoid obese individuals more than they do individuals with a normal BMI. Similarly, it has been found that compared to normal-weighted people, obese people are rated as more disgusting on the dimensions of pathogen, sexual, and moral disgust (Lieberman et al., 2012). Also, individuals attempt to maintain a greater social distance (as measured on a scale used as an index of willingness to approach or avoid the person) from obese than from non-obese people (Vartanian et al., 2016). Disfigured people also face negative social outcomes. They are perceived as less trustworthy, less popular, less competent, and hardworking (Jamrozik et al., 2019) and they encounter discrimination in the labor market (Stone & Wright, 2013). Individuals who have a facial disfigurement are also kept at a greater physical distance, i.e., avoided, compared to non-disfigured individuals (Houston & Bull, 1994; Rumsey et al., 1982).

Memory and the BIS

A large number of studies on the BIS have investigated avoidance behaviors (Duncan & Schaller, 2009; Schaller & Park, 2011; Shanmugarajah et al., 2012), and only a small number of them have focused on the cognitive aspects of the BIS, such as perceptual (Axelsson et al., 2018a, b; Sundelin et al., 2015), or attentional processes (Ackerman et al., 2009). As far as memory is concerned, studies that have focused on the relationship between memory and contamination are even more scarce (Bonin et al., 2019; Fernandes et al., 2017, 2021; Gretz & Huff, 2019; Nairne, 2015).

According to the adaptive memory view, memory was not crafted to learn all types of items equally well (Nairne, 2010, 2015, 2016; Nairne & Pandeirada, 2008) but has been shaped to retain fitness-relevant stimuli better than non-fitness-relevant stimuli (Bonin & Bugaiska, 2014; Nairne et al., 2007, 2008). In favor of this view, it has been shown that information about dangerous animals is retained better than information about non-dangerous animals (Barrett & Broesch, 2012; Prokop & Fančovičová, 2017). Toxic mushrooms are recognized better than edible mushrooms (Fančovičová et al., 2020). Of direct relevance to the current issue is the fact that contaminated things are remembered better than non-contaminated things (Bonin et al., 2019; Fernandes et al., 2017, 2021; Gretz & Huff, 2019). More precisely, objects accompanied by verbal descriptions referring to contamination (e.g., person with a constant cough, person with a rash on the skin) are remembered better than objects accompanied by neutral descriptions (e.g., person with brown hair, person with a round face) (Fernandes et al., 2017, 2021). Similar findings have been obtained with photographs of people displaying signs of contamination (e.g., eczema, conjunctivitis) (versus healthy faces) (Bonin et al., 2019; Fernandes et al., 2017, 2021). Finally, contamination effects in memory have also been obtained using videos depicting actors interacting with objects and described as "diseased-contagious" (i.e., having influenza) (Gretz & Huff, 2019). These memory findings illustrate the "law of contagion" (Frazer, 1959; Mauss, 1972; Rozin et al., 1986): Objects are envisioned as being contaminated because some kind of transfer of pathogens from objects to objects or from people to objects is imagined even when the objects are not actually contaminated. For instance, Rozin et al. (1986) found that people expressed a strong aversion to drinking fruit juice in which a sterilized cockroach had been briefly dipped.

As far as contamination effects in memory are concerned, one important issue relates to the role of disgust, and more broadly to the proximate mechanisms involved in these effects. Certain studies have shown that the emotion of disgust enhances memory more than the emotion of fear, with the result that disgusting things are remembered better than frightening things, both of which are memorized better than neutral things (Chapman, 2018; Chapman et al., 2013; Charash & McKay, 2002; Croucher et al., 2011; Schienle et al., 2021). Based on these findings, it seems reasonable to hypothesize that disgust is involved in contamination effects in memory (but see also Fernandes et al., 2021).

The Present Study

In a way similar to what has been found with real contamination cues, we expected to find "pseudo-contamination effects" in memory. More specifically, we expected that if the BIS is hypersensitive to the presence of pathogens, then cues visually resembling the presence of pathogens should be retained in a way similar to visual cues of real pathogens. This hypothesis was based on previous studies showing the following: (1) Pseudo-contamination cues activate the BIS and its core emotion, disgust (Oaten et al., 2009); (2) Disgust enhances memory. In three studies, we tested whether pseudo-contamination effects in memory occur in response to the following pseudo-contamination cues: "obesity" (study 1), "burns and scars" (study 2). As mentioned above, certain studies suggest that obesity and facial disfigurement are perceived as disgusting and lead to avoidance behaviors, even though they are not contagious (Park et al., 2007; Ryan et al., 2012). In a third study (study 3), we tested the hypothesis that an "invented" morphological deviance could serve as a signal for pathogen threat (Nussinson et al., 2018), and consequently bring about pseudo-contamination effects in memory. Thus, in study 3, bizarre-looking faces were used: The eyes of normal people were enlarged and made shiny to look similar to "alien" eyes (e.g., E.T. the extra-terrestrial, Mars Attacks).

The procedure used by Bonin et al. (2019) in their experiment 5a was employed to test pseudo-contamination effects in memory. In the three studies, pictures of everyday-life

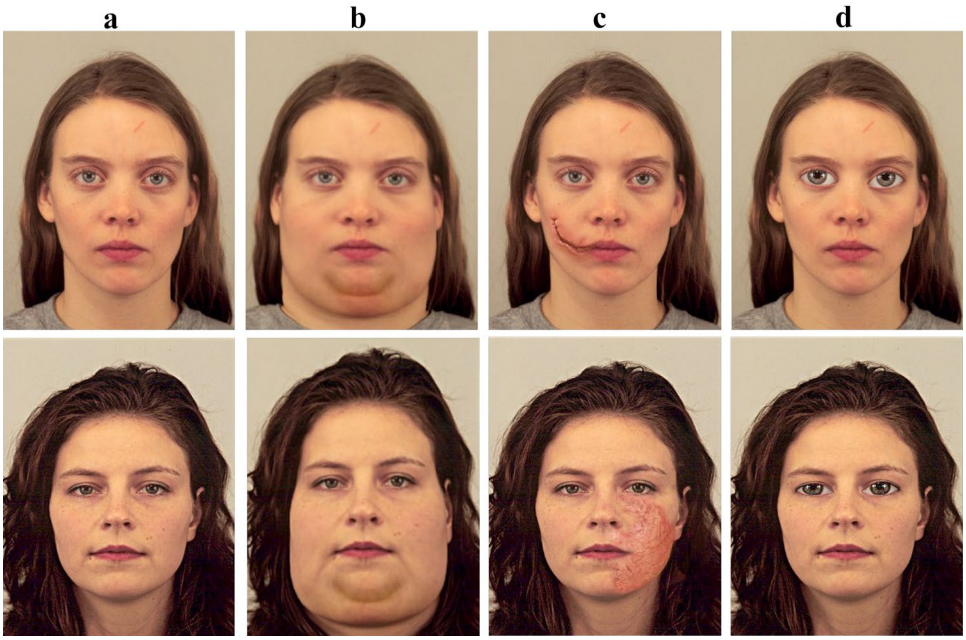

Fig. 1 Examples of stimuli used in the three studies (**a** healthy faces used in all the experiments; **b** obese faces used in study 1; **c** faces with scars or burns used in study 2; **d** faces with enlarged eyes used in study 3)

objects were presented next to photographs of female faces. We used female faces because we anticipated that our sample of participants would be predominantly female. The use of opposite-sex faces (male faces) may have potentially "sexualized" the processing of the faces, and we wanted to avoid activating the adaptive aspect of "finding a mate." In the first study, photographs of obese people versus people with a normal BMI were used (see Fig. 1 for examples). Participants had to evaluate the degree of discomfort they felt when they imagined themselves touching the different objects shown next to the different individuals. After a few minutes had elapsed, they were asked to recall the names of the objects by writing them down on a sheet of paper (a surprise-free recall test). In study 2, the same procedure was used, except that the photographs of obese people were replaced by photographs of individuals with facial scars and burns (Fig. 1). Finally, in study 3, the photographs of individuals with enlarged eyes were presented (Fig. 1). Data collection for this project started several months before French universities shifted to virtual learning in March 2020 because of the COVID-19 pandemic (a national lockdown started in France on the 17th of March 2020).

Study 1: Obesity and Memory

Method

Participants

Fifty adults ($M = 19.33$ years; $SD = 2.15$; 42 females) took part. All participants were psychology students at the University of Bourgogne. They were tested individually in a quiet room and received course credits for their participation. The participants were all native speakers of French and none of them reported taking medication that could affect the central nervous system. Two participants were excluded: One participant was excluded because she took neuroleptics, and another participant because she was not a native speaker of French. In this and the two subsequent studies, we planned to have a sample similar in size to that of Bonin et al.'s (2019) experiment 5a ($N = 46$) in which a within-subject design was used to test the recall of objects presented next to diseased (versus healthy) people. This experiment gave an estimation of the d_z effect size of 0.53[1] (G*Power, Version 3.1.9.7; Faul et al., 2007), which allowed us to estimate that 30 participants would be needed to obtain an effect of similar size with a power of 0.8 (two-tailed; $\alpha = 0.05$). However, we chose to include more participants because we anticipated that pseudo-contamination effects might be somehow lower than contamination effects in memory (with 50 participants, a d_z of 0.4 leads to a power of 0.8). Written informed consent was obtained from all participants before the beginning of the study. This study was performed in line with the principles of the Declaration of Helsinki. All the study procedures were approved by the Statutory Ethics Committee of the University Clermont Auvergne.

---

[1] It is worth noting that Fernandes et al. (2021) reported a similar effect-size (.515) in studies that are closely related to the current ones.

Table 1 Mean ratings (and standard deviations) for each version of the face stimuli used in the main experiment, as obtained from the pilot study (study 1)

	Healthy faces	Obese faces	*t*-test
Perceived health	3.83 (0.55)	2.77 (0.31)	$t(58) = -9.24$ ***
Disgust	1.56 (0.34)	2.39 (0.36)	$t(58) = 9.19$ ***
Emotional valence	3.48 (0.42)	3.04 (0.39)	$t(58) = -4.19$ ***
Discomfort	1.92 (0.45)	2.65 (0.47)	$t(58) = 6.13$ ***
Perceived obesity	1.13 (0.13)	3.93 (0.33)	$t(58) = 43.67$ ***

All scales are 5-point Likert scales. Perceived health and valence were reversed before computations

*** $p < 0.001$

Stimuli

We followed Bonin et al.'s (2019) procedure reported in the "Procedure" section of experiments 5a and 5b to design our face stimuli. First, we selected a set of 46 female faces from the Radboud Facial Database (Langner et al., 2010) and the Karolinska Directed Emotional Faces (Lundqvist et al., 1998). We then used the "Fatify" application to transform each photograph of a healthy female face into a corresponding photo depicting an obese female. Gimp software (www.gimp.org) was used to correct filter imperfections (see Fig. 1 for examples of faces). Thus, 92 pictures of female faces were created: Half depicted healthy faces with a normal BMI—the faces in their normal state as provided by Langner et al. (2010) and Lundqvist et al. (1998)—whereas the remaining half depicted the corresponding obese versions. Following Fernandes et al.'s (2017) and Bonin et al.'s (2019) procedures, we collected norms (using 5-point Likert scales) of perceived health, disgust, emotional valence, discomfort, and perceived obesity when looking at the faces from an independent sample of 46 participants ($M = 19.13$ years; $SD = 3.26$; 44 females) in response to the 92 pictures. Any given participant was presented with each face either in its obese *or* in its normal BMI version, but not with both versions (a total of 46 faces were rated per participant). Each face was presented for a duration of 15 s. We selected the 30 faces that were the most clearly identified as obese (and as normal BMI for the "non-manipulated" versions). *t*-tests (Table 1) revealed that the means obtained for the selected faces and for each of the rated variables differed reliably between the obese and normal BMI faces.

The same thirty colorized pictures of objects as those used in Bonin et al.'s (2019) study 2 (selected from the Rossion and Pourtois (2004) database) were used. The 30 pictures were divided into two lists of 15 pictures matched for 13 variables including imageability, concreteness, and name agreement (see Table 2 in Bonin et al. (2019), for the detailed statistics). The objects of the first list were assigned to 15 randomly selected healthy faces and the remaining objects were assigned to 15 obese faces that were not derived from the healthy selected faces. The same procedure was followed for the second list. The participants were randomly ascribed to one of the two lists.

Apparatus

The different scripts of the experiment were run on an Apple computer running the PsyScope software (Cohen et al., 1993) which controlled the randomization of the photographs.

Design

A within-subject design was used the type of face (normal BMI versus obese) as the independent variable.

Procedure

The participants first provided informed consent and demographic information was collected (age, gender, use of neuroleptics, level of study, native language). The instructions were then presented as follows:

> In this task, you will see objects that have been touched and handled by different individuals, some of whom are obese. Throughout this experiment, you will see drawings of objects and faces. Next to each object, you will see a photograph of the face of the person who touched and interacted with it. For each object presented, you will be asked to estimate on a 5-point scale the extent to which you would feel uncomfortable at the idea of holding it in your hands after the person had touched and interacted with it. The answer 1 corresponds to "I would feel very uncomfortable" and answer 5 is "It wouldn't do anything to me." Be careful not to deliberately focus on the extreme values and feel free to use all the values on the scale. Respond spontaneously and be aware that there are no right or wrong answers.

During the encoding phase, for each object/face pair, the participants had to use a 5-point Likert scale to rate the level of discomfort they felt at the idea of touching the object previously interacted with by the person shown in the photograph. The pictures were randomly presented in the center of the screen and the responses were self-paced. The times taken to perform the ratings were collected. A 3-min distraction phase then followed, during which the participants had to perform the "plus-minus" task from Jersild (1927) and Spector and Biederman (1976) and the "X-O" letter comparison task (Salthouse et al., 1997). A surprise-free recall test was then administered. The participants were given a sheet of paper and had 5 min to write down the names of all the objects they remembered regardless of the faces that had accompanied them. The entire experiment lasted about 20 min.

Results and Discussion of Study 1

The levels of perceived discomfort, the times taken to perform the ratings, and the proportions of correct recall rates were compared between the two conditions (normal BMI versus obese) using paired-sample *t*-tests. Correlational analyses between recall rates and perceived discomfort ratings were performed.

Levels of Perceived Discomfort The rates of discomfort[2] differed significantly between obese ($M = 3.66$, $SD = 0.66$) and normal BMI stimuli ($M = 3.94$, $SD = 0.63$), with the result that objects associated with obese faces caused more discomfort than objects associated with normal BMI faces, $t(47) = -3.61$, $p < 0.001$, $d = -0.52$.

Reaction Time for Perceived Discomfort Reaction times to rate discomfort did not differ significantly between the obese ($M = 2910$ ms, $SD = 779$) and the normal stimuli ($M = 2807$ ms, $SD = 761$), $t(47) = 1.52$, $p = 0.13$, $d = 0.22$.

Free Recall Objects associated with obese people ($M = 0.42$, $SD = 0.15$) were not remembered better than objects associated with normal BMI people ($M = 0.42$, $SD = 0.12$), $t(47) < 1$. The number of extra-list intrusions ($M = 0.05$, $SD = 0.07$) was low.

Overall, there was a significant negative correlation between perceived discomfort and free recall averaged across the two face conditions ($r = -0.295$, $p = 0.04$), with the result that the more uncomfortable the participants felt at the idea of touching and interacting with the objects, the better they remembered them. In addition, the correlation between the differences in the recall rates obtained in the obese and normal conditions and the same differences computed for discomfort ratings was marginally significant ($r = -0.24$, $p = 0.098$), suggesting that the more the participants perceived higher discomfort for obese faces compared to normal BMI faces, the more they recalled objects touched by obese compared to normal people.

The results of study 1, which used obesity as a cue of contamination, were contrary to our expectations in that objects associated with obese people were not remembered better than objects associated with normal BMI people, even though the levels of discomfort differed between the two types of stimuli. In line with the view that the BIS, and more precisely the emotion of disgust (Lieberman et al., 2012), is activated when participants perceive obese people, we found that the level of discomfort felt at the idea of touching objects was higher when the objects had been touched by obese individuals than when they had been touched by normal individuals. However, the difference in discomfort ratings did not translate into recall rates.

Study 2: Scars, Burns, and Memory

Method

Participants

Fifty-one adults ($M = 19.5$ years; $SD = 1.75$; 40 females) took part. All participants were psychology students at the University of Bourgogne. They were tested individually in a quiet room and received course credits for their participation. The participants were all native speakers of French and none of them was taking medication that could affect the central nervous system. Five participants were excluded: Four participants were excluded because their recall rate was less than two standard deviations below the mean, and another participant because she was Turkish, and thus, not a native speaker of French.

Stimuli

The procedure used to select and create the faces was the same as described in study 1. This resulted in the creation of a set of 90 pictures of female faces, half depicting healthy faces, i.e., the faces in their normal state as provided by Langner et al. (2010) and Lundqvist et al. (1998), and the other half depicting the corresponding faces with stigmata (scars or burns). In the same way as described in study 1, we collected norms (using 5-point Likert scales) of perceived health, disgust, emotional valence, discomfort, and perceived deformation from an independent sample of 40 participants ($M = 19.97$ years; $SD = 1.89$) in response to the 90 pictures. We selected the 30 faces that were the most clearly identified as “disfigured” (and as healthy for the “non-manipulated” versions). As can be seen from Table 2, *t*-tests revealed that the means for each of the rated variables differed reliably between the disfigured and healthy faces.

The pictures of objects used in this experiment were the same as those in study 1.

Apparatus

The different scripts for the experiment were run on an Apple computer running the PsyScope software (Cohen

---

[2] It is important to remember that the 5-point scale used in this study (and in the following studies) is different from the scale used in the normative studies: Value 1 is now value 5.

Table 2 Mean ratings (and standard deviations) for each version of the face stimuli used in the main experiment, obtained from the pilot study (study 2)

	Healthy faces	Stigmatized faces	*t*-test
Perceived health	3.94 (0.45)	2.79 (0.48)	$t(58) = -9.52$ ***
Disgust	1.5 (0.27)	2.85 (0.56)	$t(58) = 12.01$ ***
Emotional valence	3.36 (0.47)	2.86 (0.34)	$t(58) = -4.79$ ***
Discomfort	1.64 (0.36)	2.92 (0.45)	$t(58) = 12.18$ ***
Perceived deformation	1.25 (0.22)	4.06 (0.47)	$t(58) = 29.34$ ***

All scales are 5-point Likert scales. Perceived health and valence were reversed before computations

*** $p < 0.001$

et al., 1993) which controlled the randomization of the photographs.

Design

A within-subject design was used with type of face (normal versus disfigured) as the independent variable.

Procedure

The procedure used was identical to that of study 1. Written informed consent was obtained from all of the participants before the beginning of the study. The entire experiment lasted about 20 min.

Results and Discussion of Study 2

We performed the same type of analysis as in study 1.

Levels of Perceived Discomfort The discomfort ratings differed significantly between the stigmatized stimuli ($M = 3.50$, $SD = 0.96$) and the normal stimuli ($M = 4.05$, $SD = 1.11$), with the objects associated with stigmatized faces causing more discomfort, $t(45) = -3.26$, $p = 0.002$, $d = -0.48$.

Reaction Time for Perceived Discomfort The time taken to rate discomfort differed significantly between the disfigured stimuli ($M = 2908$ ms, $SD = 1009$) and the normal stimuli ($M = 2524$ ms, $SD = 821$), $t(45) = 4.18$, $p < 0.001$, $d = 0.62$.

Free Recall Objects paired with disfigured faces were not recalled significantly better ($M = 0.33$, $SD = 0.14$) than objects paired with normal faces ($M = 0.36$, $SD = 0.14$), $t(45) = -1.23$, $p = 0.22$, $d = -0.18$. Neither the correlation between perceived discomfort and free recall averaged across the two face conditions ($r = 0.08$, $p = 0.57$), nor the correlation between difference scores was significant ($r = 0.06$, $p = 0.69$).

In study 2, we again failed to find a pseudo-contamination effect in memory, this time using scars and burns as cues of "contamination." Objects that were associated with disfigured people were not remembered better than when the same objects were associated with healthy people. However, the level of discomfort was higher in response to faces with scars and burns than to normal/healthy faces. This finding suggests that the BIS is activated when disfigured people are perceived but that this expression of "avoidance" does not lead to differences in memorization for the two types of stimuli.

Study 3: Strangeness and Memory

Method

Participants

Fifty adults ($M = 20.42$ years; $SD = 0.95$; 46 females) took part. As in the previous studies, they were all psychology students at the University of Bourgogne. Contrary to the previous studies, the participants were tested collectively in a teaching context. The participants were all native speakers of French and none of them were taking medication that could affect the central nervous system. Two participants were excluded because their recall rate was less than two standard deviations below the mean.

Stimuli

The procedure used to select the faces was the same as that described in study 1. For each face, we used Gimp software (www.gimp.org) and the "FaceApp" application (https://www.faceapp.com/) to modify the eyes of photographs of healthy females. More specifically, we widened the eyes and made them shine.

A set of 90 pictures of female faces was used: Half depicted healthy faces, namely the faces in their normal state as provided in Langner et al. (2010) and Lundqvist et al. (1998), whereas the remaining half depicted the corresponding "strange" faces. We collected norms (using 5-point Likert scales) of perceived health, disgust, emotional valence, discomfort, and perceived strangeness from an independent sample of 40 participants ($M = 19.56$ years; $SD = 3.04$) in

Table 3 Mean ratings (and standard deviations) for each version of the face stimuli used in the main experiment, as obtained from the pilot study (study 3)

	Healthy faces	Strange faces	*t*-test
Perceived health	3.56 (0.65)	2.94 (0.38)	$t(58) = -4.49$ ***
Disgust	1.77 (0.62)	2.82 (0.55)	$t(58) = 6.94$ ***
Emotional valence	3.18 (0.48)	2.6 (0.34)	$t(58) = -5.38$ ***
Discomfort	1.92 (0.56)	3.21 (0.46)	$t(58) = 9.78$ ***
Perceived strangeness	1.9 (0.41)	3.96 (0.25)	$t(58) = 23.76$ ***

All scales are 5-point Likert scales. Perceived health and valence were reversed before computations

*** $p < 0.001$

response to the 90 pictures. Any given participant saw each face in either its stigmatized or its healthy version, but not both (a total of 45 faces rated per participant). We selected the 30 faces that were the most clearly identified as strange (and as normal for the "non-manipulated" versions). A series of *t*-tests (Table 3) revealed that the means obtained for the selected faces and for each of the rated variables differed reliably between the strange and healthy faces.

The objects used were the same as those used in studies 1 and 2.

Apparatus

The different scripts of the experiment were run on an Apple computer running the PsyScope software (Cohen et al., 1993) which controlled the randomization of the photographs.

Design

A within-subject design was used with type of face (normal versus strange) as the independent variable.

Procedure

In contrast to the previous studies, study 3 was performed during collective sessions and, contrary to the previous studies, the participants were not provided with a personal computer to provide their ratings. Thus, reaction times for making the ratings were not collected. The procedure was strictly the same as that described in the Procedure section of Bonin et al.'s (2019) experiment 5a. The photographs of faces and the pictures of objects were projected on a large white screen for 6 s (the presentation of the face-object pairs was randomized by the computer program) and the participants had to rate (using pen and paper) their level of discomfort at the idea of touching the objects associated with the different faces. The procedure was otherwise strictly identical to that of the two previous studies. Written informed consent was obtained from all participants before the beginning of the study. The duration of the experiment was about 20 min.

Results and Discussion of Study 3

As described above, since the data in this study were obtained in a collective session using pen and paper, the times taken to make the discomfort ratings could not be measured. Paired-samples *t*-tests were run on the levels of perceived discomfort and on the proportions of correct recall rates in order to compare the results for type of face (normal versus strange) taken as the independent variable. Correlational analyses between recall rates and perceived discomfort ratings were performed.

Levels of Perceived Discomfort The discomfort ratings differed significantly between the strange stimuli ($M = 3.59$, $SD = 0.64$) and the normal stimuli ($M = 4.01$, $SD = 0.53$), revealing that the objects associated with strange faces caused more discomfort, $t(47) = -5.68$, $p < 0.001$, $d = -0.82$.

Free Recall The objects associated with strange-looking people ($M = 0.40$, $SD = 0.15$) were not remembered better than those associated with normal people ($M = 0.45$, $SD = 0.20$), $t(47) = -1.77$, $p = 0.08$, $d = -0.26$. The correlation between perceived discomfort and free recall averaged across the two face conditions was not significant ($r = -0.01$, $p = 0.93$) and the correlation between the differences in recall rates obtained in the strange and normal conditions with the same differences computed for discomfort ratings was also not significant ($r = 0.13$, $p = 0.38$).

As in the previous studies, objects that were associated with strange people were not remembered better than when the same objects were associated with normal/healthy people. Also, the former stimuli caused more discomfort than the latter.

General Discussion

People are disgusted by things or people that are genuine sources of contamination (e.g., Curtis et al., 2004) but also by things or people that do not objectively threaten their health but that exhibit cues evoking contamination, thus suggesting that the BIS processes them as diseases (Crandall, 1994; Crandall & Moriarty, 1995; Hebl & Mannix, 2003; Park et al., 2003, 2007; Shanmugarajah et al., 2012; Ryan et al., 2012). Among these are obese people, individuals with burned and scarred faces, or people with port-wine stains. The present studies were designed on the basis of evidence showing that

(1) pseudo-contamination cues activate disgust—a core emotion of the BIS—and (2) disgust is able to enhance memory (Chapman, 2018; Chapman et al., 2013; Charash & McKay, 2002; Croucher et al., 2011). We sought to obtain findings similar to those already observed for avoidance behaviors and identify pseudo-contamination effects in memory. “Obesity” was used as the pseudo-contamination cue in study 1, “burns and scars” in study 2, and “enlarged eyes” in study 3. However, contrary to our expectations, we found that objects shown next to “morphologically deviant people” were not remembered better than the same objects shown next to “morphologically normal people,” even though the levels of discomfort in all three studies significantly differed between the two types of stimuli, suggesting that avoidance motivation[3] was indeed triggered by the BIS. As far as the correlations between perceived discomfort and free recall are concerned, they were all non-reliable, except for one correlation in study 1 with free recall averaged across the two face conditions.

Because our findings on recall are “null results,” we decided to use a Bayesian approach to explore further just how “null” our results in the three studies were. In effect, as claimed by Brydges and Bielak (2020): “Nonsignificant p values derived from null hypothesis significance testing do not distinguish between true null effects or cases where the data are insensitive in distinguishing the hypotheses.” (p. 58). As far as recall rates are concerned, we followed Jeffreys’ (1961) recommendations and found that there was strong evidence in favor of H0[4] in studies 2 and 3 ($BF_{01} = 12.99$ and $BF_{01} = 16.54$), whereas in study, 1 there was moderate support for H0 ($BF_{01} = 6.38$). Turning to discomfort ratings, with BF_{01} equal to 75.66, 29.63, and 40,422.87 in studies 1 to 3 respectively, the evidence in favor of higher levels of perceived discomfort for morphologically deviant stimuli was strong to extremely strong. If we assume that discomfort ratings are indicative of BIS activation, how is it possible to reconcile the finding of strong pseudo-contamination effects on discomfort ratings with the failure to observe any evidence for these effects on recall performance?

A first possibility is that, contrary to our expectations, the different components of the BIS (e.g., affective, cognitive, behavioral components) respond in different ways to identical stimuli, and thus that the higher levels of disgust[5] and/or stronger avoidance induced by some stimuli are not associated with their better memorization. These different components may not be (systematically) interconnected. One interesting study related to this possibility was conducted by Ackerman et al. (2009), who explored attention, memory, and physical disfigurement. The findings showed that disfigured faces capture attention but, at the same time, are not remembered well. Thus, a disjunction was obtained between attention and memory for the same type of stimulus. Another possibility is that evidence for pseudo-contamination effects on avoidance behaviors—which was taken as the basis for anticipating similar effects in memory—is perhaps not as strong as we first thought. Perhaps certain morphological deviations such as obesity or disability are able to activate the BIS, but only in certain contexts, and thus in a more limited way. For example, Lieberman et al. (2012) found that while disgust sensitivity was associated with more negative evaluations of obese people, this was only true for female participants. From a general standpoint, a number of studies related to the BIS have shown that this system is activated differentially in different individuals and that its level of activation is also context-dependent (Schaller & Murray, 2011; Tybur et al., 2020). For instance, in geographical regions of the world where the prevalence of infectious diseases is high, people tend to be more collectivist (Fincher et al., 2008), less extroverted, and less open to experience (Schaller & Murray, 2008). Also, compared to a prepandemic period, the BIS tends to be more highly activated when there is an acute pandemic such as the COVID-19 pandemic, with the result that higher levels of germ aversion and less motivation for social touch are observed (Thiebaut et al., 2021b). Finally, it could be that disgust is a primitive emotional reaction activating motivational behaviors such as avoidance, but that it does not necessarily activate memory mechanisms if the situation is not sufficiently health-threatening. According to Schaller and Duncan (2007): “Disgust may motivate an immediate and impulsive avoidant response, but that’s it. The emotional experience alone cannot compel wariness about future interactions, nor can disgust alone precipitate more planful actions (such as coordinated efforts at quarantine and social exclusion) that help to eliminate the long-term threat posed by possibly parasitized individuals.

---

[3] As commented by an anonymous reviewer, “discomfort ratings” are not by themselves direct measures of avoidance behaviors. We submit that discomfort ratings can serve as a reasonable proxy for the motivation to avoid contact with pathogens (see van Leeuwen and Jaeger (2022) and van Leeuwen & Petersen (2018) for other examples of the use of (dis)comfort ratings with physical contact to index pathogen avoidance).

[4] For the three studies, the alternative hypotheses were that recall would be higher for objects accompanied by morphologically deviant individuals than for objects accompanied by normal individuals (and that the reverse would be true for discomfort ratings). Computations were performed with the jamovi software (the jamovi project (2021). jamovi (Version 1.6) [Computer Software] retrieved from https://www.jamovi.org) and the default prior distribution was used (a two-tailed Cauchy distribution centered on zero with a scaling factor of 0.707).

[5] We want to stress that the levels of disgust evoked by the stimuli in the three studies were not particularly high, as revealed by the three pilot studies. However, except in study 1, the ratings of disgust for the morphologically deviant versions of the faces were all above the midpoint of the scales ($p = .105$ in the pilot study of study 1; $p = .0019$ in the pilot study of study 2 and $p = .0034$ in the pilot study of study 3).

To facilitate these kinds of fitness-relevant behaviors, various cognitive processes must be engaged as well." (p. 296) (but see also Lieberman & Patrick, 2014). Our findings (and others reported below) are in line with these assumptions; the emotion of disgust expressed towards various stimuli does not seem to result unavoidably in the activation of memory processes. Thus, even though it has been found that disgusting things may boost memory more than other negative emotions like fear (Chapman, 2018; Chapman et al., 2013; Charash & McKay, 2002; Croucher et al., 2011; Schienle et al., 2021), it is not always the case that objects presented in close proximity to disgusting stimuli are remembered better than the same objects presented next to non-disgusting stimuli. Certain findings suggest that what is needed is not disgust per se but a health-threatening context. In Fernandes et al.'s study (2017), a memory boost was found for objects presented next to sick faces compared to the objects presented in close proximity to healthy faces. In another study, the same objects were presented in proximity to sick faces but the individuals in this research were told that the sick faces were those of actresses preparing to portray sick people in a TV show, whereas the healthy faces were said to be those of viewers of this TV show. In the latter situation, the potential for contamination was lacking and no memory boost was found for the objects presented with the "fake sick faces" in comparison to the objects presented with the healthy faces. Similarly, in a later study, Fernandes et al. (2021) found that memory performance for objects presented in hands covered with a chocolate and peanut butter spread were remembered better than objects presented in clean hands, but only when the "dirty hands" were described to participants as being due to diarrhea and not when they were described to other participants as being chocolate spread. In addition, Gretz and Huff (2019) found that a noncontagious disease like cancer did not produce a memory advantage for items touched by an actor with cancer compared to items touched by a healthy actor, whereas the same situation involving a contagious disease such as influenza produced a contamination effect in memory. These results suggest that the BIS need not react hypersensitively (Schaller & Duncan, 2007), or, and more probably, that hypersensitive reactions of the BIS undergo cognitive processing which results in better retention of events with *real* (rather than probable) parasite threat.

It is important to acknowledge that our research has some limitations that may restrict its generalizability. First of all, the participants in our studies were mostly female. We know from several studies that women have consistently higher levels of disgust (e.g., Prokop & Jančovičová, 2013, see Al-Shawaf et al., 2018 for a review) as well as higher levels of germ aversion and perceived infectibility than men (e.g., Díaz et al., 2020; Duncan et al., 2009; Makhanova & Shepherd, 2020). Given the large sex asymmetry in our samples, the pattern of results reported in our three studies on levels of discomfort could have been mostly driven by females. Future studies could therefore include samples with a more balanced sex ratio. Second, we considered obesity, scars and burns, and enlarged eyes as morphological deviations, but perhaps these deviations are not threatening enough to cause memory processes to be activated. Future studies should consider non-human animals and other morphological deviations which do not objectively threaten our health but are more similar to an actual disease, such as "acne." Interestingly, one study has found greater levels of avoidance of people with facially visible contagious (e.g., influenza, conjunctivitis) and non-contagious (e.g., acne, eczema) signs of disease than of contagious people with no visible signs (e.g., glandular fever, intestinal worms) (Kouznetsova et al., 2012). Third, even though we did not obtain reliable effects on memory performance using free recall tasks, it is possible that these effects might be observable if other retention measures were used (e.g., recognition, paired associate learning, or source memory) and future studies should attempt to clarify this matter. Fourth, it cannot be excluded that the use of self-report scales to evaluate discomfort might have led participants to exaggerate their responses. Thus, the current work should be complemented by the examination of real behaviors in day-to-day situations. Finally, studies conducted in different cultures are required to make it possible to generalize the present findings.

To conclude, objects jointly presented with people having an infectious disease are remembered better than objects presented together with healthy people. However, when we turn to people having morphological deviations such as obesity and scars and burns on the face or strange eyes, there is no such memory boost for objects shown next to photographs of these individuals as compared to "normal" individuals. At the same time, pseudo-contaminated individual-object pairs cause more discomfort than their normal counterparts. We therefore suggest that the BIS does not seem to activate memory mechanisms in response to certain pseudo-contamination sources which do not involve a risk of infection.

Acknowledgements The authors thank Todd Shackelford and two anonymous reviewers for their constructive comments on previous versions of the manuscript.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Gaëtan Thiebaut, Arnaud Witt, Patrick Bonin, Pavol Prokop, and Alain Méot. The first draft of the manuscript was written by both Gaëtan Thiebaut and Patrick Bonin and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding This work was supported by an ANR Grant "ANR-19-CE28-0005" (Agence Nationale de la Recherche).

Availability of Data and Material The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Code Availability Not applicable.

Declarations

Ethics Approval This study was performed in line with the principles of the Declaration of Helsinki. All the study procedures were approved by the Statutory Ethics Committee of the University of Clermont Auvergne.

Consent to Participate Written informed consent was obtained from all participants before the beginning of the study.

Consent for Publication Not applicable.

Conflicts of Interest The authors declare no competing interests.

References

Ackerman, J. M., Hill, S. E., & Murray, D. R. (2018). The behavioral immune system: Current concerns and future directions. *Social and Personality Psychology Compass, 12*(2), e12371. https://doi.org/10.1111/spc3.12371

Ackerman, J. M., Vaughn Becker, D. V., Mortensen, C. R., Sasaki, T., Neuberg, S. L., & Kenrick, D. T. (2009). A pox on the mind: Disjunction of attention and memory in the processing of physical disfigurement. *Journal of Experimental Social Psychology, 45*(3), 478–485. https://doi.org/10.1016/j.jesp.2008.12.008

Al-Shawaf, L., Conroy-Beam, D., Asao, K., & Buss, D. M. (2016). Human emotions: An evolutionary psychological perspective. *Emotion Review, 8*(2), 173–186. https://doi.org/10.1177/1754073914565518

Al-Shawaf, L., Lewis, D. M. G., & Buss, D. M. (2018). Sex differences in disgust: Why are women more easily disgusted than men? *Emotion Review, 10*(2), 149–160. https://doi.org/10.1177/1754073917709940

Allen, J. E., & Wynn, T. A. (2011). Evolution of Th2 immunity: A rapid repair response to tissue destructive pathogens. *PLoS Pathogens, 7*(5), e1002003. https://doi.org/10.1371/journal.ppat.1002003

Axelsson, J., Sundelin, T., Lasselin, J., & Lekander, M. (2018a). How can we improve identification of contagious individuals? Factors influencing sickness detection. *Proceedings of the Royal Society B, 285*(1889), 20182005. https://doi.org/10.1098/rspb.2018.2005

Axelsson, J., Sundelin, T., Olsson, M. J., Sorjonen, K., Axelsson, C., Lasselin, J., & Lekander, M. (2018b). Identification of acutely sick people and facial cues of sickness. *Proceedings of the Royal Society b: Biological Sciences, 285*(1870), 20172430. https://doi.org/10.1098/rspb.2017.2430

Barrett, H. C., & Broesch, J. (2012). Prepared social learning about dangerous animals in children. *Evolution and Human Behavior, 33*(5), 499–508. https://doi.org/10.1016/j.evolhumbehav.2012.01.003

Bonin, P., & Bugaiska, A. (2014). « Survivre pour se souvenir » Une approche novatrice de la mémoire humaine: La mémoire adaptative. ["Surviving to remember" : An innovative approach to human memory: Adaptive memory]. *L'année Psychologique, 114*(3), 571–610. https://doi.org/10.3917/anpsy.143.0571

Bonin, P., Thiebaut, G., Witt, A., & Méot, A. (2019). Contamination is "good" for your memory! Further evidence for the adaptive view of memory. *Evolutionary Psychological Science, 5*(3), 300–316. https://doi.org/10.1007/s40806-019-00188-y

Brydges, C. R., & Bielak, A. A. (2020). A Bayesian analysis of evidence in support of the null hypothesis in gerontological psychology (or lack thereof). *The Journals of Gerontology: Series B, 75*(1), 58–66. https://doi.org/10.1093/geronb/gbz033

Cahnman, W. J. (1968). The stigma of obesity. *The Sociological Quarterly, 9*(3), 283–299. https://doi.org/10.1111/j.1533-8525.1968.tb01121.x

Chapman, H. A. (2018). Enhanced recall of disgusting relative to frightening photographs is not due to organisation. *Cognition and Emotion, 32*(6), 1220–1230. https://doi.org/10.1080/02699931.2017.1394817

Chapman, H. A., Johannes, K., Poppenk, J. L., Moscovitch, M., & Anderson, A. K. (2013). Evidence for the differential salience of disgust and fear in episodic memory. *Journal of Experimental Psychology: General, 142*(4), 1100–1112. https://doi.org/10.1037/a0030503

Chapman, H. A., Kim, D. A., Susskind, J. M., & Anderson, A. K. (2009). In bad taste: Evidence for the oral origins of moral disgust. *Science, 323*(5918), 1222–1226. https://doi.org/10.1126/science.1165565

Charash, M., & McKay, D. (2002). Attention bias for disgust. *Journal of Anxiety Disorders, 16*(5), 529–541. https://doi.org/10.1016/s0887-6185(02)00171-8

Chen, E. Y., & Brown, M. (2005). Obesity stigma in sexual relationships. *Obesity Research, 13*(8), 1393–1397. https://doi.org/10.1038/oby.2005.168

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers, 25*(2), 257–271. https://doi.org/10.3758/BF03204507

Crandall, C. S. (1994). Prejudice against fat people: Ideology and self-interest. *Journal of Personality and Social Psychology, 66*(5), 882–894. https://doi.org/10.1037/0022-3514.66.5.882

Crandall, C. S., & Moriarty, D. (1995). Physical illness stigma and social rejection. *British Journal of Social Psychology, 34*(1), 67–83. https://doi.org/10.1111/j.2044-8309.1995.tb01049.x

Croucher, C. J., Calder, A. J., Ramponi, C., Barnard, P. J., & Murphy, F. C. (2011). Disgust enhances the recollection of negative emotional images. *PLoS ONE, 6*(11), e26571. https://doi.org/10.1371/journal.pone.0026571

Curtis, V., & de Barra, M. (2018). The structure and function of pathogen disgust. *Philosophical Transactions of the Royal Society b: Biological Sciences, 373*(1751), 20170208. https://doi.org/10.1098/rstb.2017.0208

Curtis, V., Aunger, R., & Rabie, T. (2004). Evidence that disgust evolved to protect from risk of disease. *Proceedings of the Royal Society of London. Series b: Biological Sciences, 271*(suppl_4), S131–S133. https://doi.org/10.1098/rsbl.2003.0144

Dezecache, G., Frith, C. D., & Deroy, O. (2020). Pandemics and the great evolutionary mismatch. *Current Biology, 30*(10), R417–R429. https://doi.org/10.1016/j.cub.2020.04.010

Díaz, A., Beleña, Á., & Zueco, J. (2020). The role of age and gender in perceived vulnerability to infectious diseases. *International Journal of Environmental Research and Public Health, 17*(2), 485. https://doi.org/10.3390/ijerph17020485

Duncan, L. A., & Schaller, M. (2009). Prejudicial attitudes toward older adults may be exaggerated when people feel vulnerable to infectious disease: Evidence and implications. *Analyses of Social Issues and Public Policy, 9*(1), 97–115. https://doi.org/10.1111/j.1530-2415.2009.01188.x

Duncan, L. A., Schaller, M., & Park, J. H. (2009). Perceived vulnerability to disease: Development and validation of a 15-item self-report instrument. *Personality and Individual Differences, 47*(6), 541–546. https://doi.org/10.1016/j.paid.2009.05.001

Fančovičová, J., Szikhart, M., & Prokop, P. (2020). Learning about mushrooms is influenced by survival processing. *The American Biology Teacher, 82*(8), 529–534. https://doi.org/10.1525/abt.2020.82.8.529

Faul, F., Erdfelder, E., Lang, A. -G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods, 39*(2), 175–191. https://doi.org/10.3758/bf03193146

Fernandes, N. L., Pandeirada, J. N., & Nairne, J. S. (2021). The mnemonic tuning for contamination: A replication and extension study using more ecologically valid stimuli. *Evolutionary Psychology, 19*(1), 1474704920946234. https://doi.org/10.1177/1474704920946234

Fernandes, N. L., Pandeirada, J. N., Soares, S. C., & Nairne, J. S. (2017). Adaptive memory: The mnemonic value of contamination. *Evolution and Human Behavior, 38*(4), 451–460. https://doi.org/10.1016/j.evolhumbehav.2017.04.003

Fincher, C. L., Thornhill, R., Murray, D. R., & Schaller, M. (2008). Pathogen prevalence predicts human cross-cultural variability in individualism/collectivism. *Proceedings of the Royal Society B, 275*, 1279–1285. https://doi.org/10.1098/rspb.2008.0094

Frazer, J. G. (1959). *The new golden bough: A study in magic and religion* (abridged ed.). New York: Macmillan (Edited by T. H. Caster, 1922; Original work published 1890).

Gretz, M. R., & Huff, M. J. (2019). Did you wash your hands? Evaluating memory for objects touched by healthy individuals and individuals with contagious and noncontagious diseases. *Applied Cognitive Psychology, 33*(6), 1271–1278. https://doi.org/10.1002/acp.3604

Härkönen, J., Räsänen, P., & Näsi, M. (2011). Obesity, unemployment, and earnings. *Nordic Journal of Working Life Studies, 1*(2), 23–38. https://doi.org/10.19154/njwls.v1i2.2343

Haselton, M. G., & Buss, D. M. (2000). Error management theory: A new perspective on biases in cross-sex mind reading. *Journal of Personality and Social Psychology, 78*(1), 81–91. https://doi.org/10.1037//0022-3514.78.1.81

Hebl, M. R., & Mannix, L. M. (2003). The weight of obesity in evaluating others: A mere proximity effect. *Personality and Social Psychology Bulletin, 29*(1), 28–38. https://doi.org/10.1177/0146167202238369

Houston, V., & Bull, R. (1994). Do people avoid sitting next to someone who is facially disfigured? *European Journal of Social Psychology, 24*(2), 279–284. https://doi.org/10.1002/ejsp.2420240205

Inhorn, M. C., & Brown, P. J. (1990). The anthropology of infectious disease. *Annual Review of Anthropology, 19*(1), 89–117. https://doi.org/10.1146/annurev.an.19.100190.000513

Jamrozik, A., Oraa Ali, M., Sarwer, D. B., & Chatterjee, A. (2019). More than skin deep: Judgments of individuals with facial disfigurement. *Psychology of Aesthetics, Creativity, and the Arts, 13*(1), 117–129. https://doi.org/10.1037/aca0000147

Jeffreys, H. (1961). *The theory of probability*. Oxford University Press.

Jersild, A. T. (1927). Mental set and shift. *Archives of Psychology, 14*(89), 81.

Kouznetsova, D., Stevenson, R. J., Oaten, M. J., & Case, T. I. (2012). Disease-avoidant behaviour and its consequences. *Psychology & Health, 27*(4), 491–506. https://doi.org/10.1080/08870446.2011.603424

Kurzban, R., & Leary, M. R. (2001). Evolutionary origins of stigmatization: The functions of social exclusion. *Psychological Bulletin, 127*(2), 187–208. https://doi.org/10.1037/0033-2909.127.2.187

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H., Hawk, S. T., & Van Knippenberg, A. D. (2010). Presentation and validation of the Radboud Faces Database. *Cognition and Emotion, 24*(8), 1377–1388. https://doi.org/10.1080/02699930903485076

Lesaffre, B. (2008). Les maladies infectieuses émergentes, un défi « global ». [Emerging infectious diseases, a "global" challenge]. *Annales Des Mines - Responsabilité Et Environnement, 51*(3), 7–14. https://doi.org/10.3917/re.051.0007

Lieberman, D., & Patrick, C. (2014). Are the behavioral immune system and pathogen disgust identical? *Evolutionary Behavioral Sciences, 8*(4), 244–250. https://doi.org/10.1037/ebs0000018

Lieberman, D. L., Tybur, J. M., & Latner, J. D. (2012). Disgust sensitivity, obesity stigma, and gender: Contamination psychology predicts weight bias for women, not men. *Obesity, 20*(9), 1803–1814. https://doi.org/10.1038/oby.2011.247

Lochmiller, R. L., & Deerenberg, C. (2000). Trade-offs in evolutionary immunology: Just what is the cost of immunity? *Oikos, 88*(1), 87–98. https://doi.org/10.1034/j.1600-0706.2000.880110.x

Lund, E. M., & Boggero, I. A. (2014). Sick in the head? Pathogen concerns bias implicit perceptions of mental illness. *Evolutionary Psychology, 12*(4), 706–718. https://doi.org/10.1177/147470491401200403

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska Directed Emotional Faces (KDEF). *CD ROM from Department of Clinical Neuroscience, Psychology Section, Karolinska Institutet, 91*(630), 2–2. https://doi.org/10.1037/t27732-000

Makhanova, A., & Shepherd, M. A. (2020). Behavioral immune system linked to responses to the threat of COVID-19. *Personality and Individual Differences, 167*, 110221. https://doi.org/10.1016/j.paid.2020.110221

Makhanova, A., Shepherd, M. A., Plant, E. A., Gerend, M. A., & Maner, J. K. (2022). Childhood illness as an antecedent of perceived vulnerability to disease. *Evolutionary Behavioral Sciences, 16*(1), 53–66. https://doi.org/10.1037/ebs0000238

Mauss, M. (1972). *A general theory of magic*. (R. Brains, trans). New York: Norton.

Moore, P. (2020). *Le petit livre des grandes épidémies: Tout ce que vous devez savoir pour vous protéger.* [The little book of major epidemics: Everything you need to know to protect yourself.] Belin éditeur.

Murray, D. R., & Schaller, M. (2016). The behavioral immune system: Implications for social cognition, social interaction, and social influence. In J. M. Olson & M. P. Zanna (Eds.), *Advances in Experimental Social Psychology* (Vol. 53, pp. 75–129). Elsevier Academic Press.

Nairne, J. S. (2010). Adaptive memory: Evolutionary constraints on remembering. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 53, pp. 1–32). Burlington, MA: Academic Press. https://doi.org/10.1016/S0079-7421(10)53001-9

Nairne, J. S. (2015). Adaptive memory: Novel findings acquired through forward engineering. In D. S. Lindsay, C. M. Kelley, A. P. Yonelinas, & H. L. Roediger (Eds.), *Remembering: Attributions, processes, and control in human memory ?* (pp. 3–14). Psychology Press.

Nairne, J. S. (2016). Adaptive memory: Fitness-relevant "tunings" help drive learning and remembering. In C. D. Geary & B. D. Berch (Eds.), *Evolutionary Perspectives on Child Development and Education* (pp. 251–269). Springer International.

Nairne, J. S., & Pandeirada, J. N. S. (2008). Adaptive memory: Remembering with a stone-age brain. *Current Directions in Psychological Science, 17*(4), 239–243. https://doi.org/10.1111/j.1467-8721.2008.00582.x

Nairne, J. S., Pandeirada, J. N. S., & Thompson, S. R. (2008). Adaptive memory: The comparative value of survival processing. *Psychological Science, 19*(2), 176–180. https://doi.org/10.1111/j.1467-9280.2008.02064.x

Nairne, J. S., Thompson, S. R., & Pandeirada, J. N. S. (2007). Adaptive memory: Survival processing enhances retention. *Journal of*

Experimental Psychology: Learning, Memory, and Cognition, 33(2), 263–273. https://doi.org/10.1037/0278-7393.33.2.263

Nesse, R. M. (2005). Natural selection and the regulation of defenses. *Evolution and Human Behavior, 26*(1), 88–105. https://doi.org/10.1016/j.evolhumbehav.2004.08.002

Nussinson, R., Mentser, S., & Rosenberg, N. (2018). Sensitivity to deviance and to dissimilarity: Basic cognitive processes under activation of the behavioral immune system. *Evolutionary Psychology, 16*(4), 1474704918813433. https://doi.org/10.1177/1474704918813433

Oaten, M., Stevenson, R. J., & Case, T. I. (2009). Disgust as a disease-avoidance mechanism. *Psychological Bulletin, 135*(2), 303–321. https://doi.org/10.1037/a0014823

Park, J., Faulkner, J., & Schaller, M. (2003). Evolved disease-avoidance processes and contemporary anti-social behavior: Prejudicial attitudes and avoidance of people with physical disabilities. *Journal of Nonverbal Behavior, 27*(2), 65–87. https://doi.org/10.1023/A:1023910408854

Park, J. H., Schaller, M., & Crandall, C. S. (2007). Pathogen-avoidance mechanisms and the stigmatization of obese people. *Evolution and Human Behavior, 28*(6), 410–414. https://doi.org/10.1016/j.evolhumbehav.2007.05.008

Prokop, P., & Fančovičová, J. (2017). Animals in dangerous postures enhance learning, but decrease willingness to protect animals. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(9), 6069–6077. https://doi.org/10.12973/eurasia.2017.01000a

Prokop, P., & Jančovičová, M. (2013). Disgust sensitivity and gender differences: An initial test of the parental investment hypothesis. *Problems of Psychology in the 21st Century, 7*(7), 40–48. https://doi.org/10.33225/ppc/13.07.40

Richtel, M. (2019). *La grande histoire du système immunitaire.* [The great story of the immune system.] Harper Collins.

Roe, D. A., & Eickwort, K. R. (1976). Relationships between obesity and associated health factors with unemployment among low income women. *Journal of the American Medical Women's Association (1972), 31*(5), 193–204.

Rossion, B., & Pourtois, G. (2004). Revisiting Snodgrass and Vanderwart's object pictorial set: The role of surface detail in basic-level object recognition. *Perception, 33*(2), 217–236. https://doi.org/10.1068/p5117

Rozin, P., Millman, L., & Nemeroff, C. (1986). Operation of the laws of sympathetic magic in disgust and other domains. *Journal of Personality and Social Psychology, 50*(4), 703–712. https://doi.org/10.1037/0022-3514.50.4.703

Rumsey, N., Bull, R., & Gahagan, D. (1982). The effect of facial disfigurement on the proxemic behavior of the general public. *Journal of Applied Social Psychology, 12*(2), 137–150. https://doi.org/10.1111/j.1559-1816.1982.tb00855.x

Ryan, S., Oaten, M., Stevenson, R. J., & Case, T. I. (2012). Facial disfigurement is treated like an infectious disease. *Evolution and Human Behavior, 33*(6), 639–646. https://doi.org/10.1016/j.evolhumbehav.2012.04.001

Sacco, D. F., Young, S. G., & Hugenberg, K. (2014). Balancing competing motives: Adaptive trade-offs are necessary to satisfy disease avoidance and interpersonal affiliation goals. *Personality and Social Psychology Bulletin, 40*(12), 1611–1623. https://doi.org/10.1177/0146167214552790

Salthouse, T. A., Toth, J. P., Hancock, H. E., & Woodard, J. L. (1997). Controlled and automatic forms of memory and attention: Process purity and the uniqueness of age-related influences. *The Journals of Gerontology Series b: Psychological Sciences and Social Sciences, 52*(5), 216–228. https://doi.org/10.1093/geronb/52B.5.P216

Schaller, M. (2011). The behavioural immune system and the psychology of human sociality. *Philosophical Transactions of the Royal Society b: Biological Sciences, 366*(1583), 3418–3426. https://doi.org/10.1098/rstb.2011.0029

Schaller, M. (2014). When and how disgust is and is not implicated in the behavioral immune system. *Evolutionary Behavioral Sciences, 8*(4), 251–256. https://doi.org/10.1037/ebs0000019

Schaller, M. (2016). The behavioral immune system. In D. M. Buss (Ed.), *The Handbook of Evolutionary Psychology* (2nd ed., Vol. 1, pp. 206–224). Wiley.

Schaller, M., & Duncan, L. A. (2007). The behavioral immune system: Its evolution and social psychological implications. In J. P. Forgas, M. G. Haselton, & W. von Hippel (Eds.), *Evolution and the social mind: Evolutionary psychology and social cognition* (pp. 293–307). Psychology Press.

Schaller, M., & Murray, D. R. (2008). Pathogens, personality, and culture: Disease prevalence predicts worldwide variability in sociosexuality, extraversion, and openness to experience. *Journal of Personality and Social Psychology, 95*(1), 212–221. https://doi.org/10.1037/0022-3514.95.1.212

Schaller, M., & Murray, D. R. (2011). Infectious disease and the creation of culture. In M. J. Gelfand, C.-Y. Chiu, & Y.-Y. Hong (Eds.), *Advances in culture and psychology* (pp. 99–151). Oxford University Press.

Schaller, M., & Park, J. H. (2011). The behavioral immune system (and why it matters). *Current Directions in Psychological Science, 20*(2), 99–103. https://doi.org/10.1177/0963721411402596

Schienle, A., Potthoff, J., Schönthaler, E., & Schlintl, C. (2021). Disgust-related memory bias in children and adults. *Evolutionary Psychology, 19*(2), 1474704921996585. https://doi.org/10.1177/1474704921996585

Shakhar, K. (2019). The inclusive behavioral immune system. *Frontiers in Psychology, 10*, 1004. https://doi.org/10.3389/fpsyg.2019.01004

Shanmugarajah, K., Gaind, S., Clarke, A., & Butler, P. E. (2012). The role of disgust emotions in the observer response to facial disfigurement. *Body Image, 9*(4), 455–461. https://doi.org/10.1016/j.bodyim.2012.05.003

Sompayrac, L. M. (2016). *How the immune system works* (5th ed.). John Wiley & Sons.

Spector, A., & Biederman, I. (1976). Mental set and mental shift revisited. *The American Journal of Psychology, 89*(4), 669–679. https://doi.org/10.2307/1421465

Stone, A., & Wright, T. (2013). When your face doesn't fit: Employment discrimination against people with facial disfigurements. *Journal of Applied Social Psychology, 43*(3), 515–526. https://doi.org/10.1111/j.1559-1816.2013.01032.x

Sundelin, T., Karshikoff, B., Axelsson, E., Olgart Höglund, C. O., Lekander, M., & Axelsson, J. (2015). Sick man walking: Perception of health status from body motion. *Brain, Behavior, and Immunity, 48*, 53–56. https://doi.org/10.1016/j.bbi.2015.03.007

Thiebaut, G., Méot, A., Witt, A., Prokop, P., & Bonin, P. (2021a). The behavioral immune system: How does it contribute to our understanding of human behavior? . In A. M. Columbus (Ed.), *Advances in Psychology Research* (Vol. 144., pp. 1–59). New York: Nova Science.

Thiebaut, G., Méot, A., Witt, A., Prokop, P., & Bonin, P. (2021b). "Touch me if you can!": Individual differences in disease avoidance and social touch. *Evolutionary Psychology, 19*(4), 14747049211056160. https://doi.org/10.1177/14747049211056159

Troisi, A. (2020). Fear of COVID-19: Insights from evolutionary behavioral science. *Clinical Neuropsychiatry, 17*(2), 72–75. https://doi.org/10.36131/CN20200207

Tybur, J. M., Lieberman, D., & Griskevicius, V. (2009). Microbes, mating, and morality: Individual differences in three functional domains of disgust. *Journal of Personality and Social Psychology, 97*(1), 103–122. https://doi.org/10.1037/a0015474

Tybur, J. M., Lieberman, D., Fan, L., Kupfer, T. R., & de Vries, R. E. (2020). Behavioral immune trade-offs: Interpersonal value relaxes social pathogen avoidance. *Psychological Science, 31*(10), 1211–1221. https://doi.org/10.1177/0956797620960011

van Leeuwen, F., & Jaeger, B. (2022). Pathogen disgust sensitivity: Individual differences in pathogen perception or pathogen avoidance? *Motivation and Emotion, 46*, 394–403. https://doi.org/10.1007/s11031-022-09937-2

van Leeuwen, F., & Petersen, M. B. (2018). The behavioral immune system is designed to avoid infected individuals, not outgroups. *Evolution and Human Behavior, 39*(2), 226–234. https://doi.org/10.1016/j.evolhumbehav.2017.12.003

Vartanian, L. R. (2010). Disgust and perceived control in attitudes toward obese people. *International Journal of Obesity, 34*(8), 1302–1307. https://doi.org/10.1038/ijo.2010.45

Vartanian, L. R., Trewartha, T., & Vanman, E. J. (2016). Disgust predicts prejudice and discrimination toward individuals with obesity. *Journal of Applied Social Psychology, 46*(6), 369–375. https://doi.org/10.1111/jasp.12370