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Adaptive memory: The mnemonic value of contamination

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ABSTRACT

Humans likely evolved an adaptive disease avoidance system, the Behavioral Immune System, to mitigate the fitness costs posed by pathogens. This system is specially attuned to cues connoting infection risk: When perceived, these cues drive affective, cognitive, and behavioral responses, which work in an articulated way to enhance the organism's chances of survival. The current work investigated the cognitive aspect of this system, specifically if human memory preferentially retains potentially contaminated items. Participants were shown pictures of objects that were touched by sick or healthy people. Each object was linked to verbal descriptions (Experiment 1a and 1b) or visual cues (faces; Experiment 2 and 3) about the person initiating the contact. During encoding participants were required to decide whether each object had been touched by a sick or a healthy person. Then, after a short distractor task, a surprise free recall task for the objects was given. In all experiments, objects touched by sick people were remembered better than those touched by healthy people. This mnemonic advantage was obtained using the same procedure in two different countries suggesting its robustness. Finally, it seems not to rely on the visual cues accompanying the objects, but rather on whether the context presented establishes a real opportunity for contamination. These results suggest that memory might play a key role in the Behavioral Immune System.

1. Introduction

Throughout evolutionary history, humans repeatedly faced a wide variety of pathogenic microorganisms that threatened their chances of survival and reproduction, and consequently imposed strong selection pressures (Fumagalli et al., 2011; Tooby, 1982; Tybur, Lieberman, & Griskevicius, 2009). In response to this adaptive problem, humans evolved a set of interlocking mechanisms: the *Biological Immune (BIO) System* - designed to detect and destroy pathogens present in the body (Parham, 2014), and the *Behavioral Immune (BEH) System* - designed to avoid contact with sources of potential infection (Murray & Schaller, 2016; Schaller, 2006; Schaller & Duncan, 2007).

Adaptive disease avoidance systems have been found across a broad range of animal species (Moore, 2002; Prokop & Fedor, 2013). For example, animals avoid grazing in faecally contaminated areas (e.g., alpine ibex: Brambilla, von Hardenberg, Kristo, Bassano, & Bogliani, 2013; sheep: Cooper, Gordon, & Pike, 2000; horses: Fleurance et al., 2007; reindeer: Van der Wal, Irvine, Stien, Shepherd, & Albon, 2000), avoid and respond negatively to pathogen-carrying conspecifics (e.g., spiny lobsters: Behringer, Butler, & Shields, 2006; chimpanzees: Goodall, 1986; mice: Kavaliers & Colwell, 1995; bullfrog tadpoles: Kiesecker, Skelly, Beard, & Preisser, 1999), and groom themselves and each other to remove parasites (e.g., cats: Eckstein & Hart, 2000; ungulates: Mooring, Blumstein, & Stoner, 2004; insects: Zhukovskaya, Yanagawa, & Forschler, 2013). Similarly, human beings display affective (disgust), cognitive (e.g., attention), and behavioral (avoidance) responses in reaction to potential contaminants (Schaller & Duncan, 2007; Schaller & Park, 2011).

The perception of disease-connoting cues is likely to trigger the emotional experience of disgust, a “basic” emotion universally expressed and recognized across cultures (Curtis & Biran, 2001; Curtis, de Barra, & Aunger, 2011). There seems to be a straightforward relationship between disgust elicitors and transmission paths of pathogens, because many of the things people find disgusting reliably accommodate harmful infectious disease-causing agents (Curtis & Biran, 2001; Oaten, Stevenson, & Case, 2009; Tybur, Lieberman, Kurzban, & DiScioli, 2013). Disgust is triggered by a broad range of stimuli, such as foods (e.g., spoilt, contaminated, and unfamiliar food), bodily products (feces, urine, vomit, phlegm, and semen), potentially contaminating animals (e.g., ticks, worms, flies, rats), inappropriate sexual behaviors, poor hygiene, body envelope violations (blood, gore, and deformity), death, and observable cues that suggest possible infection (Oaten et

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al., 2009; Rozin, Haidt, & McCauley, 2008). This emotional reaction is generally believed to drive a pathogen avoidance behavior in humans, constituting a key component of the BEH system (Curtis et al., 2011; Oaten et al., 2009).

Memory, similar to our physical systems, evolved to solve adaptive problems related to survival and reproduction, and should, therefore, be selectively "tuned" to process and remember fitness-relevant information (Nairne & Pandeirada, 2008). In line with this proposal, several mnemonic phenomena have been revealed. For example, people remember information better when it has been previously processed in survival-related scenarios (e.g., Nairne, Pandeirada, & Thompson, 2008; Nairne, Thompson, & Pandeirada, 2007) or when the encoding condition has a fitness-relevant dimension (Nairne, Pandeirada, Gregory, & Van Arsdall, 2009). People are also particularly good at retaining animate items, as compared to inanimate items, which are arguably more relevant to one's survival and reproduction (e.g., Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013). Regarding reproduction, recent work has reported that females remember the faces of males better when these were previously considered in a long-term mating context as compared to a long-term worker context (Pandeirada, Fernandes, Nairne, Marinho, & Vasconcelos, 2015). Threatening stimuli also tend to be better remembered. For example, females tend to remember well the spatial location of highly attractive members of their own gender – potential intrasexual rivals that can threaten their own reproductive success (Becker, Kenrick, Guerin, & Maner, 2005; Maner, Miller, Rouby, & Gailliot, 2009). Faces of male outgroup members displaying an angry expression, who are usually judged as posing greater risk to physical safety, are better remembered than those belonging to ingroup members (Ackerman et al., 2006). Other studies have also demonstrated that children preferentially learn and remember socially transmitted fitness-relevant information (e.g., which plants are edible and which animals are dangerous) compared with survival-irrelevant information (e.g., animal naming and diet) (Barrett & Broesch, 2012; Wertz & Wynn, 2014). Given their clear relevance to fitness, disgusting and disease-relevant stimuli should also be remembered well preventing people from initiating contact and, thus, avoiding a potential opportunity for contamination.

Even though some research already has focused on understanding the effects of disgust on memory, more work is needed to fully characterize this relation (Al-Shawaf, Conroy-Beam, Asao, & Buss, 2015). For example, it has been reported that disgusting words and images are better retained than frightening ones (Charash & McKay, 2002; Croucher, Calder, Ramponi, Barnard, & Murphy, 2011). People displaying behaviors perceived as disgusting are also remembered well. In the work by Bell and Buchner (2010), participants were shown photographs of faces associated with descriptions of disgust (e.g., "K.S. is a laborer. To save money, he cooks dog food in a big pot to eat it all by himself.", p. 32), neutral (e.g., "J.L. is a gardener. He often orders lunch at work from a local Italian restaurant, because he cannot cook very well.", p. 34), and of pleasant behavior (e.g., "O.H. is a miller. When he has friends over, the smell of freshly baked cakes and cookies fills his apartment.", p. 34). Following the encoding phase in which participants had to rate the likability of each person, faces were presented again and participants were asked to identify the type of descriptor previously presented with the face (disgusting, neutral, or pleasant). Source memory for the faces previously associated with the disgusting behaviors was enhanced compared with source memory for other types of descriptors.

The mnemonic advantage for disgusting stimuli remains significant even when arousal, valence, distinctiveness and attention are controlled at encoding. More specifically, Chapman, Johannes, Poppenk, Moscovitch, and Anderson (2013) found enhanced memory for disgusting stimuli (e.g., certain insects, body products, disease, and deformity) compared to fearful (e.g., human or animal threat, disasters, and social unrest) and neutral stimuli (e.g., household objects). Further, a recent study has shown that information on disease carriers, specifically human parasites, are better remembered than non-disease carriers such as hormones (Prokop, Fančovičová, & Fedor, 2014).

Again, these mnemonic biases or tunings are sensible given that disgusting objects often carry the potential for contamination as they are closely linked to sources of disease. Interestingly, people also treat objects that have been in contact with other disgusting objects in a special way by assuming that some of the contaminating properties of the disgusting objects can be transferred to other objects through this contact (Rozin & Fallon, 1987). This 'magical' spread of contamination is referred to as the "law of contagion", one of the laws of sympathetic magic (Frazer, 1959; Mauss, 1972; Tylor, 1974), which holds that "once in contact, always in contact" (Frazer, 1959, p. 12 as cited in Coughtrey, Shafran, & Rachman, 2014).

Empirically, studies have shown that people evaluate as less favorable and are unwilling to interact with objects that have simply come in contact with disgusting things (e.g., Morales & Fitzsimons, 2007; Rozin, Millman, & Nemeroff, 1986). For example, people were reluctant to drink juice if a sterilized dead cockroach was briefly dipped in it (Rozin et al., 1986), to eat foods that had been tasted by either unsavory or disliked persons (Rozin, Nemeroff, Wane, & Sherrod, 1989), and to eat trout after a disgust-evoking experience (a trout dissection), particularly if participants were high anxious and disgust-sensitive (Randler, Desch, im Kampe, Wüst-Ackermann, Wilde, & Prokop, 2017). In a different experiment, Rozin et al. (1989) also asked participants to imagine wearing a laundered sweater belonging to different people (e.g., a friend, a lover, a dislike, or an unsavory). People rated the sweater that previously belonged to a person they disliked, or to a person seen as unsavory, as being significantly more unpleasant. Similarly, Argo, Dahl, and Morales (2006) reported that knowing that a piece of clothing had been touched and tried on by strangers, negatively affected both a consumer's evaluation and intention to purchase it.

More recently, Morales and Fitzsimons (2007) tackled the law of contagion by presenting participants with a set of products in contact with each other in a grocery cart. The authors reported that, when a product deemed to be disgusting (e.g., feminine napkins) was in direct physical contact with a neutral product (e.g., cookies, notebook paper), consumers experienced higher levels of disgust which, in turn, lessened both their willingness to try the neutral product and the judgments of its quality. Propensity for this type of response is consistent with an evolutionary perspective, because organisms that successfully avoid potentially contaminated items are more likely to survive and reproduce.

In the present work, inspired by the law of contagion, we explored a possible mnemonic tuning for potentially contaminating items as proposed by Nairne and Pandeirada (2008; see also, Nairne, 2015). Specifically, we predicted that objects that have come in contact with disgusting or disease-signaling cues should show enhanced retention compared to when those same objects are associated with neutral types of cues. Previous work demonstrating a mnemonic advantage for disgusting items typically compares memory performance for different items (e.g., disgusting vs. non-disgusting items) introducing potential item-selection concerns (that is, uncontrolled properties that might exist between items). In our proposed experiments, everyone is asked to remember exactly the same items; what differed were the cues associated with each object indicating whether it had been in contact with a potential source of contamination or not. In the first experiment, object pictures were presented along with a descriptor that indicated whether that object had been touched by a sick or a healthy person. This experiment was run initially in a sample of undergraduate students at Purdue University (USA; Experiment 1a) and was then replicated in a sample of students from the University of Aveiro (Portugal; Experiment 1b). In Experiments 2 and 3, object pictures were presented with faces containing signs of contagious diseases (sick faces) or faces containing no such cues (healthy faces). Importantly, in Experiment 2, the sick faces were described as depicting actual sick people, whereas in Experiment 3 they were described as actresses who were preparing to portray sick people in a TV-show. Thus, in the first case, the "sick" faces represented a potential source of contamination but in the second, although the faces were exactly the same, they did not convey potential for contamination. In all experiments, participants were given a final surprise memory task in which they were asked to recall the names of the objects associated with the cues.

2. Experiment 1a

In Experiment 1a, people were shown pictures of everyday objects along with a descriptor signifying the health status of a person who had recently "touched" the object. For example, a picture of a ball might be shown along with the statement "person with a constant cough" or the statement "person with a straight nose." After every third item, the three preceding items were shown again and people were required to classify whether each had been touched by a sick or a healthy person. This immediate test was included simply to ensure that people paid attention to the descriptor. After a series of these presentations, and after a short distractor period, everyone was given a surprise free recall test for all of the presented objects (see Fig. 1 for a schematic illustration of the procedure). Of main interest was whether people would remember more of the items touched by a sick person.

2.1. Method

2.1.1. Participants

Thirty-eight undergraduate students (females = 16) from Purdue University (USA) participated in exchange for course credits. Data from five other participants were excluded, three due to low immediate memory performance (<60% correct), and two others due to low performance on the distractor task (<15% correct).

2.1.2. Materials

2.1.2.1. Objects. Thirty black-and-white line drawings of objects that could be easily manipulated by people were selected from the Snodgrass and Vanderwart (1980) picture set. According to the same norms, the average name agreement for these objects was 95.9% ($SD = 6.99$).

2.1.2.2. Sentences. A set of 10 sentences of equivalent length, $t(8) = 1.59$, $p = 0.15$, was created with 5 describing signs and/or symptoms of a sick person and another 5 referring to "neutral" sentences describing characteristics of a person (see Table 1); the latter were indicated to the participants as being descriptors of a "healthy" person.

Table 1
Sick and healthy descriptors used in Experiments 1a and 1b.

Sick	Healthy
person with a high fever	person with a round face
person with a sore throat	person with a straight nose
person with a runny nose	person with brown hair
person with a rash on the skin	person with green eyes
person with a constant cough	person with long fingers

2.1.2.3. Stimulus. Each stimulus was composed of an object picture and a descriptor. The combination of the descriptor and the object was randomly determined for each participant.

2.1.3. Procedure

A simple within-subject design was used: Each participant processed and recalled objects associated either with sick or healthy descriptors. Participants were tested on individual computers running the *software E-prime 2.0 Professional* (Schneider, Eschman, & Zuccolotto, 2002) in sessions that included up to four people. Each session lasted approximately 20 min. On arrival at the laboratory, after consenting to participate, participants were randomly assigned to one of the two counterbalancing versions of the experiment (see below).

The initial instructions informed participants about the nature of task, and also about the immediate memory task, as follows:

> "In this task, you will be asked to remember objects that have been touched by different people—some sick with a deadly disease and others who are healthy. Throughout the experiment, you will see pictures of objects with a short description written below. This short description will give you a clue about whether the person who touched the item was sick or healthy. You will need to decide whether the item was touched by a sick or healthy person and then remember this information for a memory test. Objects and their corresponding short descriptions will be presented one at a time, in sets of three. After each set of three, the objects will appear again and you will be asked to remember whether each was touched by a sick or a healthy person. If the person who touched the object was sick, press the "Z" key at this time. If the person was healthy, press the "M" key. After you have entered your responses for each item, a new set of three objects will be presented."

Participants were also warned they would have only 5 s to view each stimulus and 5 s to make their memory decision. Throughout the

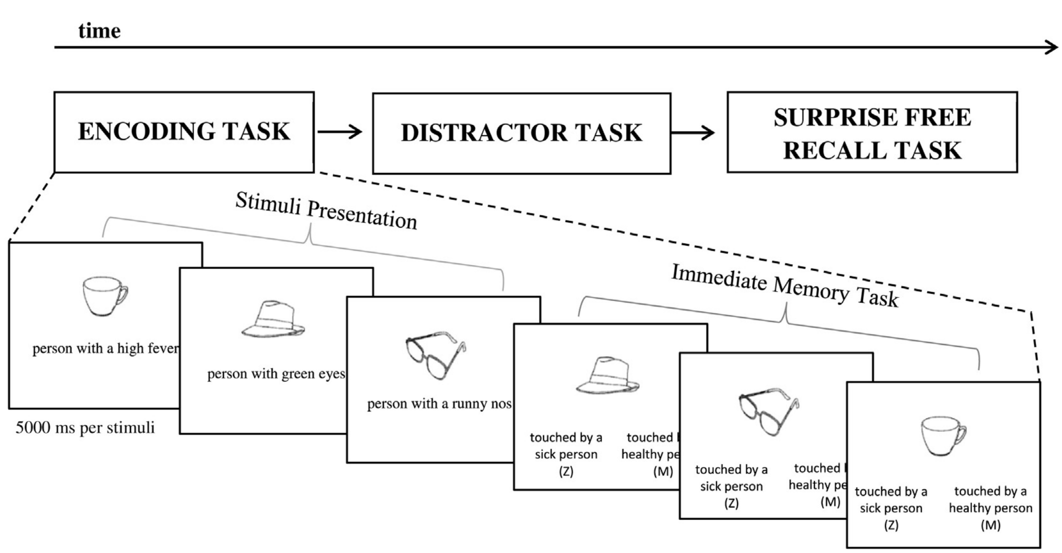

Fig. 1. Schematic representation of the procedure.

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experiment participants saw 10 sets of three stimuli each (object + descriptor), for a total of 30 stimuli. One extra set of three stimuli was presented during a practice trial for familiarization with the task. As indicated in the instructions, each object picture was displayed on the screen with the descriptor below it (presentation phase). After each third stimulus, the immediate memory task followed in which the just presented three objects were again presented individually on the screen and participants had to identify if the item had been touched by a "sick" or a "healthy" person. An ITI of 250 ms preceded the presentation of both the stimuli and the immediate memory slide. The objects were randomly assigned to each condition and the order of presentation of the objects during the immediate memory task was randomized; therefore, objects were not necessarily presented in the same order as in the presentation phase (see Fig. 1). However, we pre-established the condition presentation in each triad to make sure that: 1) both conditions were present in each triad of stimuli (e.g., 2 objects were presented with a sick descriptor and 1 with a healthy descriptor; this was counterbalanced in two versions of the experiment); 2) the first two trials presented different conditions (to prevent guessing of the last stimuli of the triad); 3) and, in each half of the task an approximately equal number of sick and healthy descriptors was presented. Each descriptor was repeated 3 times during the experiment but never within a given triad of stimuli. Performance in the immediate memory task allowed us to ensure participants were relating the descriptor to the object and to confirm that the sentences were being correctly interpreted by participants as descriptive of a sick or a healthy person.

After the encoding phase, a distractor task followed for about 2 min. In this task, single digits were presented on the screen at a rate of 2 s each and participants were asked to decide whether the presented digit was even or odd. Responses were made by selecting the E or O keys on the keyboard, respectively. The experiment ended with a final surprise free recall task in which participants were asked to remember the names of as many objects as they could, irrespectively of the decision made earlier about the object. Responses were written on a recall sheet during a 10 min period; everyone was told that they could recall the objects in any order. Participants were fully debriefed at the end of the experiment.

2.2. Results

For all the experiments here reported, analyses were performed using the *Statistical Package for Social Sciences* (IBM SPSS) version 21. The statistical level of significance was set at $p < 0.05$ for all analyses.

2.2.1. Immediate memory

In both conditions, performance on the immediate memory task was close to perfect with an average of 97% correct responses in both conditions, $t(37) < 1$. This result indicates participants were successfully associating the objects with the corresponding descriptors and that our descriptors were being correctly identified as describing a sick or a healthy person.

2.2.2. Free recall

The results obtained in the final surprise free recall task are presented in Fig. 2. As predicted, participants remembered significantly more of the items previously associated with the sick descriptors compared to those previously associated with the healthy descriptors, $t(37) = 2.88$, $p = 0.003$, Cohen's d = 0.47.

3. Experiment 1b

Experiment 1b was designed to replicate the first experiment in an independent study and a different population in an effort to help establish the generality of this finding. As noted by Roediger (2012), and advocated in many recent replication projects (e.g., Open Science Collaboration, 2015), and other publications (e.g., special issue edited by Pashler & Wagenmakers, 2012), replication is a necessary condition to help establish a phenomenon.

3.1. Method

3.1.1. Participants

One hundred and six students (females = 95) from the University of Aveiro (Portugal) participated in exchange for course credits. All participants consented to participate voluntarily before starting the experiment. Data from one other participant was excluded due to low immediate memory performance (<60% correct).

3.1.2. Materials and procedure

The objects and descriptors (translated into European Portuguese), as well as the procedure, were the same as in Experiment 1. Up to 8 participants were tested in each session.

3.2. Results

3.2.1. Immediate memory

Performance in the immediate memory task was around 93% in both conditions, $t(105) < 1$, indicating participants were correctly relating the condition (sick and healthy) with the objects.

3.2.2. Free recall

The results obtained in this replication are displayed in Fig. 2 and reveal, as in Experiment 1a, significantly better memory for the items previously "touched" by sick people, $t(105) = 5.74$, $p < 0.001$, Cohen's d = 0.56.

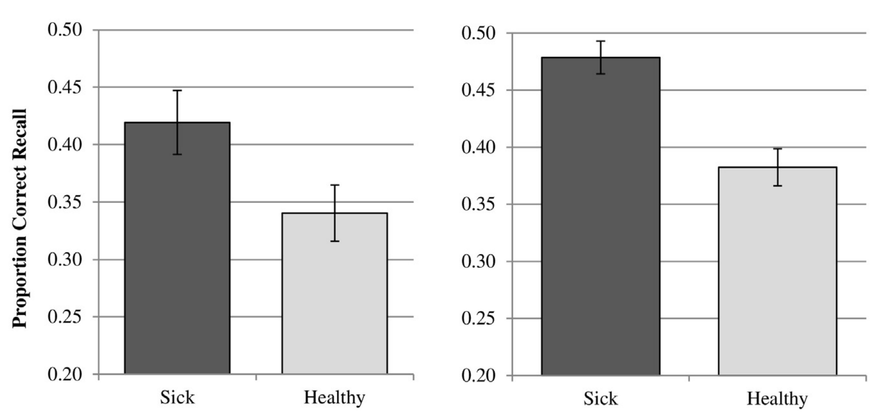

Fig. 2. Average proportion of correct recall for each condition in Experiment 1a (on the left) and in Experiment 1b (on the right). Error bars represent Standard Errors of the Mean.

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3.3. Discussion for Experiments 1a and 1b

As predicted, items that were described as having been in contact with a sick person—a source of potential contamination—were remembered better by participants compared to when the same objects were described as having been in contact with a person described with a healthy characteristic. Notably, everyone was remembering exactly the same information in these experiments; what varied was the context with which the object was associated. Such a methodology effectively eliminates item selection concerns—that is, inherent and potentially uncontrolled differences among to-be-remembered stimuli—that have been a concern in some previous work on memory for disgusting and non-disgusting stimuli (e.g., Chapman et al., 2013). The current experiments also provide further support for the law of contagion or contact, albeit in the present case what is passed from one item to the next is a form of mnemonic salience.

4. Experiment 2

In Experiment 2, we manipulated the potential for contamination using another type of cue: Photos of faces displaying signals of potentially contaminating diseases. The procedure of the previous experiments was followed but rather than presenting the objects with descriptions of a sick or a healthy person, the objects were presented with faces of people who touched and interacted with the object. The key manipulation was whether the faces contained cues indicative of contagious diseases —a potential source of contamination. This manipulation more closely represents the experiences we face in our everyday lives as we are constantly observing other people interacting directly with objects.

4.1. Method

4.1.1. Participants

Forty-eight undergraduate psychology students (females = 42) from the University of Aveiro (Portugal) participated in exchange for course credit ($M_{age} = 22.25$ years, $SD = 5.58$). Data from two other participants were excluded, one due to low immediate memory performance (<60% correct), and another due to a technical error that prevented data from being saved. Informed consent was obtained from all participants.

4.1.2. Materials

4.1.2.1. Objects. The same thirty black-and-white line drawings of objects used in the previous experiments were used.

4.1.2.2. Face stimuli. Female faces from the Karolinska Directed Emotional Faces (Lundqvist, Flykt, & Öhman, 1998) and the Radboud Facial Database (Langner et al., 2010) were manipulated using Adobe Photoshop CC to display conspicuous disease-connoting cues, namely perioral dermatitis, conjunctivitis, eczema, herpes, sweet syndrome, ringworm and butterfly-shaped rash. We then conducted a pilot study in which an independent sample of 38 participants ($M_{age} = 20.05$ years, $SD = 2.14$) were asked whether they perceived the person as containing a disease, to evaluate the disgust and arousal triggered by each face, and also to indicate to what extent they would feel uncomfortable being around the person. The questions were presented sequentially for a given face, but the ordering of the questions was randomly determined for each face. Ordering of the faces was also randomly determined for each participant. Each participant saw each face either in its manipulated form (sick) or in its normal state (healthy) (total of 48 faces rated per participant with 19 ratings collected overall per face). All decisions were provided using a visual analog scale ranging from 0 (not at all) to 100 (very much) and were self-paced.

The pilot study revealed that two of our medical condition manipulations (perioral dermatitis and butterfly-shaped rash) were not very effective at eliciting disgust; these were excluded from the final selection of sickness representations. From the five remaining categories we selected the six disease manipulations and faces that caused the highest disgust and discomfort; these same faces elicited low levels on these dimensions when the corresponding non-manipulated (healthy) versions were presented. The average values obtained for the selected faces and for each of the rated dimensions, along with the statistics comparing the ratings obtained for the sick and healthy faces, are presented in Table 2. These reveal that the faces with disease-connoting cues (sick faces) were perceived as appearing significantly unhealthier, more disgusting, more arousing and to produce more discomfort in a hypothetic situation of close contact, as compared to the same faces in their healthy form.

Four counterbalancing versions of the experiment were created making sure that, across participants, each face appeared an equal number of times in its healthy and sick version, and that each condition appeared an equal number of times in each position of the list during encoding.

4.1.3. Procedure

Up to six participants were tested in each session which lasted approximately 20 min. On arrival at the laboratory, participants were randomly assigned to one of the counterbalancing versions of the experiment. The experiment was run using individual computers and the presentation of the experiment was controlled using the *software E-prime 2.0 Professional* (Schneider et al., 2002).

The procedure was very similar to that used in the previous experiments (see Fig. 1). Some adjustments were made in the encoding instructions considering that faces were now being presented rather than descriptors:

> "In this task, you will be asked to remember objects that have been touched and handled by different people; some of these people were infected with a highly contagious disease, whereas others were healthy people. Throughout the experiment, you will see pictures of objects along with a photo of the face of the person who touched and interacted with each object. The faces will give you a clue about whether the person who touched the item was sick or healthy. You will need to decide whether the object was touched by a sick or healthy person and then remember this information for a memory test. Objects and their corresponding faces will be presented one at a time, in sets of three. After each set of three, the objects will appear again and you will be asked to remember whether each was touched by a sick or healthy person. If the person who touched the object was sick, press the "Z" key at this time. If the person was healthy, press the "M" key. The face will not appear when you have to make this decision, so you will have to remember who touched and handled each of the objects. After you have entered your responses for each item, a new set of three objects will be presented and this task sequence will be repeated."

Participants were also warned they would have only 5 s to view each stimulus or to make their memory decision. As before, the procedure described in the instructions was repeated 10 times for a total of 30 trials. A brief practice phase containing three additional stimuli preceded

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

	Healthy faces	Sick faces	t-test comparisons
Perceived disease	5.35 (3.35)	63.94 (7.21)	$t(58) = -40.39^{***}$
Disgust	3.76 (2.45)	53.06 (8.51)	$t(58) = -30.50^{***}$
Arousal	6.54 (2.94)	54.41 (5.81)	$t(58) = -40.28^{***}$
Discomfort	5.10 (3.09)	52.28 (8.26)	$t(58) = -29.32^{***}$

*** $p < 0.001$.

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the presentation of the scored trials to ensure understanding of instructions. The distractor task that followed the encoding phase was as described in the previous experiments. For the surprise final free recall task participants were allowed 5 mins to write down on a sheet of paper as many of the objects shown previously, in any order they liked and regardless of the type of person previously paired with the object. At the end of the recall period participants were asked to go over their recalled objects and identify whether that object had been touched by a sick or a healthy person (source memory task).

4.2. Results

4.2.1. Immediate memory

In both conditions, participants performed at about 95% indicating they were identifying the faces correctly as corresponding to a sick or a healthy person and also associating the objects with the corresponding condition, t (47) < 1.

4.2.2. Free recall

Participants recalled more objects associated with faces of sick people than those associated with faces of healthy people (see Fig. 3). A paired-samples t-test revealed that this mnemonic advantage for the potentially "contaminated" items was statistically significant, $t(47) = 2.82$, $p = 0.007$, Cohen's d = 0.421.

4.2.3. Source memory

In this task, we calculated the proportion of times participants correctly identified the source for the objects they recalled. Data from only 43 participants are reported as four of the participants did not respond to this task. Data from one additional participant were not included here as she recalled only items from the sick condition; she correctly identified the source memory for all of these items. One additional participant failed to identify the source for about half of the recalled items (about 57% of the items were from the healthy condition and 43% from the sick condition). Data from this participant were still included as she identified the source for the other half of the recalled items.

The results revealed that participants were significantly better at identifying the source for the objects that had been previously paired with a sick face as compared to those previously paired with a healthy face, $t(42) = 2.146$, $p = 0.038$, Cohen's d = 0.336 (see Fig. 4).

It is possible that this result was driven by a bias to assign the recalled items to the sick rather than to the healthy condition. In order to help clarify this question we looked at the source memory attributions given to intrusions. Although the number of intrusions was very low ($M_{intrusions} = 0.58$ per participant), more than half were attributed to the healthy condition (57.1%) in the source memory task, whereas only 28.6% of the intrusions were assigned to the sick condition; Participants did not provide a source memory response for the remaining 14.3% of the intrusions. These results suggest that the enhanced source memory performance obtained for the sick condition cannot be explained by a simple response tendency to assign the recalled items to this condition.

4.3. Discussion

The present data largely confirm our main hypothesis that potentially contaminated items are remembered particularly well compared to non-contaminated items: Objects associated with faces of sick people were remembered better than objects associated with faces of healthy people. Our next experiment tests whether the attribution of fitness-relevance is an important determinant of the mnemonic effect. Experiment 3 is an exact replication of Experiment 2, except that the sick faces were now described to the participants as belonging to actresses preparing to portray sick people in a TV-show whereas the healthy faces were described as being from viewers that used to watch this television series. Memory for the same objects associated with the same faces was tested in this experiment; what differed was the lack of the fitness-relevant dimension—the potential for contamination.

5. Experiment 3

5.1. Method

5.1.1. Participants

Forty-eight undergraduate students (female = 36) from the University of Aveiro (Portugal) took part in this experiment (M_{age} = 22.27 years, $SD = 7.08$). Participants received a monetary compensation or course credits for participation. Data from 13 participants were excluded due to low performance in the immediate memory task (<60% correct; $n = 8$) or for failure to follow instructions ($n = 5$). Informed consent was attained prior to participation.

5.1.2. Materials

The stimuli were the same as those used in Experiment 2.

5.1.3. Procedure

All aspects of the procedure from Experiment 2 were employed with the exception of the instructions describing the sick and healthy people which were as follows:

"Some of these people were actresses who were cast members of a medical television series (similar to 'Grey's Anatomy') and were using makeup to act as patients with different medical conditions, whereas others were viewers that used to watch this television series and do not have any facial makeup characterization. Throughout the experiment, you will see pictures of objects along with a photo of the face of the person who touched and interacted with each object. The faces will

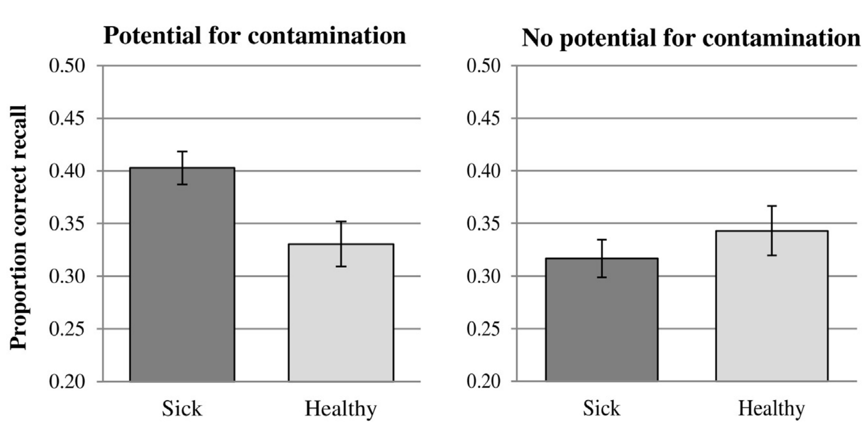

Fig. 3. Average proportion of correct recall for each condition in Experiment 2 (on the left) and in Experiment 3 (on the right). Error bars represent Standard Errors of the Mean.

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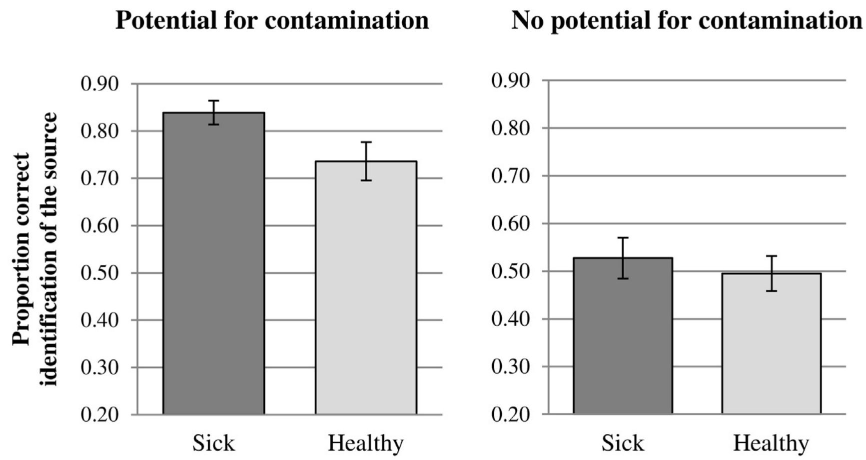

Fig. 4. Average proportion of correct Source Identification in Experiment 2 (on the left) and in Experiment 3 (on the right). Error bars represent Standard Errors of the Mean.

give you a clue about whether the person who touched the item was an actress or a TV-show viewer. You will need to decide whether the object was touched by an actress or a TV-show viewer and then remember this information for a memory test. Objects and their corresponding faces will be presented one at a time, in sets of three. After each set of three, the objects will appear again and you will be asked to remember whether each was touched by an actress or a TV-show viewer. If the person who touched the object was an actress, press the "Z" key at this time. If the person was a viewer, press the "M" key.".

5.2. Results

5.2.1. Immediate memory

As in the previous experiment, performance in the immediate memory task was very high with an average percentage of 93% correct responses in both conditions, $t(47) < 1$, certifying that participants were relating the objects with the corresponding faces.

5.2.2. Free recall

The data presented in Fig. 3 indicate that participants remembered about the same percentage of objects previously paired with the sick faces as with the healthy faces; this observation was confirmed by the non-significant difference obtained in the paired t-test, $t(47) < 1$.

5.2.3. Source Memory

The average proportions of correct source identifications for the recalled objects are presented in Fig. 4. Data from one participant were not included as no responses were provided in this task. Some participants ($n = 7$) also did not provide a source memory response for all of their recalled items, seeming reluctant to guess a response. More than half of the items without a source memory response were from the healthy condition (62.5%). Because these participants assigned a source memory response to recalled items from both conditions, their data were still included in the analyses.

Performance in both conditions was close to 50% with no difference between conditions, $t(46) < 1$. In fact, a one-sample t-test with chance level (50%) indicated participants performed at chance in both conditions (both $ts(46) < 1$). As in the previous experiment, we explored the possibility of response bias by looking at source memory assignment to the intrusions. As before, a small number of intrusions occurred ($M_{intrusions} = 0.65$ per participant) with a similar percentage of these being attributed to the healthy condition (48.4%) and the sick condition (45.2%); for the remaining 6.4% of the intrusions no source memory response was provided. These results are in agreement with the chance-level performance and do not suggest any response bias.

5.3. Discussion

In this experiment, participants were asked to remember exactly the same objects associated with exactly the same faces as in Experiment 2; what differed was the fitness-relevancy of the context associated with the faces: Whereas in Experiment 2 these were described as potential sources of contamination, in Experiment 3, even though they contained exactly the same disease-connoting cues and were correctly identified as representing a sick person, they were not considered to be potential vehicles of contamination. This experiment provides more concrete support for the mnemonic value of contamination by showing that memory advantage occurs only when objects were processed within a fitness-relevant context.

6. General discussion and conclusions

The BEH system evolved to help our ancestors effectively detect and avoid fitness-relevant threats, thereby increasing their chances of survival and reproduction. This system is characterized by affective, cognitive, and behavioral processes that work in concert to mitigate the fitness costs potentially posed by infectious microorganisms (Schaller & Duncan, 2007; Schaller & Park, 2011). Disgust is regarded a key element of the BEH system: Potential sources of infection trigger this emotional response which, in turn, seems to facilitate memory retention. Accordingly, studies have shown that people remember disgusting objects better than neutral objects (e.g., Chapman et al., 2013). However, we asked, would neutral objects that have come in contact with disgusting or disease-signaling cues yield enhanced retention as well? Inspired by the law of contagion we predicted that objects that had come in contact with a source of contamination —a sick person —would be remembered better than those that had been contacted by a healthy person. The data obtained in three experiments provided strong support for this hypothesis: Objects described as having been touched by sick people were better remembered than when they were described as having been touched by healthy people. This effect was obtained when the potential for contamination was transmitted by associating objects with sentences describing signals and symptoms of disease (Experiments 1a and 1b), as well as when they were associated with faces containing signs of potentially contagious diseases (Experiment 2). The same "sick" faces were presented again in Experiment 3 along with the same objects, but participants were led to believe that the facial cues were actually from the application of makeup rather than from disease. Under these conditions, no memory advantage for the associated objects was found in comparison to those presented with the healthy faces. These results suggest that the stimuli have to be put in a fitness-relevant context —a contamination threat —for the memory advantage to occur.

Our results might be considered to be at odds with previous findings of no recognition effects for disease-relevant stimuli. For example, Ackerman et al. (2009) found that participants seem to remember the location of disfigured faces well but their recognition for the disfigured faces was less accurate than that of normal faces; specifically, participants confused disfigured faces with each other more than with normal faces. Miller and Maner (2012) reported that participants with increased disease concerns incorrectly categorized others as obese and claimed to remember seeing more obese than average-weight individuals. In both of these studies, memory was tested via a recognition task for the potentially-disgusting individuals whereas in our case we tested the free recall for items that could constitute vehicles of contamination due to previous "contact" with potential sources of contamination. It is possible that humans evolved a diversity of specialized, but still adaptive, memory strategies to deal with contamination. In fact, dissociations between recall and recognition have been known for a long time (e.g., Balota & Neely, 1980). Also, the processes involved in face recognition seem to differ substantially from other memory processes (e.g., Farah, Humphreys, & Rodman, 1999; Maurer, Le Grand, & Mondloch, 2002). On the other hand, the reported biases in recognition memory may still reflect an adaptation as noted by Miller and Maner (2012): "the costs of mistakenly assuming that a disease carrier is healthy are much greater than the costs of mistakenly assuming that a healthy person is a disease carrier; failing to identify and avoid a contagious individual could lead one to catch a potentially harmful, energetically depleting, and perhaps fatal disease" (p. 1199). Further research is needed to explore how different memory processes might be involved in this phenomenon.

Our initial proposal was that this mnemonic tuning may belong to the general cognitive toolkit that evolved as a part of the BEH system to help us lessen the likelihood of coming into close contact with pathogens. However, it is possible that this result can simply be explained by more general cognitive mechanisms put into the service of ensuring the survival and safety of individuals. For example, studies have revealed enhanced allocation of attention to disgusting and disease-relevant stimuli compared to neutral or fearful stimuli (van Hooff, Devue, Vieweg, & Theeuwes, 2013), particularly when participants were primed with disease threats (Ackerman et al., 2009). Such exposure to information about germs and transmission of contagious diseases also led people to rate themselves as less extraverted and motivated arm avoidant movements toward photographs of faces, thereby reducing potentially harmful social interaction (Mortensen, Becker, Ackerman, Neuberg, & Kenrick, 2010). Ackerman et al. (2009) found that people with facial disfigurement (heuristically perceived as a sign of disease), caught and held attention more than normal faces. Considering that attention influences memory processes (e.g., Cowan, 1998), one could expect a boost in memory for such cues. In our procedure, though, we were not testing memory for the faces themselves (which contained the disfigurative elements and that could capture more of the participants' attention), but rather for the objects that accompanied the faces; according to this idea, memory for the objects could actually be worsened by the simultaneous presentation of the manipulated faces, the opposite result of what we obtained. Even though attention could certainly be involved in these results, our procedure does not allow us to draw conclusions regarding this process. Future studies with more appropriate designs (e.g., manipulating the presentation timings or using shorter presentation times; e.g., van Hooff et al., 2013) should be conducted to explore this hypothesis.

Emotionality could also be playing a role in the reported results. It has been shown that high-emotionally arousing stimuli are remembered better than low-arousing stimuli (Bradley, Greenwald, Petry, & Lang, 1992; Levine & Pizarro, 2004; Sharot & Phelps, 2004). In most studies, however, the items representing each condition differed in many ways allowing aspects other than the valence or arousal of the stimuli to influence memory performance. Cahill and McGaugh (1995) tested the influence of emotional arousal in memory using a procedure that is more similar to ours: Participants in both the arousal and neutral conditions were asked to remember the same information (components of slides depicting parts of a story); what differed was the emotional tone of the narrated story with one referring to an emotionally-arousing episode (a child is hurt in an automobile accident) and the other to a neutral situation (a child visits the hospital during a practice disaster drill). They found memory enhancement for information in the slides when these were accompanied by the emotionally arousing story.

Our sick stimuli might naturally induce emotional arousal which, in turn, could mediate the memory advantage we obtained. However, given that the same stimuli were used in Experiments 2 and 3, we think that the attribution of fitness-relevance transmitted by the initial instructions—the potential for contamination— was likely more responsible for the effect than the stimuli themselves. A direct comparison of the two experiments using an Analysis of Variance including experiment (2 vs. 3) as a between-subjects variable and condition (sick vs. healthy) as a within subject variable, revealed no main effect of experiment, $F(1,94) = 3.265$, $MSE = 0.020$, $p = 0.074$, no main effect of type of face, $F(1,94) = 1.42$, $MSE = 0.018$, $p = 0.236$, but a significant interaction, $F(1,94) = 6.571$, $MSE = 0.117$, $p = 0.012$, $\eta_p^2 = 0.065$. This interaction represents the memory advantage found for the objects associated with the sick faces in Experiment 2 but not in Experiment 3.

Participants were also particularly good at identifying the source of the objects previously presented with the sick faces, as compared to those presented with the healthy faces, but only when the former were described as actual potential contaminants (Experiment 2); When they were presented in the non-fitness relevant context of Experiment 3, source memory performance was at chance levels for both conditions. An analysis of the source attributed to the intrusions suggests this pattern of results is not due to any response bias, although this conclusion should be taken with care given the small number of intrusions. The source memory enhancement for the items previously associated with the sick faces parallels the findings of Bell and Buchner (2010), which the authors attributed to negative valence. However, further work by this group led the authors to argue that "negativity or arousal per se do not automatically enhance memory. Rather, the information has to be threatening (i.e., associated with negative consequences for other people) to be especially well remembered" (Bell & Buchner, 2012, p. 406). This conclusion is in line with our results.

Different threat-management systems likely evolved over the course of evolutionary history to help our ancestors effectively manage specific kinds of fitness-relevant threats (e.g., self-protection and disease-avoidance systems proposed by Neuberg, Kenrick, & Schaller, 2011). Our studies focused on the mnemonic tuning for disease threats but one could also expect this tuning to be extended to threat-related items. For example, Štefaniková and Prokop (2015) have shown that memory excels when the suggested source of threat is indeed convincingly threatening (such as presenting pictures of dangerous animals described as such) as compared to when the information is not so convincing (such as non-threatening pictures accompanied by a description of being threatening). Other studies have revealed that items scoring high in fear are remembered better than neutral items (e.g., Chapman et al., 2013). If we used our procedure referring directly to physical threat, rather than to contamination, would we get the same result? Do these systems involve separate mechanisms or can they simply be explained by general evolutionary mechanisms that help us survive? These are, ultimately, empirical questions that need to be investigated. Considering the research suggesting that stimuli inducing disgust (more closely related to contamination) affect memory in a different way from those that induce fear (more related to the physical threat) (Chapman et al., 2013) one might expect different results. One could also explore how different manipulations would affect the obtained results. For example, disease concerns, either due to dispositional (individual differences in perceived vulnerability to disease) or situational (priming) factors, seem to influence how people perceive and

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remember individuals heuristically associated with pathogen threat (e.g., obese, elderly foreigners). As noted before, enhanced disease concerns influence memory in particular ways (see Ackerman et al., 2009; Miller & Maner, 2012). Future studies should be done to address these questions.

Efficient detection, processing, and memorization of stimuli that potentially threaten an individual's survival, compared with other non-threatening stimuli, constitute adaptive features of the cognitive component of the BEH system, as each potentially promotes individuals' survival. The current results provide the first demonstration of a memory tuning for potentially contaminating objects and add to the growing body of evidence supporting the robustness and universality of adaptive memory phenomenon: The idea that memory should perform particularly well in contexts that yield a fitness-relevant component. Alongside with the survival processing effect (Nairne & Pandeirada, 2016) and a memory advantage for animates (Nairne, VanArsdall, & Cogdill, 2017), we present evidence for a mnemonic tuning for another domain that certainly played a role during evolution: contamination.

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