Evolution and Human Behavior 47 (2026) 106821

Contents lists available at ScienceDirect

Evolution and Human Behavior

journal homepage: www.elsevier.com/locate/ens

Adaptive memory in contamination contexts: Exploring the role of emotionality

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ARTICLE INFO

Keywords:
Contamination effect
Adaptive memory
Emotionality
Contamination potential

ABSTRACT

Previous studies have reported a memory advantage for information previously associated with contamination cues (vs. non-contamination) – the contamination effect. In four experiments, we explored the role of emotionality in this effect. Participants recruited on prolific academic saw pictures (Experiment 1, $N = 97$; Experiment 4, $N = 100$) or names (Experiment 2, $N = 92$) of objects alongside illness (vs. neutral) descriptors or objects held by dirty (vs. clean) hands (Experiment 3, $N = 100$). Then, they recalled the objects and evaluated them in five dimensions. In Experiment 4, participants evaluated the objects before the recall task. The contamination effect was replicated across all experiments. Objects in contamination (vs. non-contamination) conditions were rated as more arousing, negative, disgusting, frightening, and with greater contamination potential. The contamination effect correlated significantly but modestly with the emotional ratings and was fully mediated by contamination potential. These findings suggest that emotionality plays a role but does not fully explain the effect.

1. Introduction

From an evolutionary perspective, memory systems evolved to favor information that enhances our chances of survival and reproduction (Nairne et al., 2007). This argument has been supported by documented processing advantages in fitness-related contexts (vs. multiple control conditions), such as survival and reproduction (Nairne et al., 2025).

Another adaptive challenge arises from pathogenic microorganisms that threaten humans' chances of survival (e.g., Karlsson et al., 2014). In response to this selective pressure, two immune systems emerged: the Biological Immune System (BIO) and the Behavioral Immune System (BIS) (e.g., Schaller & Duncan, 2007). The BIO comprises physiological mechanisms to facilitate detection and combat pathogens in the body (Parham, 2014). However, biological immune defenses have metabolic costs for the organism (Murray & Schaller, 2016), requiring less costly measures. These are provided by the BIS through a set of psychological mechanisms that facilitate pathogen detection and guide the organism's behavior in avoiding potential diseases. The BIS includes emotional (e.g., disgust), cognitive (e.g., attention), and behavioral responses (e.g., avoidance) triggered when potential contagion cues (perceptual or inferential) are perceived in the environment (Murray & Schaller, 2016; Schaller & Duncan, 2007). Memory contributes to the BIS cognitive component as individuals need to learn and recognize contamination cues to enable effective avoidance.

Memory's involvement in the BIS can be related to disgust, as most disgusting things are likely to hold pathogenic agents (e.g., rotten organic matter, parasites, unhygienic conditions). Accordingly, studies have shown that people remember disgusting items better than neutral ones (e.g., Chapman, 2018; Ferré et al., 2018; but see West & Mulligan, 2021).

Inspired by the idea that objects acquire properties of things through contact (i.e., the law of contagion; Rozin & Fallon, 1987), Fernandes et al. (2017) presented images of objects alongside short descriptors depicting signs of disease (e.g., person with a constant cough) or neutral characteristics (e.g., person with brown hair), or paired with faces with (or without) signs of contagious diseases. Participants consistently recalled more objects previously associated with a potential contamination source (vs. non-contamination) - the contamination effect. Recently, Fernandes et al. (2021) replicated these findings with photographs of real objects and objects held by dirty (vs. clean) hands.

Although there is empirical evidence of a memory tuning to contamination cues driven by the ultimate need to avoid pathogenic

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https://doi.org/10.1016/j.evolhumbehav.2025.106821
Received 3 September 2025; Received in revised form 14 November 2025; Accepted 27 December 2025
Available online 13 January 2026
1090-5138/

threats and enhance survival, the proximate mechanisms underlying this contamination effect remain unclear. Two possible mechanisms were advanced by Fernandes et al. (2021). First, the advantage for contaminated items may result from other BIS-related mechanisms, namely attention (Schaller & Duncan, 2007). People seem to pay particular attention to disgusting / disease-related stimuli (Perone et al., 2021; Santos et al., 2023; van Hooff et al., 2013). Given the prominent role of attention in memory (for a review, see Cowan et al., 2024), the effect could simply derive from increased attention allocated to the contamination cues (e.g., descriptors, faces), which are often deemed more disgusting. However, this could reduce the attention available to the associated neutral objects. Still, participants are equally effective in identifying the condition in which the objects are presented at encoding, and yet a final recall advantage is obtained in the contamination condition. Thus, attention may contribute to but does not fully explain the phenomenon.

Emotionality is another potential mechanism for this memory advantage, as people may experience a stronger activation towards contaminated (vs. uncontaminated) objects. Fernandes et al. (2021; Exp. 3) asked participants how aroused and disgusted each presented stimulus (objects held by dirty or clean hands) made them feel and how likely someone would get sick if they interacted with the objects. As predicted, contaminated stimuli were rated as more arousing, disgusting, and with higher contamination potential. However, these ratings did not correlate significantly with the observed contamination effect, suggesting other factors might be contributing to the memory advantage.

Further studies reported similar findings. For example, Bonin et al. (2019) observed a memory advantage for information encoded in potential contamination scenarios (e.g., "you are travelling in a foreign country, and you have a wound that can cause a dangerous infection") and for objects associated with the faces of contaminated (vs. healthy) individuals. They also found a significant correlation between the discomfort elicited by the faces containing disease-connoting cues and the recall of the associated objects.

Using a different procedure, Gretz and Huff (2019) exposed participants to videos of an actor described as healthy, having cancer (noncontagious), or influenza (contagious) interacting with several objects. As predicted, participants recalled more touched than non-touched objects, and source recognition was greater in the contagious condition. Participants' germ aversion and correct source attributions to touched items also correlated significantly. These results suggest that contagion potential enhances memory for objects, particularly in individuals with a greater aversion to germs.

Thiebaut et al. (2022) replicated the contamination effect with objects held by clean hands of a healthy person or a person infected with COVID-19. Additional evaluations of individuals' sensitivity to disgust and perceived vulnerability to disease were not significantly correlated with recall. Still, when asked to anticipate interacting with an object previously touched by an infected person, participants reported higher fear of contamination than disgust.

The role of emotionality has been investigated in another fitness-relevant context: the survival processing effect (Nairne et al., 2007). This effect documents a memory advantage for items encoded in a survival scenario (vs. a control scenario; e.g., moving to a new country, rating the pleasantness of words, or taking a vacation). In support of an emotionality-related account, Fiacconi et al. (2015) observed a greater heart rate deceleration (fear bradycardia) in the survival condition. Furthermore, the survival scenario was rated as more arousing and negative. Saraiva et al. (2020) explored this same account based on the argument that the emotional system is less recruited in a second language (e.g., Harris, 2004; Hayakawa et al., 2016). As expected, the survival processing advantage was replicated with participants using their native but not their second language (see also Kazanas et al., 2021).

Although the survival processing and contamination effects may share the same ultimate mechanism of increasing the chances of survival, the former depends on contextual framing during encoding, whereas the latter arguably involves more specific contamination elicitors. Thus, they might also differ in the degree and/or forms of emotional engagement. In the case of survival, fear is the most likely associated emotion, whereas disgust is a stronger candidate for contamination. Still, some authors propose that the contamination effect may also involve fear (of being contaminated) (Thiebaut et al., 2022).

The current work systematically investigated the role of emotionality[1] in the contamination effect. Across four experiments, we presented objects paired with cues indicating contamination (vs. non-contamination). In addition to recall, participants rated those objects (without any cues) on five emotionality-related dimensions. We expected higher recall for objects presented in the contamination condition, replicating the contamination effect. Moreover, ratings should indicate that objects presented in the contamination condition acquire the emotional properties conveyed by the contamination cues.

2. Experiments overview

In Experiment 1, we used photographs of objects presented alongside descriptors of (non)contamination (Fernandes et al., 2021); in Experiment 2, the photographs of the objects were replaced by their written name; and, in Experiment 3, the objects were presented being held by dirty or clean hands (Fernandes et al., 2021). After a free recall task, the objects were presented again (without any cue of (non-)contamination), and participants rated them on five emotional dimensions: arousal, valence, disgust, fear, and contamination potential. We expected higher recall of objects presented in the contamination condition and "contaminated" objects to be rated as more arousing, negative, disgusting, scary, and with greater contamination potential, reflecting the retention of their contamination potential status. Still, one could argue that the higher recall expected for contaminated objects could affect their subsequent emotionality ratings. To address this possibility, in Experiment 4, the evaluation of the objects occurred before the final free recall task.

The studies were approved by the ethics committee of Ispa-Instituto Universitário [approval I-170-12-24]. Participants were recruited using Prolific (www.prolific.co) and compensated with £3 (£3.50 in Experiment 4). Data were collected online using Qualtrics software. The experiments lasted approximately 25 min (35 min; Experiment 4). Data from all experiments were analyzed using IBM SPSS V29.

Before data collection, sample size, manipulated variables, hypotheses, and planned analyses of Experiments 3 (https://aspredicted.org/cm3kc.pdf) and 4 (https://aspredicted.org/P9R_KLD) were preregistered. Additional details about the materials (SM-1 & SM-2) and the raw data used in the reported analyses are available on OSF (https://osf.io/ntv8u/?view_only=f90a4a1b94d14837800cf152098469af).

3. Experiment 1

In this experiment, we used photographs of everyday objects being held by clean hands paired with descriptors referring to signs of illness (contamination) or neutral (non-contamination). To explore the potential involvement of emotion in the contamination effect, after the final recall task, participants were tasked to rate the objects on the dimensions mentioned above.

3.1. Method

3.1.1. Participants

A sample of 36 participants was determined by a priori power

[1] In the present paper, emotionality is operationalized as the extent to which a stimulus is perceived as emotionally salient, as assessed through participants' subjective ratings on various emotionality-related dimensions.

analysis (G*Power) using as a reference the effect size reported by Fernandes et al. (2017) ($d_z = 0.56$) and a power $1 - \beta = 0.90$. As we were testing a new potential explanatory mechanism for the contamination effect, we set out to collect at least 72 participants. The final sample comprised 97 European Portuguese participants ($M_{age} = 31.09$; $SD = 7.90$; 54 female). No participant was excluded based on performance on the immediate memory task (hits <60 %; see Fernandes et al., 2017, Fernandes et al., 2021).

3.1.2. Materials and design

Twenty-four photographs of objects (four objects from each of six categories: office supplies, toys, fruits, vegetables, kitchen utensils, and women's accessories) held by clean hands (frontal viewpoint), along with three additional photographs for practice trials, were selected from the Objects-on-Hands Picture Database (Fernandes et al., 2019). The selected objects presented high name agreement (98.2 %) and high familiarity ratings ($M = 4.82$, $SD = 0.18$).

The objects were paired with 12 descriptors. Ten were selected from Fernandes et al. (2017), and two additional descriptors were created to ensure that each descriptor was presented to each participant only twice. Six of the descriptors portrayed symptoms of sick people (e.g., person with a constant cough) and constituted the contamination condition; the remaining described neutral physical characteristics of potentially healthy people (e.g., person with brown hair) and composed the non-contamination condition. The length of the descriptors (i.e., number of characters) was not significantly different between conditions, $t(10) = -1.09$, $p = .302$. More details on the materials are provided in SM-1.

Participants were exposed to both types of descriptors (sick vs. neutral). The stimuli (object + descriptor) were presented in eight experimental blocks, each consisting of three trials. We created four versions of the task to counterbalance the order of the descriptors and ensure that, across participants, all objects were paired with different sick and neutral descriptors. Each descriptor was repeated twice during the experiment, but never within the same block. The first two trials within each block always represented different conditions (sick vs. neutral) to prevent participants' attempts to guess the condition of the last stimulus in the block.

3.1.3. Procedure

After consenting to participate, participants provided sociodemographic information (i.e., age, gender) and were randomly assigned to one of the four versions.

The instructions followed those used by Fernandes et al. (2017). Participants were informed that they would see images of objects that had been touched by either individuals with a deadly disease or by healthy individuals, and that they would later be asked to remember whether each object had been touched by a sick or a healthy person. Specifically, they were told they would see images of objects along with a brief description. This description would indicate whether the person who touched the object was sick or healthy. The object-descriptor pairs were then presented, one at a time, for 5 s each, in blocks of three. At the end of each block, an immediate memory task followed. Each object was randomly presented again without the descriptor, and participants had to identify whether a sick or healthy person had touched the object. The response options "SICK" or "HEALTHY" were presented below the object image, and participants had 5 s to click on their chosen option. This procedure was repeated for the eight experimental blocks. An additional block of three stimuli was used as a practice trial to familiarize participants with the task before the experiment began. After the encoding phase, participants completed a 2-min filler task (classifying randomly presented digits from 1 to 9 as even or odd; see Fernandes et al., 2017).

In a subsequent 5-min surprise free recall task, participants were asked to write the names of as many objects as they could remember, regardless of the person who had touched them. After the recall task, they rated the previously presented objects on five dimensions using 9-point scales: arousal ("How calm or excited does this object make you feel?"; 1 = Very calm to 9 = Very excited), valence ("How negative or positive is this object for you?"; 1 = Very negative to 9 = Very positive), disgust ("To what extent do you feel disgusted by this object?"; 1 = Not at all disgusted to 9 = Very disgusted), fear ("To what extent are you scared by this object?"; 1 = Not at all scared to 9 = Very scared), and contamination potential ("If you interacted with this object, how likely would you be to get sick?"; 1 = Not likely to 9 = Very likely). During this task, objects were presented being held by clean hands, without descriptors. This task was self-paced. The presentation order of the objects was randomized, as was the presentation order of the evaluative dimensions across objects. Finally, using a similar procedure, participants rated all the descriptors on the same evaluative dimensions.

3.2. Results

3.2.1. Immediate memory

Participants' performance on the immediate memory task was high in both conditions (contamination: 94 %; non-contamination: 95 %), indicating an effective association between the objects and their corresponding conditions. The difference between the two conditions was not significant, $t(96) = -1.40$, $p = .165$, $dz = -0.142$, 95 % CI [−0.34, 0.06].

3.2.2. Free recall

Participants recalled significantly more objects previously paired with sick descriptors ($M = 0.53$, $SD = 0.18$) than with the neutral descriptors ($M = 0.36$, $SD = 0.18$), replicating the contamination effect, $t(96) = 8.62$, $p < .001$, $dz = 0.875$, 95 % CI [0.64, 1.11].

3.2.3. Objects ratings

Table 1 presents participants' average ratings for each evaluative dimension depending on the condition (contamination vs. non-contamination). Overall, objects in the contamination (vs. non-contamination) condition were evaluated as more arousing, negative, disgusting, frightening, and with greater contamination potential.

3.2.4. Descriptors ratings

As expected, the sick descriptors (contamination condition) were rated as more arousing, negative, disgusting, frightening, and with higher contamination potential than the neutral descriptors (non-contamination condition; all p's < 0.001) (see Appendix).

4. Experiment 2

Experiment 1 replicated the contamination effect. Additionally, objects previously associated with sick (vs. neutral) descriptors obtained higher ratings (lowest for valence) in all emotional dimensions. Notably, these results were obtained for "neutral" objects in the absence of potential contamination cues. Still, previous studies have shown that pictures can elicit stronger emotional reactions than verbal stimuli (e.g., Kensinger & Schacter, 2006). Experiment 2 further explores the role of emotionality in the contamination effect, replacing the objects' pictures with their names. This procedure constitutes a stricter test of our hypothesis, as words should elicit weaker emotional responses and are less likely to become "contaminated".

4.1. Method

4.1.1. Participants

A sample of 72 participants was pre-determined as in Experiment 1. One participant was excluded for performing below 60 % (hits) in the immediate memory task (see Fernandes et al., 2017; Fernandes et al., 2021). The final sample comprised 92 European Portuguese participants ($M_{age} = 24.87$; $SD = 6.59$; 46 female).

Table 1
Mean ratings (and SDs) of the objects for each dimension across conditions in the four experiments and results of the comparison between conditions.

		Evaluative Dimensions				
	Condition	Arousal *M* (*SD*)	Valence *M* (*SD*)	Disgust *M* (*SD*)	Fear *M* (*SD*)	Contamination *M* (*SD*)
Experiment 1	Contamination	4.70 (1.53)	5.52 (1.47)	3.18 (1.89)	3.07 (1.89)	4.06 (2.16)
	Non-contamination	4.08 (1.27)	6.05 (1.10)	2.46 (1.25)	2.48 (1.16)	2.99 (1.36)
	t(96)	4.05***	−3.58***	4.89***	4.21***	5.69***
	95 % CI	[0.20, 0.62]	[−0.57, −0.16]	[0.28, 0.71]	[0.22, 0.63]	[0.36, 0.79]
	dz	0.411	−0.364	0.496	0.427	0.578
Experiment 2	Contamination	3.88 (1.67)	5.73 (1.26)	2.35 (1.60)	2.37 (1.51)	3.06 (1.92)
	Non-contamination	3.53 (1.57)	5.88 (1.03)	2.03 (1.11)	2.08 (1.17)	2.62 (1.45)
	t(91)	2.92**	−1.66	2.84**	2.59*	3.19***
	95 % CI	[0.09, 0.51]	[−0.38, 0.33]	[0.09, 0.50]	[0.06, 0.48]	[0.12, 0.54]
	dz	0.304	−0.173	0.296	0.270	0.333
Experiment 3	Contamination	4.60 (1.81)	5.07 (1.53)	3.14 (2.43)	2.72 (2.12)	3.52 (2.39)
	Non-contamination	3.94 (1.37)	5.72 (1.03)	2.22 (1.18)	2.08 (1.15)	2.57 (1.35)
	t(98)	4.11***	−4.21***	4.77***	3.81***	5.16***
	95 % CI	[0.21, 0.62]	[−0.63, −0.22]	[0.27, 0.69]	[0.18, 0.59]	[0.31, 0.73]
	dz	0.413	−0.423	0.480	0.383	0.518
Experiment 4	Contamination	4.49 (1.53)	5.15 (1.28)	3.42 (2.11)	3.17 (2.02)	4.41 (2.40)
	Non-contamination	3.71 (1.35)	5.87 (1.02)	2.36 (1.14)	2.34 (1.05)	2.69 (1.10)
	t(99)	5.28***	−5.22***	5.88***	5.01***	7.68***
	95 % CI	[0.32, 0.74]	[−0.73, −0.31]	[0.37, 0.80]	[0.30, 0.72]	[0.54, 0.99]
	dz	0.528	−0.522	0.588	0.501	0.768

Note: *** $p < .001$; ** $p < .01$; * $p < .05$.

4.1.2. Materials, design, and procedure

Materials, design, and procedure were as described in Experiment 1, but we presented the names of the objects instead of their images. The names of the objects had high imagery ($M = 6.06$, $SD = 1.47$), concreteness ($M = 6.64$, $SD = 0.70$), and subjective frequency ($M = 5.02$, $SD = 1.23$) (Soares et al., 2016; see SM-2). In the final object rating task, only the object names were presented.

4.2. Results

4.2.1. Immediate memory

Participants' performance in the immediate memory task was high (contamination: 94 %; non-contamination: 95 %) and did not differ between conditions, $t(91) = -0.483$, $p = .630$, $dz = -0.05$, 95 % CI [−0.26, 0.15].

4.2.2. Free recall

Participants recalled significantly more object names previously paired with sick descriptors ($M = 0.36$; $SD = 0.19$) than with neutral descriptors ($M = 0.26$; $SD = 0.16$), replicating the contamination effect, $t(91) = 4.63$, $p < .001$, $dz = 0.483$, 95 % CI [0.27, 0.70].

4.2.3. Objects ratings

Overall, the ratings of the objects, now represented through their names, replicated those found in Experiment 1 (see Table 1). Participants rated the objects as more arousing, disgusting, frightening, and with greater contamination potential when presented in the contamination condition than in the non-contamination condition. This difference did not reach significance for the valence dimension.

4.2.4. Descriptors ratings

As in Experiment 1, participants rated the sick descriptors as more arousing, negative, disgusting, frightening, and with greater contamination potential than the healthy descriptors (all p's < 0.001; see Appendix).

As expected, based on the descriptive data and significance levels of the difference between conditions, the emotional ratings reported for the objects' names were lower in this Experiment than in Experiment 1, which used the objects' pictures. Nonetheless, a memory advantage was still observed for the contaminated objects (words), which were also rated in the expected direction.

5. Experiment 3

Experiment 3 further examined the role of emotionality in the contamination effect, using a different contamination cue: objects held by dirty (vs. clean) hands. Contrary to the prior experiments in which the contamination source was depicted through various descriptors, here, the objects were presented in direct physical contact with the same (non)contamination cue. Pairing the same cue with all objects could induce habituation and cue overload, reducing the manipulation influence on the final rating and memory data. Moreover, this visual contamination cue (i.e., dirty hands) may limit participants' ability to recreate the imagery of the object-cue association that occurs when objects are presented with descriptors. Therefore, lower activation and emotional involvement levels could be expected, affecting the mnemonic effect and subsequent object ratings. Alternatively, the strength of this visual contamination cue could counteract (at least to some extent) these predictions.

5.1. Method

5.1.1. Participants

This experiment follows the procedure of the disease condition reported by Fernandes et al. (2021; Experiment 3), in which an effect size of $d_z = 0.514$ was obtained. A power analysis using G*Power indicated that a sample of 42 participants would have sufficient power (1-β = 0.90) at a significance level of α = 0.05 to detect such an effect. However, because we were most interested in exploring the contamination effect on the final emotional ratings and anticipating that such an effect would be smaller, we collected data from at least twice that number of participants. The final sample comprised 100 European Portuguese participants ($M_{age} = 25.09$; $SD = 3.43$; 51 female).

5.1.2. Materials and design

We presented twenty-four photographs (plus 3 for practice trials) of objects being held by clean or dirty hands. Most of these objects (21) were the same as those presented in Experiment 1 (for more details, see SM-1). Two photographs of each object were selected from the Objects-on-Hands Picture Database (Fernandes et al., 2019): one held by clean hands and the other by hands dirty with chocolate. The selected objects had a high name agreement (98.3 %) and familiarity ($M = 4.82$, $SD = 0.44$) (see SM-1 for more details).

We created two stimulus lists to ensure that, across participants, all objects were presented in the dirty hands (contamination) and the clean hands (non-contamination) conditions. Each object was presented in one of the conditions only once to each participant. As in the previous experiments, the first two trials of each block were under different conditions to prevent participants from guessing the condition of the last trial.

5.1.3. Procedure

After consenting to participate, participants provided sociodemographic information (i.e., age, gender) and were randomly assigned to one of the experiment versions. The task began with a description of two people who had touched the objects. These descriptions were translated from Fernandes et al. (2021, Experiment 3; disease condition instructions) to European Portuguese. People's names were changed to unusual Portuguese names. In the contamination condition, the person (Berta) was described as suffering from a contagious gastrointestinal illness with severe episodes of diarrhea. In the non-contamination condition, the person (Alda) was described as having a newborn child and as being constantly concerned about her child's safety. Participants were told they would see photographs of objects held by Berta, whose hands were covered with diarrhea, or by Alda, whose hands were clean. Initially, the image of the object alone was presented in the center of the screen (without hands) for 2 s to ensure participants recognized the object (Fernandes et al., 2021). Then, the same object was presented, being held by dirty or clean hands for 3 s, after which the next object appeared, and so on. After each set of three stimuli (object + object on hands), an immediate memory task displayed the object alone (without hands). Participants had 5 s to decide who had touched the object by clicking on the corresponding option (Berta or Alda); the program automatically advanced to the next object after the time elapsed. After a practice trial, the procedure was repeated for eight trials of 3 objects each. This was followed by a 2-min digit even/odd classification filler task, after which participants received a surprise free recall task. In the end, participants evaluated the objects (without any hands) and the pictures of the clean and dirty hands using the same five evaluative dimensions.

5.2. Results

5.2.1. Immediate memory

Participants' performance in the immediate memory task was high in both conditions (contamination: 96 %; non-contamination: 95 %). This small descriptive difference between conditions was statistically significant, $t(99) = 2.75$, $p = .007$, $dz = 0.275$, 95 % CI [0.07, 0.47].

5.2.2. Free recall

Participants recalled significantly more objects held by dirty hands ($M = 0.50$; $SD = 0.17$) than held by clean hands ($M = 0.46$; $SD = 0.20$), $t(90) = 2.01$, $p = .047$, $dz = 0.201$, 95 % CI [0.01, 0.40], replicating the contamination effect.

5.2.3. Objects ratings

Data from one participant was excluded from this analysis for not completing this task. Replicating the pattern observed in the first two studies, objects previously held by dirty hands were rated as more arousing, negative, disgusting, frightening, and with greater contamination potential than objects held by clean hands (see Table 1).

5.2.4. Hands ratings

Participants rated the dirty hands as more arousing, negative, disgusting, frightening, and with greater contamination potential than the clean hands (all p's < 0.001, see Appendix).

5.3. Interim discussion of Experiments 1–3

In three experiments, we gathered data on free recall for (non-)contaminated objects and their emotional assessment in the absence of any cues. In what follows, we report the association between the objects' ratings and the contamination effect. To that end, we followed the procedure reported in Fernandes et al. (2021) and correlated the difference between objects' ratings in each condition (contamination and non-contamination) for each evaluative dimension (e.g., arousal ratings for contaminated objects - arousal ratings for non-contaminated objects) and the contamination effect (difference between the recall in the contamination condition and the recall in the non-contamination condition), for the three experiments ($N = 288$).

As shown in Table 2, the differences between objects' ratings in each condition across all evaluative dimensions were highly and significantly associated (all p's < 0.001). Notably, the magnitude of the contamination effect was positively and significantly, although modestly, associated with the difference between ratings, except for valence ($p = .07$). In other words, the greater the rating differences between the two conditions, the larger the contamination effect. All means and standard deviations are reported in Table 2, and the same correlations for each experiment are available on OSF (SM-3).

6. Experiment 4

The findings from the previous experiments revealed a positive association between the rating differences of the objects on emotionality-related dimensions (except for valence) and the size of the recall advantage in the contamination (vs. the con-contamination) condition. This pattern suggests that emotionality plays a role in the contamination effect. However, the objects' evaluation might have been affected by the objects' previous recall. In other words, because participants recalled more objects in the contamination condition, they may have rated them higher on emotionality simply because they were more activated in memory. To disentangle this confound, Experiment 4 used the procedure described in Experiment 1; however, here, the evaluation of the objects occurred without a prior recall task.

6.1. Method

6.1.1. Participants

The sample size was determined as in Experiment 1. The final sample comprised 100 European Portuguese participants ($M_{age} = 27.31$; $SD = 5.12$; 37 female). One participant was excluded based on performance on the immediate memory task (hits <60 %; see Fernandes et al., 2017, Fernandes et al., 2021).

6.1.2. Materials and design

The same as in Experiment 1.

6.1.3. Procedure

After consenting to participate, participants provided sociodemographic information (i.e., age, gender) and were then randomly assigned to one of the four versions of the experiment (as in Experiment 1).

The instructions, the stimuli (object + descriptor) presentation, and the immediate memory task were the same as in Experiment 1. After the encoding phase, the same 2-min filler task of even/odd digit classification followed. To ensure that the interval between object encoding and their ratings was the same as in the previous Experiments, participants

Table 2
Descriptive results (*M* and *SD*) and correlations between the rating difference for each evaluative dimension and the magnitude of the contamination effect.

	M	*SD*	1	2	3	4	5
1-Contamination Effect	0.106	0.215	–				
2-Arousal	0.547	1.438	0.140*	–			
3-Valence	−0.451	1.343	−0.107	−0.773***	–		
4-Disgust	0.657	1.539	0.120*	0.839***	−0.836***	–	
5-Fear	0.510	1.402	0.118*	0.839***	−0.769***	0.834***	–
6-Contamination potential	0.826	1.707	0.172**	0.809***	−0.790***	0.872***	0.807***

Note. *** $p < .001$, ** $p < .010$, and * $p < .050$.

then engaged in a Tetris game for 5 min (the time available to complete the recall task in the previous experiments). Then, participants rated the objects and the descriptors using the same five evaluative dimensions. In a subsequent 5-min surprise free recall task, participants were asked to write the names of as many objects as they could remember, regardless of the person who had touched them.

6.2. Results

6.2.1. Immediate memory

Participants' performance in the immediate memory task was high (contamination: 94 %; non-contamination: 95 %) and not different between conditions, $t(99) = -0.428$, $p = .669$, $dz = -0.04$, 95 % CI [−0.24, 0.15].

6.2.2. Objects ratings

Overall, the ratings of the objects replicated those found in the previous experiments (see Table 1). Participants rated the objects from the contamination condition (vs. non-contamination) as more arousing, negative, disgusting, frightening, and with greater contamination potential.

6.2.3. Descriptors ratings

As in Experiments 1 and 2, participants rated the sick descriptors (vs. the neutral descriptors) as more arousing, negative, disgusting, frightening, and with greater contamination potential (all p's < 0.001, see Appendix).

6.2.4. Free recall

Participants recalled significantly more objects when previously paired with sick descriptors ($M = 0.62$; $SD = 0.18$) than with neutral descriptors ($M = 0.55$; $SD = 0.18$), replicating the contamination effect, $t(99) = 3.63$, $p < .001$, $dz = 0.363$, 95 % CI [0.16, 0.57].

6.2.5. Mediation analysis

To further examine the role of emotionality in the contamination effect, we conducted separate mediation analyses for each evaluative dimension. In these models, the condition in which the object was presented (contamination vs. non-contamination) served as the predictor, object ratings on each dimension as mediators, and recall performance as the outcome. Overall, the analyses confirmed the significant effect of condition on object recall ($b = 0.074$, $p = .004$).

Among the five mediators tested, only disgust and contamination potential showed significant mediation effects. Specifically, disgust had a significant indirect effect on the relationship between condition and recall ($b = 0.016$, 95 % CI [0.001, 0.035]). In other words, contaminated objects were remembered better in part due to increased feelings of disgust. Still, when controlling for disgust, the direct effect of condition on recall remained significant ($b = 0.058$, $t = 2.203$, $p = .029$), indicating partial mediation.

Moreover, contamination potential fully mediated the effect of condition on recall, with a significant indirect effect ($b = 0.033$, 95 % CI [0.010, 0.059]). The direct effect was not significant ($b = 0.041$, $t = 1.483$, $p = .140$). This pattern suggests that the condition effect on recall occurred primarily through changes in perceived contamination potential.

Detailed mediation results for all evaluative dimensions are available on OSF [SM-4].

In Experiment 4, the object evaluation occurred without a prior recall task, and the evaluative differences remained between conditions. As a result of the re-exposure to the objects, the overall recall performance increased (compared to Experiment 1), particularly for the objects in the non-contamination condition. Nonetheless, a memory contamination advantage was still obtained despite a longer interval between the object's initial encoding and recall.

7. General discussion

Humans are believed to have developed a behavioral immune system — a set of affective, cognitive, and behavioral processes that detect and avoid fitness-relevant risks, thereby enhancing their chances of survival and reproduction (Schaller & Duncan, 2007). Memory plays a critical role in the effectiveness of this system (Murray & Schaller, 2016). Accordingly, several studies have reported a mnemonic advantage for objects that were in contact with potential contamination (vs. non-contamination) sources (e.g., Bonin et al., 2019; Fernandes et al., 2017; Fernandes et al., 2021; Thiebaut et al., 2022).

The current work investigated the role of emotionality in the contamination effect. This effect—enhanced recall for objects presented in the contamination versus non-contamination condition—was replicated across four experiments, even under conditions designed to progressively reduce its likelihood.

Experiment 1 replicated the effect using object photographs. Experiment 2 demonstrated the robustness of the effect using written instead of visual stimuli. Experiment 3 was particularly challenging, requiring associations between each object and contamination cue (dirty vs. clean hands) and between each stimulus pair (object+hands) and a specific person. Still, the effect was observed. Observing the contamination effect in Experiment 4 was particularly striking. To our knowledge, these are the first data to show that the effect resists somewhat longer retention intervals and potential interference from another task. The consistent results across experiments confirm the robustness of the contamination effect.

As in Fernandes et al. (2017, 2021), performance on the immediate memory task was high, confirming that objects were successfully encoded in their intended condition (contamination vs. non-contamination). Moreover, performance was comparable across conditions (except in Experiment 3), suggesting that the memory advantage for potentially contaminated objects is unlikely to result from differences in attention allocation during encoding.

Furthermore, across experiments, the contamination cues (Experiments 1, 2, and 4: descriptors; Experiment 3: dirty hands) were consistently evaluated as more arousing, negative, disgusting, frightening, and with greater contamination potential, suggesting they effectively activated a contamination-related subjective state.

Notably, participants consistently rated the objects presented in the contamination condition as more arousing, negative, disgusting, frightening, and with higher contamination potential, suggesting the effectiveness of associating contamination cues with neutral objects. Although the ratings were relatively low, significant differences between conditions were observed for objects presented without any contamination cue (i.e., descriptor/hands) and for objects presented after some time had elapsed between encoding and the object evaluation. While this occurred with object photographs in Experiment 1, observing the effect in Experiment 2 was even more notable because words (the names of objects) are known to elicit less emotional activation than images. In Experiment 3, the objects in the contamination condition were presented in direct physical contact with the same contamination source (the same dirty hands). Thus, participants' emotional activation could have been lower due to cue habituation. Still, the pattern of objects' emotional ratings remained.

Across experiments, the difference in object ratings between the two conditions was modestly but positively correlated with the contamination effect. In other words, the larger the rating difference, the stronger the mnemonic advantage for contaminated objects. While this pattern suggests the role of emotionality in the contamination effect, the higher ratings for contaminated objects might have resulted from their previous recall. However, Experiment 4 replicated the exact rating pattern in the absence of a prior recall task. Therefore, the emotionality ratings across all experiments suggest that the objects acquire properties inherent to the contamination condition (e.g., more arousing). These results align with the law of contagion (Rozin & Fallon, 1987), which holds that contamination characteristics can be transferred to neutral items through contact (descriptors and hands that "touch" the objects in our experiments).

Contamination potential was the dimension showing the largest rating differences between the two conditions. Moreover, in Experiment 4, contamination potential fully mediated the relationship between condition and recall. Although we initially focused on this dimension as tapping emotional processes, recent evidence suggests that it also entails a cognitive component. As suggested by Rouel et al. (2018), contamination aversion involves both affective and cognitive processes that interact to evaluate the threat of contamination; disgust seems to respond primarily to direct contaminants, whereas cognitive appraisals (e.g., threat estimation) respond to indirect or inferred contamination cues (which may be the case in our study). Such interpretation is consistent with prior research showing that the contamination effect depends on contextual framing—that is, it emerges when cues are described to participants as real contamination risks (e.g., diarrhea; faces signalling infectious diseases) but not when the exact same stimuli are framed as non-contaminating (e.g., chocolate spread; faces of actresses with makeup; Fernandes et al., 2017; Fernandes et al., 2021).

Interestingly, among the emotional dimensions assessed, the second-largest difference between conditions occurred for disgust; this was also the dimension that most strongly correlated with contagion-risk judgments. Consistently, in Experiment 4, disgust partially mediated the relationship between condition and recall, although this effect was modest (lower confidence interval near zero; see SM-4).

We should note that the emotional dimensions were measured subjectively (ratings). Future studies might examine further when and how these emotional mechanisms surface, their psychophysiological correlates (e.g., heartbeat rate), and whether emotionality constitutes a necessary condition for the emergence of the contamination effect and other adaptive memory processes. Other mechanisms that might also contribute to the contamination effect, such as attention, also warrant future research.

Overall, our results suggest that emotionality-related dimensions, particularly disgust, seem to play a modest role in the contamination effect. Instead, the effect seems to reflect the combined operation of affective reactions and cognitive evaluations of risk and safety, with cognitive processes as the primary driver. This conclusion is consistent with the Behavioral Immune System framework, which argues that different types of responses (affective, cognitive, and behavioral) make independent (although coordinated) contributions to the effective functioning of this preventive system.

Declarations of competing interest

None.

CRediT authorship contribution statement

Magda Saraiva: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Josefa N.S. Pandeirada:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Margarida V. Garrido:** Writing – review & editing, Methodology, Investigation, Conceptualization.

Funding

These studies were partly supported by Fundação para a Ciência e Tecnologia, Portugal, with grants awarded to the first (CEECINST/00089/2021) and second authors (CEECIND/01914/2017) and through support obtained from the WJCR (UID/04810/2025).

Declaration of competing interest statement

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Magda Saraiva reports financial support was provided by Foundation for Science and Technology. Josefa Pandeirada reports financial support was provided by Foundation for Science and Technology. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Appendix

Mean ratings (and SDs) of the (non-)contamination cues for each evaluative dimension in the four experiments and results of the comparison between conditions.

		Evaluative Dimensions				
	Cue	Arousal *M*(*SD*)	Valence *M*(*SD*)	Disgust *M*(*SD*)	Fear *M*(*SD*)	Contamination *M*(*SD*)
Experiment 1	Sick descriptors	5.55 (1.90)	2.91 (1.11)	4.69 (1.82)	5.02 (1.90)	6.11 (1.51)
	Neutral descriptors	2.20 (1.51)	6.66 (1.49)	1.46 (0.92)	1.41 (0.91)	1.55 (1.10)
	t(96)	13.13***	−18.89***	16.10***	17.46***	23.19***
	95 % CI	[1.06, 1.61]	[−2.25, −1.58]	[1.33, 1.94]	[1.45, 2.09]	[1.97, 2.74]
	dz	1.33	−1.92	1.64	1.77	2.36

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(*continued*)

	Cue	Evaluative Dimensions Arousal M(SD)	Valence M(SD)	Disgust M(SD)	Fear M(SD)	Contamination M(SD)
	Sick descriptors	5.12 (1.87)	2.98 (1.00)	4.11 (1.82)	4.47 (1.96)	5.97 (1.55)
	Neutral descriptors	2.22 (1.35)	6.06 (1.35)	1.36 (0.67)	1.31 (0.64)	1.55 (1.07)
Experiment 2	*t*(91)	13.80***	−16.35***	15.01***	15.92***	24.04***
	95 % CI	[1.15, 1.73]	[−2.02, −1.38]	[1.26, 1.87]	[1.34, 1.97]	[2.07, 2.90]
	dz	1.44	−1.70	1.57	1.66	2.51
	Dirty hands	7.66 (1.33)	1.47 (0.90)	8.40 (1.07)	6.00 (2.71)	8.37 (1.27)
	Clean hands	2.33 (1.68)	7.19 (1.68)	1.39 (0.84)	1.28 (0.73)	2.05 (1.33)
Experiment 3	*t*(98)	23.55***	−27.95***	52.20***	17.71***	29.57***
	95 % CI	[1.98, 2.75]	[−3.25, −2.37]	[4.49, 6.00]	[1.46, 2.10]	[2.51, 3.40]
	dz	2.37	−2.81	5.25	1.78	2.98
	Sick descriptors	5.26 (1.94)	3.01 (0.97)	4.68 (1.88)	4.75 (2.14)	6.31 (1.41)
	Neutral descriptors	2.23 (1.47)	6.23 (1.35)	1.45 (0.97)	1.48 (0.94)	1.44 (1.05)
Experiment 4	*t*(99)	13.46***	−16.98***	17.45***	15.55***	26.59***
	95 % CI	[1.07, 1.62]	[−2.00, −1.39]	[1.43, 2.06]	[1.26, 1.85]	[2.24, 3.08]
	dz	1.35	−1.70	1.75	1.56	2.66

Notes: *** $p < .001$; The (non-)contamination cues in Experiments 1, 2, and 4 were the sick and neutral descriptors; in Experiment 3, these were the clean and dirty hands.

Data availability

The data associated with this research are available on OSF (https://osf.io/ntv8u/?view_only=f90a4a1b94d14837800cf152098469af).

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