Universidade de Aveiro Departamento de Educação e Psicologia
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SISTEMA IMUNITÁRIO COMPORTAMENTAL: CONSEQUÊNCIAS COGNITIVAS DA CONTAMINAÇÃO

THE BEHAVIORAL IMMUNE SYSTEM: COGNITIVE CONSEQUENCES OF CONTAMINATION

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Psicologia, realizada sob a orientação científica da Doutora Josefa N. S. Pandeirada, Equiparada a Investigador Principal no Departamento de Educação e Psicologia da Universidade de Aveiro, e co-orientação científica do Professor Doutor James S. Nairne, Reece McGee Distinguished Professor no Department of Psychological Sciences da Purdue University.

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o júri

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Sistema imunitário comportamental, contaminação, nojo, memória adaptativa, atenção adaptativa, evitamento de doenças, Base de Imagens de Objetos-em-Mãos, diferenças individuais.

resumo

As doenças infeciosas têm representado uma verdadeira ameaça à vida humana. Em resposta a este problema adaptativo, desenvolveu-se o sistema imunitário "biológico", através de processos de seleção natural, o qual é responsável por detetar e eliminar microorganismos invasores.
Adicionalmente, desenvolveu-se o sistema imunitário “comportamental”, o qual induz processos afetivos, cognitivos e comportamentais em resposta a potenciais fontes de doença, de modo a facilitar o evitamento de situações de risco que possam comprometer a nossa saúde. Ancorado numa perspectiva evolutiva, este projeto teve como objetivo explorar os mecanismos cognitivos subjacentes a este último sistema, tendo-se focado essencialmente nas consequências mnésicas da contaminação. Ao longo de sete estudos, examinámos se a memória humana retém preferencialmente itens potencialmente contaminados (comparativamente com itens não-contaminados). A fim de asseverar a replicabilidade e robustez do efeito, testámos a memória para a contaminação em diferentes grupos culturais, adotando paradigmas experimentais, veículos de doença e contextos de codificação diversos. Globalmente, os nossos estudos fornecem evidência de uma vantagem mnésica para a contaminação – melhor memória para itens contaminados (vs. itens não-contaminados) – contribuindo para a crescente constatação empírica de que a nossa memória funciona de modo a potenciar as nossas probabilidades de sobrevivência e/ou reprodução, as forças motrizes da evolução. Um problema comummente enfrentado por investigadores nesta área corresponde a preocupações inerentes à seleção dos itens. Para colmatar esta dificuldade, no início do presente projeto, desenvolvemos de raiz uma base de imagens, as quais foram utilizadas em algumas das experiências. Também foram recolhidos dados normativos em várias dimensões e em diferentes países para que esta possa constituir uma ferramenta de trabalho útil para outros investigadores
Com vista à investigação do envolvimento de um outro processo cognitivo no sistema imunitário “comportamental”, explorámos se itens potencialmente contaminados captam a atenção visual, utilizando para o efeito uma tarefa de identificação de letras. Observámos um viés atencional para a contaminação, sugerindo que a atenção também cumpre uma função adaptativa. Finalmente, explorámos o efeito de algumas diferenças individuais na magnitude da vantagem mnésica para a contaminação.
Além da contribuição teórica deste trabalho para a compreensão do funcionamento do sistema imunitário “comportamental”, os resultados obtidos serão potencialmente úteis no desenvolvimento de programas de saúde pública visando aumentar comportamentos de prevenção de doenças infeciosas, uma das principais causas de mortalidade no mundo.

keywords

Behavioral immune system, contamination, disgust, adaptive memory, adaptive attention, disease-avoidance, Objects-on-Hands Picture Database, individual differences.

abstract

Infectious diseases have long been a threat to human life. As one potential solution to this adaptive problem, natural selection forged the “biological” immune system, which is responsible for recognizing and eliminating invading microorganisms within the body. In addition, a sort of “behavioral” immune system has evolved as well, which prompts specific affective, cognitive, and behavioral reactions in response to potential sources of disease, as a means of facilitating the avoidance of risky situations that could compromise our health. Anchored in an evolutionary framework, this project aimed to explore the cognitive mechanisms underpinning the latter system. The main focus was on the mnemonic consequences of contamination: Across seven studies, we examined if the human memory preferentially retains potentially contaminated items (as compared to non-contaminated items). In order to confirm the replicability and robustness of the effect, memory for contamination was tested in different cultural groups, using a variety of stimuli, encoding-contexts, and experimental designs. Collectively, our studies provided evidence of a mnemonic tuning for contamination – enhanced memory for contaminated items (vs. non-contaminated items) – adding to the accumulating evidence that our memory works in the service of maximizing our chances of survival and of reproduction, the driving wheels of evolution. Item-selection is a common issue that researchers face when conducting research in this topic. To overcome such issue, at the beginning of this project, a new database of stimuli to be used as material in some of the experiments was purposely developed. Norming information on several dimensions and in different countries was also collected turning this database of use to other researchers.

Aiming to consider other cognitive functions potentially involved in the “behavioral” immune system, we also explored if contaminated items preferentially capture humans’ visual-attention by employing a letter-identification task. An attentional bias for contamination was observed, suggesting that attention also fulfills an adaptive function. Finally, the potential influence of some key individual variables on the strength of the mnemonic advantage for contamination was explored.

Besides the theoretical contribution of this work to understanding the functioning of the “behavioral” immune system, our findings could be potentially useful for developing future public health programs aimed at promoting prophylactic behaviors and reduce infectious diseases, a leading cause of mortality worldwide.

Table of contents

PART III: EMPIRICAL STUDIES

CHAPTER 5

CHAPTER 6

PART IV: GENERAL DISCUSSION AND CONCLUSIONS

CHAPTER 7

List of Figures

List of Tables

List of Abbreviations

A	Generation of autobiographical episodes
ARC	Adjusted ratio of clustering
BIO	Biological immune system
BIS	Behavioral immune system
C	Generation of contamination situations
CS-	Unreinforced conditioned stimulus
CS+	Reinforced conditioned stimulus
DKN	Don’t know name
DKO	Don’t know object
DP	Disgust propensity
DPS	Combined disgust propensity and sensitivity
DPSS-R	Disgust Propensity and Sensitivity Scale-Revised
DS	Disgust sensitivity
DV	Dependent variable
GA	Germ aversion
IAPS	International Affective Picture System
IBM SPSS	Statistical Package for Social Sciences
IRB	Institutional review board
IV	Independent variable
KDEF	Karolinska Directed Emotional Faces Database
LDT	Lexical decision task
LED	Light-emitting diode
LSA	Latent semantic analysis
NS	Neutral stimulus
OSF	Open Science Framework
P	Pleasantness ratings
PDS	Pathogen Disgust Subscale of the Three Domain Disgust Scale
PI	Perceived infectability
PVD	Perceived vulnerability to disease
PVDS	Perceived Vulnerability to Disease Scale
RaFD	Radboud Facial Database
RT	Response time
SEM	Standard errors of the mean
SOA	Cue-target stimulus onset asynchrony
TOT	Tip-of-the tongue
USA	United States of America
%NA	Percentage of name agreement

Preamble

Human living bodies are astoundingly complex systems shaped and sculpted over generations using nature's criterion to solve pressing fitness-related problems. Each of the body’s organs is uniquely designed to help us survive and reproduce: the heart pumps blood, lungs extract oxygen, kidneys filter impurities, and so on (Nairne, 2010). An identical analogy to the mind has been proposed by Tooby and Cosmides (1992), which posits that the architecture of the human mind was an outcome of evolution by natural selection. In light of this, it has been proposed that humans are equipped with an integrated set of domain-specific mechanisms (Tooby & Cosmides, 2005) that effectively address potential adaptive problems that might have been recurrently faced by our ancestors (e.g., resource acquisition, self-protection, disease avoidance, mate selection, parenting: Kenrick, Griskevicius, Neuberg, & Schaller, 2010; Kenrick, Li, & Butner, 2003; Neuberg, Kenrick, & Schaller, 2011).

A “*tessera”* from this ample mosaic of fitness-relevant problems has captivated our curiosity and guided the proposal of this PhD research project: namely, the threat posed by pathogens. Several signatures of adaptations have likely been driven by a strong selection pressure exerted by diseases. Both body and mind seem to work synergistically and in a functional integrated manner to protect us from all sorts of potentially harmful pathogenic infections (Miller & Maner, 2011; Schaller, Miller, Gervais, Yager, & Chen, 2010). For that end, natural selection designed the standard immune system to detect and destroy pathogens within the human body, and the *behavioral immune system* (henceforth the BIS), that orchestrates a number of effective pathways to prevent contact with such pathogens in the first place (Schaller, 2006; Schaller & Park, 2011). Such systems seem to be highly adaptive as they significantly reduce the likelihood of people succumbing from diseases.

Drawing on an evolutionary psychology framework, the present PhD thesis is mainly focused on understanding the functioning mechanisms of the BIS, bringing forth value to the findings obtained to date. The BIS has been the focus of growing interest since its initial description just over a decade ago, and the already available data demonstrate the cornucopia of insightful ideas that can be gleaned from investigations in this area. This system is hypothesized to function by detecting disease-connoting cues and driving affective (e.g., disgust), cognitive (e.g., faster allocation of attention and better memory), and behavioral (e.g., avoidance and grooming) mechanisms that minimize one’s exposure to harmful pathogens (Schaller & Park, 2011). Special emphasis will be placed on the cognitive mechanisms underpinning the BIS.

The first part of this work provides an overall theoretical introduction to the topic under study. Chapter 1 of this introduction, entitled *The behavioral immune system: Mechanisms and disease-avoidance function,* explores the bundle of psychological mechanisms that operate to detect the potential presence of pathogens in the environment and to facilitate behaviors that minimize infection risk and enhance fitness. An introduction to the BIS – what it is and how it works – is provided, along with a brief account of the three components considered to be key parts of the BIS: affective, cognitive and behavioral. In the second chapter, *The behavioral immune system: Functional flexibility and individual differences*, a summary overview of extant empirical research exploring the individual variation in the extent to which the BIS is activated, is presented. In addition to this overall theoretical introduction, a brief theoretical framing is provided for the empirical studies described in Part II and III of this work.

The second part of the thesis presents Chapter 3, *The Objects-on-Hands Picture Database.* During the development of this research project, we felt the need to create a database of images, with more ecologically-valid stimuli that were capable of minimizing item-selection confounds, to be used as material in our experiments. This chapter presents a full characterization of this set of stimuli, along with norming information on naming agreement and familiarity obtained from a sample of Portuguese and North American participants. Additionally, norming data regarding three emotion-related variables – arousal, disgust and emotional valence – is provided for each stimulus when these are described under different encoding contexts.

A set of empirical studies exploring two of the cognitive components of the BIS – memory and attention – are presented in Part III. This includes Chapter 4, entitled *"Remind myself not to touch it, it is contaminated!": Memory and contamination*, in which we present a set of experiments that provide evidence in support of the mnemonic value of contamination. Memory for potentially contaminated items was tested in two cultural groups using a variety of stimuli, encoding-contexts, and experimental designs. Chapter 5, *"Watch out for that disgusting thing!": Attention and contamination*, explores the attentional bias for potentially contaminated items; results from an initial study are presented. Chapter 6, named *"It is not as bad for me as it is for you!": Individual differences,* presents an exploratory analysis of the impact of individual differences – propensity and sensitivity to disgust, perceived vulnerability to disease, and health status – on the mnemonic tuning for contamination. Finally, Part IV and last chapter of this thesis, *What did we find out and where to go next?*, presents a summary and integration of the experimental findings of the different studies here reported, and outlines practical implications, limitations and directions for future studies.

A substantial part of this thesis has already been reported in peer-review journals, in a book chapter, and in conferences. Additionally, it has been made available to the general public through the social media (e.g., newspapers). Thus, some of the information presented in this thesis overlap with what has already been published in these products (see “scientific products” specified at the beginning of each chapter).

All studies here reported were carried out in accordance with the Declaration of Helsinki and had been approved by the Ethics Committee of the University of Aveiro (for studies conducted in Portugal – Ref. number: 8/2017, Principal Investigator: Josefa N. S. Pandeirada) and the Institutional Review Board of the Purdue University (IRB; for studies conducted in the United States of America [USA] – Ref. number: 1301013109, Principal Investigator: James S. Nairne). All aspects of the experiments’ procedure (e.g., sentences, instructions and self-report instruments) were formulated in European Portuguese and English when the experiments were conducted with Portuguese and American samples, respectively. In the experiments were both Portuguese and American samples were used, the procedural aspects material and stimuli were the corresponding translation to each language.

PART I

THEORETICAL INTRODUCTION

I

THEORETICAL INTRODUCTION

CHAPTER 1.

The Behavioral Immune System: Mechanisms and disease-avoidance function

. Disease threats: A functionally unique fitness problem

. Pathogens detection and the ‘smoke detector principle’

. The affective signature of the BIS: Disgust

. The cognitive toolkit of the BIS: Memory and attention

. The behavioral machinery of the BIS: Precautionary behaviors against pathogens

1.1 Disease threats: A functionally unique fitness problem

“What's past is prologue.”
–Shakespeare, *The Tempest*, 1611, act 2, sc. 1

Throughout human evolutionary history, pathogenic microorganisms have posed one of the most staggering and overwhelming threats to survival and reproduction, historically accounting for more deaths than any other cause (Fumagalli et al., 2011; Tooby, 1982; Zuk, 2007). Evidence gathered through a variety of specialized fields, such as paleopathology, parasitology, and molecular biology, suggests that pathogens infected humans as early as 500,000 years ago (e.g., Mycobacterium tuberculosis: Comas et al., 2013; malaria-causing Plasmodium falciparum parasite: Kwiatkowski, 2005; bacterium Helicobacter pylori: Moodley et al., 2012; human papillomavirus: Pimenoff, de Oliveira, & Bravo, 2016; Mycobacterium leprae: Witas, Donoghue, Kubiak, Lewandowska, & Gładykowska-Rzeczycka, 2015). The migration and colonization of new habitats, the exponential increase in population density, the rise of agriculture and close cohabitation with animals, which occurred fairly recently – within the past 100,000 years or so – have led to the emergence of new diseases and, consequently, strongly increased the selective pressures exerted by pathogens on human populations (Karlsson, Kwiatkowski, & Sabeti, 2014; Wolfe, Dunavan, & Diamond, 2007). To face these threats, natural selection designed and refined a sophisticated set of physiological mechanisms to detect and destroy pathogens that enter the body, which has been designed as the “classical” (Fincher & Thornhill, 2012), “physiological” (Ackerman, Hill, & Murray, 2018) or “biological” immune system (henceforth the BIO; Miller & Maner, 2011), and includes both the innate and the adaptive immune responses (Parham, 2014; Sompayrac, 2016).

Despite its undeniable benefits, the activation of such a system can carry heavy costs. The BIO consumes substantial resources that could otherwise be allocated to other physiological systems (Murray & Schaller, 2016; Schaller, 2016); for example, fighting off infectious diseases limits the energy available for cognitive development, as indicated by a strong negative correlation between parasite stress and cognitive ability (Daniele & Ostuni, 2013; Eppig, Fincher, & Thornhill, 2010). Usually, an individual with a sedentary lifestyle needs ~10,000 kJ daily (Blaxter, 1989). In the basal metabolic state (i.e., in an inactivated state) the BIO requires ≈ 1600 kJ/d; when activated, the total energy expenditure of the BIO can increase by 9-30% (or even 60% in the case of sepsis), consuming roughly the same amount of energy as the brain (2200 kJ/d; Straub, Cutolo, Buttgereit, & Pongratz, 2010). Fever, for example, a physiological immune response triggered in an attempt to eliminate bacterial infections, implies a substantial energetic cost, with an increase of about 13% in metabolic activity to raise body's temperature by 1°C (Baracos, Whitmore, & Gale, 1987). Additionally, the acute-phase response of the BIO is associated with sickness-related behaviors, including lethargy, anhedonia, increased sleep, decreased appetite/food intake, decreased sexual activity, and social withdrawal, all of which play an important role in fending off pathogenic infection (Ackerman et al., 2018; Baumann & Gauldie, 1994; Kelley et al., 2003), but that temporarily compromise the pursuit of other fitness-related goals, such as acquiring resources, mating or caring for offspring (Schaller, 2016).

Although generally effective, the BIO is far from being perfect. Pathogens generally have relatively short life cycles, allowing them to evolve much faster than their hosts' immune systems and, consequently, to develop successful strategies for escaping immune surveillance (Duffy, Shackelton, & Holmes, 2008; Dybdahl & Storfer, 2003). Further, an immune response is typically initiated after specific cells and proteins of the BIO recognize and bind pathogenic antigens (Parham, 2014). It is possible, thus, that pathogens “wreak significant damage during the latency period between the time they enter the body and the time that the immune system mobilizes a defensive response” (Murray & Schaller, 2016, p. 78). In addition, inflammatory responses have been found to temporarily render individuals more susceptible to other illness (A. M. LeVine, Koeningsknecht, & Stark, 2001) as well as to induce oxidative stress and decrease cellular antioxidant capacity, both of which are thought to promote aging and diseases (Gassen et al., 2018).

Given the costs and the imperfect nature of the immune response, an additional suite of mechanisms aimed to detect sources of potential infection and selectively prevent or reduce contact with them, minimizing the likelihood of becoming infected, would have utmost adaptive value (Stevenson, Case, & Oaten, 2011). Accordingly, recent evidence suggests that selective pressures have also shaped behavioral disease-avoidance strategies that complement and/or compensate the BIO (Ackerman et al., 2018). These evolved strategies have been found in human beings as well as in a wide range of animal species (for a more detailed review see, for example, Curtis, 2014; Moore, 2002; Parker, Barribeau, Laughton, de Roode, & Gerardo, 2011). The system that prompts disease-avoidance responses has often been referred to as the BIS[1] (Schaller & Park, 2011; see section 1.2 of Chapter 1 for alternative designations), a system that serves as an important “first-line defense” against health threatening infectious agents. Over the past years, a sizable body of literature has been devoted to exploring and understanding this system, shedding light on its underlying mechanisms and psychological implications (for a review, see Murray & Schaller, 2016).

1.2 Pathogens detection and the ‘smoke detector principle’

> “The first step toward mitigating a threat is to identify it.”
> (Neuberg, Kenrick, & Schaller, 2011, p. 8)

Humans must be able to detect and encode threats posed by pathogens in order to respond in an adaptive fashion, safeguarding their health and, ultimately, their survival. Disease-causing microorganisms (e.g., bacteria, viruses, helminths) are, however, functionally different from most other threats to human health and welfare (e.g., predators, threatening conspecifics, natural hazards). The major difference between pathogens and other fitness-relevant threats lies in the fact that most pathogenic microorganisms are invisible to the naked eye and cannot be perceived directly, but must instead be indirectly inferred based on certain sensory cues (Schaller, 2016). How do we know which stimuli may carry a threat to our health? A broad range of stimuli seem to accommodate harmful infectious disease-causing agents, including rotting foods, dead bodies, potentially contaminating animals, bodily products such as feces, vomit, phlegm, and blood, among others (Oaten, Stevenson, & Case, 2009; Rozin, Haidt, & McCauley, 2008). Sensory cues signaling disease-threat include visual (e.g., morphological and behavioral changes observable in sick people), olfactory (e.g., the rotting smell of dead bodies, feces, or garbage), gustatory (e.g., the taste of sour milk or spoiled food), auditory (e.g., the sound of someone sneezing or vomiting), or even tactile (e.g., the texture of a viscous or sticky substance) input (Curtis, Aunger, & Rabie, 2004; Curtis & Biran, 2001). Pathogens, however, frequently cannot be detected at all. In contrast, because of their size, most

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[1] First introduced by Schaller in 2006, the designation “behavioral immune system” was adopted since “psychological immune system” – that best fit the concept – was already in use, denoting a distinct set of processes. Hence, the term “behavioral” should not be confined to ethology but rather extended to psychology more generally.

other sources of threat are readily detectable and more likely to be appraised as such (Murray & Schaller, 2016; Schaller, 2016).

In addition, tiny disease-causing parasites and large predators are different in the ways in which they might be mitigated or overcome. As proposed by Schaller and collaborators, most of the strategies believed to be very effective to deal with some threats are, however, unsuitable against the transmission of diseases. For example, aggregating in groups may be useful as a means of reducing the threat posed by predators, but may be useless, or even harmful, as a means of protection against the transmission of infectious diseases (Murray & Schaller, 2016; Schaller, 2016).

Such differences were likely to account for the development of a set of psychological response mechanisms specifically designed to mitigate the threat posed by pathogens. Accordingly, some researchers have proposed that different threat-management systems likely evolved, through natural selection, to help our ancestors effectively manage specific kinds of fitness-relevant threats (Aunger & Curtis, 2013; Murray & Schaller, 2016; Schaller, 2016). These systems are characterized as unique motivational systems, responsive to different environmental signals that motivate functionally specific affective, cognitive, and behavioral responses (Neuberg et al., 2011; Schaller, Kenrick, Neel, & Neuberg, 2017). Neuberg et al. (2011) propounded two domain-specific and functionally distinct threat-management systems that operate in a complex and coordinated fashion to enhance reproductive fitness: the “self-protection system” and the “disease-avoidance system”. Whereas the former is mainly associated with the emotion of fear and facilitates escape or fighting behaviors, the latter is mediated primarily by the emotion of disgust and motivates withdrawal and avoidance behaviors. Aunger and Curtis (2013), in accordance, proposed two distinct motivational systems, which they labeled according to the emotions of fear and disgust. These systems prevent damage from threats attacking the body from the outside (i.e., “hurt-from-without threats”; e.g., predators) and from the inside (i.e., “hurt-from-within threats”; e.g., parasites), respectively.

The *disease-avoidance system* or BIS seems to be adaptively tuned to perceive potential contamination threats in the immediate environment (Neuberg et al., 2011). It is difficult, however, to determine whether a specific cue reliably accommodates harmful infectious disease-causing agents, giving rise to a signal-detection problem. Albeit helpful, disease-connoting cues are not necessarily accurate. Since an inaccurate and inefficient detection of pathogens can lead to harm and death, that is, the costs to one's fitness of missing a real threat strongly outweigh the costs of erroneously perceiving a non-threatening cue as threatening, the BIS evolved a bias to over-infer threat situations (Haselton & Nettle, 2006; Nesse, 2005). Accordingly, this system seems to operate on the basis of “the smoke detector principle” (Nesse, 2005). Smoke detectors are calibrated to respond in a sensitive manner to the slightest hint of smoke (i.e., to err on the side of false-positive errors), thereby avoiding failure to detect and respond adequately to a real-threatening house fire (i.e., to err on the side of an extremely costly false-negative error; Schaller & Park, 2011). Similarly, “natural selection has shaped perceptual, cognitive and emotional systems to minimize the likelihood of making whichever form of error is most harmful to reproductive fitness” (Neuberg et al., 2011, p. 14). False-negative errors (e.g., mistakenly judging a sick individual to be healthy, or a contaminated food to be safe to eat) impose substantially higher fitness costs compared to false-positive errors (e.g., mistakenly perceiving a healthy individual to be sick, or a nutritious food to be contaminated). Therefore, humans should be biased towards mistakenly inferring pathogens' presence when they are absent instead of failing to detect their actual presence (error management theory: Haselton & Nettle, 2006; Haselton, Nettle, & Murray, 2015; Johnson, Blumstein, Fowler, & Haselton, 2013).[2]

The upshot is that people heuristically relate harmless physical conditions with contagious disease, including elderly (e.g., Duncan & Schaller, 2009; Miller & Maner, 2012), facial disfigurements (e.g., Ackerman et al., 2009; Miller & Maner, 2011; Ryan, Oaten, Stevenson, & Case, 2012), physical disabilities (e.g., Park, Faulkner, & Schaller, 2003), and obesity (e.g., Lund & Miller, 2014; Park, Schaller, & Crandall, 2007). This strong tendency towards false-positives errors may be at the root of some manifestations of prejudice and stigmatization, such as racism, homophobia, and ageism (Haselton et al., 2015; Kurzban & Leary, 2001).

1.3 The affective signature of the BIS: Disgust

> “The war against pathogens is waged on many fronts, and disgust is but one defense”.
>
> (Strohminger, 2014, p. 480)

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[2] Note that, similarly to the BIS, the BIO has been designed to err on the side of false-positives; some foreign microorganisms are assumed to be dangerous health threats when they are, in fact, harmless. Miller and Maner (2012) referred allergies as a common example of such bias.

Imagine yourself travelling to Paris in the mid' 1880s. The scenario you would most likely find is something similar to what was described in *Le Figaro* – a putrid and insufferable stench:

> "In every street the pipes gushed out where decaying rat carcasses drank everything in, tails dangling and whiskers bristling with greenish lumps. Bellies in the air, they floated amid apple peels, asparagus stalks and cabbage cores…it was like a vast infection of tooth decay, like the flatulence of a rotting stomach, like the emanations of a man who has drunk too much, like the dried sweat of rotting animals, like the sour poison of a bedpan…this avalanche of excretions tumbling down the length of the purulent streets…let off its nocturnal fragrances." Un Chapitre inédit de M. Zola, *Le Figaro*, August 24, 1880 (as cited in Barnes, 2006, p. 246)

What kind of thoughts or emotions does this description awaken in you? The perception of disease-connoting cues is likely to trigger the emotional experience of disgust, which generally operates at an unconscious "gut level" (Rozin, Millman, & Nemeroff, 1986). Disgust has been recognized as a basic emotion (Darwin, 1998; Ekman & Friesen, 1971) and is universally expressed and accurately recognized across cultures (Curtis & Biran, 2001; Curtis, de Barra, & Aunger, 2011). Whereas other emotional experiences, such as fear, anger, and sadness, have a well-established empirical foundation, disgust has received relatively less empirical attention (Phillips, Senior, Fahy, & David, 1998). Interest in disgust has increased in recent years but, still, a number of issues are largely unknown and have poorly been explored (Strohminger, 2014).

Disgust is believed to have evolutionary roots in distaste, an initial form of response towards contaminated foods (Rozin et al., 2008). However, its adaptive value is not exclusively confined to preventing the ingestion of harmful substances; it extends to a broader disease-avoidance function, constituting a key component of the BIS (Curtis et al., 2011; Oaten et al., 2009; Rozin et al., 2008; Tybur, Lieberman, Kurzban, & DiScioli, 2013). This highly-arousing and negatively-valenced emotional reaction is generally believed to have been crafted by natural selection as an adaptive response to help us avoid pathogens (Curtis et al., 2004). There is ample evidence supporting its functional value, including its characteristic facial expression and physiological responses. The facial expression of disgust (e.g., activation over the levator labii facial muscle region: Vrana, 1993) is thought to prevent the invasive entry of potentially infectious agents into the mucus membranes of the face (i.e., to wrinkle the nose restricts the airflow through the nose, to squint the eyes limits the exposed surface area of the eyes, and the raise of the upper lip prevents pathogens from entering the mouth; Chapman & Anderson, 2012; Rozin et al., 2008; Tybur et al., 2013). Disgust is often accompanied by the protrusion of the tongue, which have been interpreted as a vestige of the gag reflex, as well as by nausea, desire to vomit, increased salivation, and loss of appetite (Angyal, 1941; Rozin & Fallon, 1987; Rozin et al., 2008). These reactions may function to expel potential pathogens that have already been ingested or to reduce the likelihood of ingesting harmful pathogens (Chapman & Anderson, 2012; Tybur et al., 2013), providing support for the pathogen-avoidance account of disgust. Disgust motivates both avoidance and rejection behaviors, such as spitting out bad-tasting food or dropping the disgusting-eliciting stimuli, as well as the engagement in precautionary behaviors, such as washing the hands (Olatunji & McKay, 2009).

In fact, 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 et al., 2009; Tybur et al., 2013). Disgust is triggered by a broad range of stimuli, such as foods (e.g., spoilt, contaminated, and unfamiliar food), bodily products (e.g., feces, urine, vomit, phlegm, and semen), potentially contaminating animals (e.g., ticks, worms, flies, rats), inappropriate sexual behaviors, poor hygiene, body envelope violations (e.g., blood, gore, and deformity), death, and observable cues that suggest possible infection (Oaten et al., 2009; Rozin et al., 2008). Though there is some flexibility and cultural variability in what is considered disgusting (from individual to individual and from culture to culture), there is also cross-cultural consistency in some disgust elicitors (Curtis & Biran, 2001; Rozin et al., 2008). It is worth keeping in mind that the presence of pathogens does not always elicit the experience of disgust; for example a cooked hamburger that houses *Escherichia coli* bacteria does not elicit disgust even though it is a major vehicle of disease transmission (Tybur & Lieberman, 2016). This is understandable given the microscopic nature of pathogens and the subsequent inherent imperfection of pathogen-detection systems.

Interestingly, innocuous objects that have been in close contact with disgusting objects are also treated in a special way because people believe there is a transference of the disgusting or contaminating properties through contact (Rozin & Fallon, 1987). Thus, for a stimulus to become disgusting, it is often enough for it to touch or even be near something that is naturally disgusting (Rozin et al., 1986). 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, 1922, p. 12, as cited in Coughtrey, Shafran, & Rachman, 2014).

This seems to be an unique feature of disgust and does not generalize to other emotions in the same way; for example, people who come into close contact with a frightening predator do not become frightening themselves (Inbar & Pizarro, 2016). It is also a “part of what makes it such an effective defense against pathogens, as it mimics the mechanism by which disease actually spreads” (Inbar & Pizarro, 2016, p. 366). Empirical support for this idea comes from studies demonstrating that people evaluate more negatively and are unlikely or unwilling to interact with objects that have simply come in contact with disgusting things (e.g., Morales & Fitzsimons, 2007; Rozin et al., 1986). For example, people are reluctant and/or refuse to drink a juice that has briefly contacted a sterilized dead cockroach (Rozin et al., 1986), to drink from a sterilized glass that once held dog feces (Rozin & Nemeroff, 1990) or to eat foods that have been handled or bitten by unsavory or disliked persons (Rozin, Nemeroff, Wane, & Sherrod, 1989). In work by Rozin et al. (1989), participants were instructed to imagine interacting with a variety of objects (e.g., wearing a sweater or brushing their hair with a hairbrush) that once belonged to and were used by different people (e.g., a friend, a lover, a disliked, or an unsavory person). Objects that previously belonged to or were used by a disliked or unsavory person were rated as significantly more unpleasant. Likewise, knowing that a piece of clothing had been touched and tried on by strangers, negatively impacts both a consumer’s evaluation and the intention to purchase that item (Argo, Dahl, & Morales, 2006).

Employing a scenario in which participants were shown a set of products in a grocery cart, Morales and Fitzsimons (2007) found that the mere physical contact between a tightly sealed package of a disgusting product and another non-disgusting product, such as placing feminine napkins next to cookies, substantially decreased participants’ willingness to try the latter product and lowered the judgments of its quality. Another study recently explored the impact of superficial packaging damage on consumers’ product evaluations and purchase intentions (White, Lin, Dahl, & Ritchie, 2016). People showed negative reactions and avoidance toward these products, which seemed to derive from perceptions of contamination and subsequent concerns with health and safety risks.

A second law of sympathetic magic, namely the “law of similarity” (Nemeroff & Rozin, 2000; Rozin & Nemeroff, 1990), also accounts for some features of disgust. This law holds that things that look alike share fundamental properties or essence (that is, “appearance is reality”). Thus, perfectly harmless stimuli resembling, in some way, a threat-relevant disgust elicitor, are also treated as disgusting. For example, in a study of Rozin et al. (1986), individuals refused to eat objectively safe foods shaped into a form of a disgusting object, such as chocolate fudge shaped like dog feces. It is reasonable to suppose that both the aforementioned laws of sympathetic magic may be triggered by “the smoke detector principle” (Nesse, 2005) as a mean to deploy a pathogen avoidance response, preventing the potentially high costs of infection.

Stimuli can also be seen as disgusting either via classical conditioning (e.g., Olatunji, Tomarken, & Puncochar, 2013), or by observing others’ facial expressions of disgust (e.g., Stevenson, Oaten, Case, Repacholi, & Wagland, 2010). For example, in 2016, Borg, Bosman, Engelhard, Olatunji, and de Jong conducted a disgust-conditioning study using food items as neutral stimulus (NS) and film clips as unconditioned stimulus. During conditioning, the presentation of the NS was followed by the exhibition of a video-clip in which a woman was vomiting (thus becoming a reinforced conditioned stimulus; CS+), or a neutral clip illustrating the production of handmade glass (becoming an unreinforced conditioned stimulus; CS-). Results showed that, after acquisition, the CS+ was judged as more disgusting, less positive, and less tasty than the CS-. Importantly, participants also reported a lowered willingness-to-eat the CS+ food items.

In sum, there is ample evidence that disgust serves to defend individuals from disease. Note that, as several authors have pointed out, disgust’s function extends well beyond pathogen avoidance. Chapman and Anderson (2012) suggested that disgust has expanded its role from protecting us against diseases to protecting us against other fitness-threats (e.g., incest, costly sexual partners). Tybur and collaborators have also proposed three disgust-domains: pathogen, sexual, and moral. The first drives pathogen avoidance, the second precludes individuals from mating with low-quality mates, and the latter discourages social transgressions (Tybur, Lieberman, & Griskevicius, 2009; Tybur et al., 2013). We do not discuss further these other disgust-domains, because they go beyond the scope of this thesis.

1.4 The cognitive toolkit of the BIS: Memory and attention

> “Because of this increased importance for parasites in the ecological milieu of humans (…) parasites are paramount in the evolution of Homo sapien’s social and cognitive uniqueness.”
>
> (Thornhill & Fincher, 2014, p. 258)

The idea that one of the core outputs of the BIS is the emotion of disgust is well established (Curtis et al., 2011; Oaten et al., 2009; Tybur et al., 2013). Nonetheless, a variety of other adaptive mechanisms may also be implicated in shielding us from contracting diseases. For example, the perception of disease-connoting cues should prompt: (a) conceptual knowledge about health and illness; (b) reasoning strategies; (c) learning mechanisms, and so on (Tybur et al., 2013). We believe that attentional and mnemonic processes are also functionally designed to defend us against infectious disease and, therefore, can also be cast as key components of the BIS.

1.4.1 Memory for disgusting and disease-related stimuli

Drawing on a functional-evolutionary perspective, Nairne proposed that "particular selection pressures, or adaptive problems, fueled the development of human memory systems; consequently, the proximate mechanisms that enable us to remember and forget are likely tuned to solving such problems" (Nairne, 2010, p. 3). Thus, memory may be optimized to process and retain survival-relevant information to serve the ultimate function of enhancing our reproductive fitness (Nairne & Pandeirada, 2016). Accordingly, an impressive body of evidence has been accumulating over the past decade demonstrating that memory is enhanced when information is processed for fitness-relevant problems (for reviews, see, Kazanas & Altarriba, 2015; Nairne & Pandeirada, 2016; Scofield, Buchanan, & Kostic, 2018). For example, people remember information better when asked to rate its relevance to survival-related scenarios – better than rating its relevance to other encoding scenarios and a host of deep-encoding techniques (e.g., imagery, pleasantness judgments; Nairne, Pandeirada, & Thompson, 2008; Nairne, Thompson, & Pandeirada, 2007). 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, & Cogdill, 2017; 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, Vasconcelos, & Nairne, 2017).

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 intra-sexual 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 in-group 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; Prokop & Fančovičová, 2014; Wertz & Wynn, 2014).

Given their clear relevance to fitness, disgusting and disease-relevant stimuli should also be remembered well helping people to prevent initiating contact and, thus, avoiding a potential opportunity for contamination. Consequently, we might expect memory to be biased or “tuned” to potential sources of contamination (Nairne, 2015). Accordingly, research has shown that individuals are more likely to recall and recognize disgust-eliciting stimuli compared to frightening, positive or neutral stimuli (see KaYan, Ginting, & Cakrangadinata, 2016, for contrary results). For example, following a Stroop color-naming task, Charash and McKay (2002) found better memory for disgust-related (e.g., vomit, rotting) over fear-related (e.g., murder, tortured) and neutral (e.g., candles, pumpkin) words on a free-recall memory task in which participants were instructed to write down all of the words that they could remember from the Stroop task. Care was taken to match the lists for word frequency. However, as pointed out by some researchers (e.g., Ferré, Haro, & Hinojosa, 2018), other uncontrolled confounding variables might account for the differences found, precluding drawing strong conclusions from this study.

More recently, Ferré et al. (2018) further explored memory for disgusting, frightening, and neutral words while controlling for several variables, including affective (valence, arousal), lexical (word length, number of syllables, logarithm of word frequency, etc.) and semantic dimensions (imageability, concreteness, familiarity, etc.). In their study, participants performed a lexical decision task (LDT), in which they were asked to indicate if a string of letters corresponded to a Spanish word or not. Immediately following the LDT, participants were given an unexpected memory task, in which they were asked to recall as many words as they could remember from those presented during the LDT (free recall task, Experiment 1) or had to specify whether each word was old or new (recognition task, Experiment 2). An enhanced memory for disgusting words compared to fearful and neutral words was found in both free recall and recognition tasks. However, when applying a deeper-encoding task, in which participants were asked to identify if each word was a positive word or not (affective categorisation, Experiment 3), the memory advantage was found for disgust over neutral words (but not over fearful words). The authors concluded that this overall pattern of results suggests that the mnemonic advantage found for the disgusting items is possibly due to a higher elaboration naturally afforded by these words as compared to the neutral or fearful words.

A similar mnemonic advantage was found for images. For example, Croucher, Calder, Ramponi, Barnard, and Murphy (2011) found higher recognition memory for disgusting relative to frightening images taken from the International Affective Picture System (IAPS: Lang, Bradley, & Cuthbert, 1997). In this study, the images were carefully matched for pleasantness, approach-avoidance tendency, distinctiveness, visual complexity, anger and sadness in an effort to control for other potentially memory-relevant variables. Images were distinct on disgust and fear ratings. Additionally, the disgust advantage was apparently not mediated by arousal because the disgusting images were considered to be significantly less arousing than the frightening ones. Chapman, Johannes, Poppenk, Moscovitch, and Anderson (2013) also replicated the mnemonic advantage for disgusting stimuli while controlling for arousal, valence, distinctiveness, visual salience or complexity of the stimuli, and attention at encoding. In their study, participants were given an incidental encoding task in which they performed a line location discrimination task while disgusting (e.g., certain insects, body products, disease, and deformity), fearful (e.g., human or animal threat, disasters, and social unrest), and neutral images (e.g., household objects) – also from the IAPS – were presented. After a short (10 min) or long delay (45 min and 1 week), memory for the images was tested (a surprise free recall task after a 10 or 45 min study-test delay and a recognition task after the 1 week delay). They found a slight mnemonic advantage for the disgusting images after the short delay which became highly significant when memory was tested at the longer delays. Importantly, additional analyses revealed that disgust accounted for this memory advantage over and above other variables (e.g., arousal, valence, or enhanced attention at encoding).

A line location discrimination task followed by an unexpected free recall task after a 45 min delay was similarly employed by Chapman (2018) who aimed to explore if this “disgust” advantage was due to a higher organization among the disgusting stimuli. In accordance with previous studies, disgusting images were better recalled than frightening images but the differences in recall performance could not be accounted for by differences in organization as the images from the various categories were equally interrelated. Adjusted ratio of clustering (ARC) scores and Latent Semantic Analysis (LSA) lent additional support for such results, since the ARC suggested that participants did not rely on a categorical recall strategy and the LSA suggested that the fearful images were more semantically related to one another than the disgusting images. In addition, and as had already been suggested by previous studies, the differences in recall were not underpinned by emotional dimensions since images were matched on valence and arousal ratings (Chapman, 2018). However, the author noted that the mnemonic advantage for disgust may be mediated by attention, which contradicts previous research (e.g., Chapman et al., 2013). Performance on a directed-forgetting task, in which participants were first presented with images and subsequently instructed to remember or forget them, also showed better recognition for disgusting than neutral, sad, or fearful images, even when participants were explicitly asked to forget them (Marchewka et al., 2016).

In a different type of study, Bell and Buchner (2010) asked participants to rate the likability of faces paired with descriptions of behaviors that were either disgusting, pleasant or neutral. Disgusting information included references to lack of hygiene, intake of spoiled food, body secretions, animals, and injuries; an example would be: “K.S. is a laborer. To save money, he cooks dog food in a big pot to eat it all by himself.” (p. 32) Examples of pleasant and neutral descriptions used in this study included, respectively: “O.H. is a miller. When he has friends over, the smell of freshly baked cakes and cookies fills his apartment.”, and “J.L. is a gardener. He often orders lunch at work from a local Italian restaurant, because he cannot cook very well.” (p. 34). Following the encoding phase in which participants had to rate the likability of each person, faces were presented again and participants performed an old/new recognition task for the faces and a source memory task for the type of behavior previously associated to the face (that is, was it a disgusting, a neutral, or pleasant descriptor). Although no recognition advantage was found for the faces, source memory performance was better for faces of people associated with the disgusting behaviors.

Taken together, these studies suggest that free recall, old/new recognition and source monitoring are often boosted for disgust-eliciting stimuli compared to other types of stimuli. This mnemonic advantage may well be tied to the fact that disgusting objects reliably hold harmful infectious disease-causing agents, and therefore carry a high potential for contamination. Nevertheless, Medina, Clark, and Thorne (2016) found decreased memory for visual details of a disgusting (vs. a neutral) scene, suggesting disgust enhances general memory but not necessarily specific forms of contextual memory. Even though some research has already focused on understanding the effects of disgust on memory (see Table 1 for a summary of the available research), more work is needed to fully characterize this relation (Al-Shawaf, Conroy-Beam, Asao, & Buss, 2015).

Table 1.

Summary of studies assessing memory for disgust-related stimuli.

Main Result	Study	Sample	Type of Stimuli	Encoding Task	Retention Time	Memory Task
Increased memory for disgust	Charash and McKay (2002)	*N* = 60	Words: disgusting, frightening, and neutral	Stroop color-naming task	NA	Free recall
	Bell and Buchner (2010)	*N* = 61	Facial photographs + behaviors descriptions: disgusting, neutral, and pleasant	Rating task (likability of faces)	NA	Recognition and source memory
	Croucher et al. (2011); Exp. 1	*N* = 32	Images: disgusting, frightening, and positive	Rating task (red color)	≈ 2-weeks	Recognition
	Chapman et al. (2013)	Exp. 1: *N* = 51 Exp. 2: *N* = 23 Exp. 3: *N* = 50	Images: disgusting, frightening, and neutral	Line discrimination task	Exp. 1: 10-min or 45-min Exp. 2: 45-min Exp. 3: ≈ 1-weak	Exp. 1 and 2: Free recall Exp. 3: Recognition
	Marchewka, et al. (2016)	*N = 18*	Images: disgusting, frightening, sad and neutral	Directed forgetting task	30-min	Recognition
	Chapman (2018); Exp. 1	*N* = 30	Images: disgusting, frightening, and neutral	Line discrimination task	45-min	Free recall
	Ferré et al. (2018)	Exp. 1: *N* = 42 Exp. 2: *N* = 56 Exp. 3: *N* = 36	Words: disgusting, frightening, and neutral	Exp. 1 and 2: Lexical decision task Exp. 3: Affective categorisation task	NA	Exp. 1: Free recall Exp. 2 and 3: Recognition
Decreased memory for disgust	KaYan, et al. (2016)	*N* = 130	Images: disgusting, frightening, positive, and neutral	Visual presentation	NA	Recognition
	Medina, Clark, and Thorne (2016)	*N* = 81	Stories + images: disgusting, and neutral	Auditory listening + visual presentation	NA	20-item pencil/paper questionnaire

Chapter 4 explores this issue further by testing if neutral objects that have come in contact with disgusting or disease-signaling cues – potential sources of contamination – yield enhanced retention as well. Our studies differ from the aforementioned experiments as we tested memory for the same neutral items, whereas the majority of previous studies tested memory for different stimuli (i.e., disgusting, frightening, positive and neutral stimuli). Such comparisons, however, may suffer from potential confounding factors that may obscure the interpretation of the data. To handle item-selection concerns, in our studies every neutral object was processed as being either contaminated or uncontaminated across participants (see Introduction of Chapter 4 for a more detailed description on this matter).

1.4.2 Attention to disgusting and disease-related stimuli

We live immersed in an "ocean" of information. At every waking moment, our sensory systems are inundated by a tremendous amount of stimuli competing for limited attentional resources (Beck & Kastner, 2009). We must, therefore, be able to sort out "the wheat from the chaff, selecting relevant information out of irrelevant noise" (Carrasco, 2011, p. 1484). Given our "limited capacity of processing" and "the need to detect vital information in a multifarious world" (Vuilleumier, 2005, p. 585), natural selection should have favored an attentional bias toward fitness-related information. Such a bias would have been highly adaptive during the course of evolution by facilitating fast and reliable detection of survival-relevant stimuli, leading to flexible and effective adaptive responses, and, ultimately, promoting survival and reproductive success. Accordingly, attention seems to be adaptively tuned to facilitate automatic and rapid encoding of evolutionarily-related stimuli, including physically attractive potential mates or intrasexual competitors (e.g., Maner, Gailliot, Rouby, & Miller, 2007), and animate stimuli (e.g., New, Cosmides, & Tooby, 2007).

Several studies have also shown that threat-related stimuli are especially prone to "capture" one's visual-attention system (Fox, Griggs, & Mouchlianitis, 2007; Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001). For example, people detect threatening stimuli (e.g., snakes, spiders, angry faces) more quickly and accurately than non-threatening stimuli (e.g., flowers, mushrooms, caterpillars, faces displaying either a neutral, a sad or a happy expression; Eastwood, Smilek, & Merikle, 2001; LoBue & DeLoache, 2008; Öhman, Flykt, et al., 2001; Öhman, Lundqvist, & Esteves, 2001; Pinkham, Griffin, Baron, Sasson, & Gur, 2010). However, evidence of an attentional advantage of threatening over non-threatening stimuli has been obtained using mainly fear-inducing stimuli. Does the effect extend to disgust or contamination-related stimuli?

There is, in fact, some evidence suggesting that people preferentially allocate attentional resources to disgusting over neutral and even over fearful stimuli (e.g., Ackerman et al., 2009; van Hooff, Devue, Vieweg, & Theeuwes, 2013). Data to support the attentional bias for disgust have been gathered from a variety of experimental paradigms tapping into different attentional processes and using different type of stimuli (e.g., words, images, faces). Krusemark and Li (2011), for example, measured response time during a visual search task in which participants were required to find a horizontal target-bar among several vertical distractor-bars superimposed on disgusting, fearful, or emotionally neutral distractor-pictures. The authors found that disgust interfered with task performance to a significantly greater extent than did neutral or fearful-themed pictures, since participants took longer to detect the targets on trials that contained disgusting distractors. Similarly, results from a digit categorization task by Carretié, Ruiz-Padial, López-Martín, and Albert (2011), which required participants to discriminate if two digits – also superimposed on disgusting, fearful, or neutral pictures – were concordant (i.e., both even or both odd) or discordant (i.e., one even and the other odd), revealed that people were slower and less accurate when the target-digits co-occurred with disgusting pictures. Adopting a line location-discrimination task, Chapman and collaborators (2018; 2013) provided further evidence that disgust-distractors divert attentional resources from target-items. In their study, participants were asked to indicate, as quickly and accurately as possible, whether a line was placed above or below an image presented centrally, which could be disgusting, fearful or neutral. Slower reaction times in the ongoing task were observed in the presence of disgusting stimuli, as compared to the remaining conditions.

The dot-probe detection task has also been used to explore attentional biases for disgust. In Vogt and collaborators' study (Vogt, Lozo, Koster, & De Houwer, 2011), two stimuli (disgust and neutral, disgust and clean, or neutral and clean) were shown briefly and simultaneously above or below a fixation cross. Immediately after the stimuli offset (after 350 ms), a square appeared in the location occupied by of one of the two images and participants were required to detect, as fast and accurately as possible, the location of the square. People were faster at detecting the target-square when it was located on the position previously occupied by the disgusting images compared to when it appeared in the location occupied by the neutral images, suggesting that when neutral and disgust-related stimuli compete for the participants' attention, they attend more rapidly to disgusting cues. Interestingly, people also demonstrated an orienting bias for images representing cleanliness. The authors suggested that the allocation of attention is not "purely stimulus driven but is also guided by the goal to alleviate this emotional state" (Vogt et al., 2011, p. 466).

When experimentally primed with disease-connoting cues, participants also allocated more visual attention to faces bearing noncontagious disfigurements (e.g., faces with a port wine stain or with strabismus) than to normal unaltered faces. In this study by Ackerman et al. (2009), participants completed a dot-probe task in which faces appeared in one quadrant of a computer screen. Faces then offset (after 500 ms) and were replaced by shapes (a circle or a square) that appeared in the same or in a different quadrant. Participants had to identify the shape as quickly and precisely as possible.

Charash and McKay (2002) conducted a modified version of the Stroop-task to test whether disgust captured people's attention, leading to *interference* in the processing of other information (i.e., colors). In their study, participants were presented with words – the meaning of which was either neutral, disgust- or fear-related – and were asked to identify the ink color in which each word was written, as fast as possible, while ignoring the semantic/ emotional content of the stimulus. Performance was interfered by words' emotional content: People took longer to name the colors of disgust-related words relative to neutral words. Disgusting words, however, did not summon people's attention more than did fear-related words (Charash & McKay, 2002).

Ciesielski, Armstrong, Zald, and Olatunji (2010) addressed attentional-interference to disgust – more specifically the attentional blink phenomenon – by means of a rapid serial visual presentation task. This task consists of targets (neutral images rotated 90 degrees to the left or to the right) and distractors (disgust, fear, erotic and neutral images) presented sequentially and rapidly. Following each stream, participants were required to detect the target that occurred at various lags subsequent to a distractor stimulus. Targets were more difficult to detect when presented shortly after an emotional stimulus (i.e., at 200 ms, 400 ms, and 600 ms), regardless of specific content, than when following neutral stimuli. Additionally, target detection accuracy following emotional stimuli gradually improved with longer time lags. Nevertheless, as pointed out by van Hooff, Devue, Vieweg, and Theeuwes (2013), "close inspection of their data also showed that at the shortest time lag (200 ms), accuracy was slightly lower following disgust- as compared to fear-images, suggesting somewhat greater attention allocation to the disgust pictures at early processing stages" (p. 2). In a van Hoof and collaborators' study (van Hooff et al., 2013), participants performed a letter-identification task in which they indicated which of two possible target letters (Z or N) was presented shortly after a disgusting, frightening, or neutral image. Targets were presented at different locations (either above, below, to the left, or to the right of the central stimulus) and at different lags (200, 500, 800, or 1100 ms after the onset of the central stimulus, which remained visible throughout the trial). Targets were identified less accurately and more slowly when they followed disgust-evoking than fear-evoking or neutral stimuli, but only when presented 200 ms after image onset; these results suggest that disgust appears to hold attention at earlier stages of visual processing.

Evidence for an attentional bias for disgust has already been obtained, as just described in the aforementioned studies. However, further work is required to establish the attentional consequences of items potentially contaminated by contact with vehicles of disease; that is, using procedures that rely on the 'law of contagion'. Chapter 5 aimed to explore attentional bias for potentially contaminated stimuli.

1.5 The behavioral machinery of the BIS: Precautionary behaviors against pathogens

> "Animals have evolved an array of behavioral strategies that enable them to live in an environment teeming with health-threatening pathogens and parasites."
>
> (Hart, 2011, p. 3414)

Conspecifics are potentially one of the greatest sources of disease risk, harboring a large number of parasites and pathogens. In 2003, Park and co-authors proposed that "given the potentially high costs of interacting with diseased others (those who were already infected with disease-causing parasites), it would have been functional for individuals – and ultimately adaptive within populations – to readily identify diseased individuals and to avoid contact with them" (p. 68). In line with this idea, researchers have shown that, both humans (e.g., Schaller & Neuberg, 2012) and other animals (e.g., spiny lobsters: Behringer, Butler, & Shields, 2006; chimpanzees: Goodall, 1986; mice: Kavaliers & Colwell, 1995; bullfrog tadpoles: Kiesecker, Skelly, Beard, & Preisser, 1999) have a strong aversion towards and avoid or respond aggressively to pathogen-carrying conspecifics, particularly if they are believed to carry contagious diseases (Crandall & Moriarty, 1995). In the majority of our studies (see Part III), sick people were used as disease cues to test our hypothesis of a mnemonic tuning (Chapter 4) and attentional bias (Chapter 5) for contamination.

There is an extensive literature suggesting that social interactions seem to be mediated by the BIS (Murray & Schaller, 2016). Researchers have documented prejudice against, and avoidance of: (a) sick people (e.g., Crandall & Moriarty, 1995); (b) people with perceptual anomalies in facial and/or body morphology (e.g., facial disfigurements, physical disabilities: Park et al., 2003; Ryan et al., 2012); (c) out-group members that harbor novel parasites to which the BIO lack the ability to respond properly (i.e., xenophobia: e.g., Faulkner, Schaller, Park, & Duncan, 2004; see, however, van Leeuwen & Petersen, 2018 for contradictory findings). Additionally, people exposed to experimental manipulations of pathogen salience or living in areas with high levels of infectious diseases reported lower levels of sociosexuality, extraversion, agreeableness, and openness to experience (Oosterhoff, Shook, & Iyer, 2018; Schaller & Murray, 2008). Such an impact on personality dimensions allegedly lowers the probability of encounters with pathogens.

The BIS seems to also have strong effects on mating by influencing the extent to which certain characteristics are valued in a mate (see Tybur and Gangestad, 2011, for a revision on the direct and indirect benefits of mating a healthy mate). Animals avoid mating with infected mates or choose mates with traits signaling their immunocompetence or ability to cope with parasites (e.g., mice: Kavaliers, Choleris, Ågmo, & Pfaff, 2004; birds: Møller, Dufva, & Erritzøe, 1998). In the same line, people avoid infected or infection-prone individuals as mates, and preferentially select mates with certain attributes (e.g., physically attractiveness) associated with health (DeBruine, Jones, Crawford, Welling, & Little, 2010; Tybur & Gangestad, 2011).

But conspecifics are not the only vehicle for pathogen transmission. People also prevent disease acquisition through avoiding contact with surfaces, objects, foods, and so on, that potentially hold pathogens. For example, just as herbivores avoid grazing in patches contaminated by feces (e.g., alpine ibex: Brambilla, von Hardenberg, Kristo, Bassano, & Bogliani, 2013; sheeps: Cooper, Gordon, & Pike, 2000; horses: Fleurance et al., 2007; reindeers: van der Wal, Irvine, Stien, Shepherd, & Albon, 2000), people avoid intake of potentially contaminated foods (e.g., Rozin et al., 1986).

In addition to strict avoidance of contact with vehicles of diseases, other behavioral strategies have been found to reduce the likelihood of catching diseases. For example, visual cues of disgusting and disease-related threat along with verbal information on health risks prompted people to engage in grooming behaviors that preventively reduce ectoparasitic load (Prokop, Fančovičová, & Fedor, 2014; Thompson, 2010) and in post-toileting hand washing behaviors that strongly reduce the transmission of infectious diseases (Porzig-Drummond, Stevenson, Case, & Oaten, 2009). Similarly, animals groom themselves and each other to remove parasites (e.g., cats: Eckstein & Hart, 2000; ungulates: Mooring, Blumstein, & Stoner, 2004; insects: Zhukovskaya, Yanagawa, & Forschler, 2013). Eating spicy foods might also function as an anti-pathogen defense mechanism because certain spices' compounds have been shown to be very effective in killing bacteria/ fungi and in inhibiting their growth (Billing & Sherman, 1998; Ohtsubo, 2009; Prokop & Fančovičová, 2011; P. W. Sherman & Hash, 2001). The use of dietary resources as an anti-pathogen defense mechanism (e.g., ingestion of certain plant toxins or carotenoid-rich foods) has also been observed in animals (e.g., great apes: Huffman, 2001; monarch butterflies: Lefèvre, Oliver, Hunter, & De Roode, 2010; bear caterpillars: Singer, Mace, & Bernays, 2009).

The ultimate goal of the BIS is to motivate specific forms of behavioral responses (such as the aforementioned contact avoidance) that serve the adaptive function of preventing life-threatening disease infections. The dynamic interrelation among affective, cognitive and behavioral responses may facilitate or be instrumental in accomplishing these ends. For example, the activation of disgust may facilitate attention to, and memory for, health-relevant information which, in turn, may enable health-promoting behaviors.[3] Attention and memory are the two elements under scrutiny in our empirical work (see Chapters 4 and 5).

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[3] These behaviors are not a goal of this research project and, therefore, were not empirically tested in this work. Nevertheless, and given their important contributing role in preventing diseases, a brief overview on this topic was given in order to attain a full understanding of the BIS. The behaviors described in this section only scratch the surface of the total number of behaviors related to disease-avoidance.

I

THEORETICAL
INTRODUCTION

CHAPTER 2.

The Behavioral Immune System: Functional flexibility and individual differences

. BIS as a universal but variable system: Disgust sensitivity and propensity

. Benefit-cost trade-offs and the ‘functional flexibility principle’

. Compensatory up-regulation of the BIS depending on vulnerability to disease
  - Subjective vulnerability to disease
  - Objective vulnerability to disease

2.1 BIS as a universal but variable system: Disgust sensitivity and propensity

> "If you think about your friends and family members, you can probably pick out some individuals who seem to experience disgust more intensely or frequently than others – some people are more bothered by disgusting odors, who hesitate more to drink out of the same cup as a friend, or who blanch at the thought of using a portable toilet."
>
> (Tybur & Karinen, 2018, p. 160)

Needless to say, the ability to detect and avoid disease-causing pathogens confers a selective advantage over those individuals lacking such capacity. Although disease-avoidance strategies are thought to be panhuman, there seems to be substantial individual variability in terms of the likelihood and magnitude of exhibiting a behavioral immune response (Faulkner et al., 2004). Interest in and research on individual differences in the activation strength of the BIS has burgeoned in recent years, especially with regard to the emotion of disgust – a core part of the BIS. While disgust is universally experienced (Curtis et al., 2011), people vary in the degree to which they are disgusted by disease-connoting cues[4] (Haidt, McCauley, & Rozin, 1994).

Disgust propensity – the dispositional tendency to experience disgust (that is, how easily or frequently one feels disgusted) – in relation to specific stimuli, has been mostly examined by administering self-report instruments, such as the Disgust Questionnaire (Rozin, Fallon, & Mandell, 1984), the Disgust Scale (Haidt et al., 1994), the Disgust Emotion Scale (Kleinknecht, Kleinknecht, & Thorndike, 1997), and the Three-Domain Disgust Scale (Tybur et al., 2009). Others measures, such as The Disgust Propensity and Sensitivity Scale (Cavanagh & Davey, 2000), have been developed to assess not only disgust propensity, irrespective of disgust elicitors, but also disgust sensitivity[5] – the emotional impact of disgust experiences (that is, how negatively one appraises the experience of disgust).

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[4] Several behavioral problems have been recognized in people at the extreme ends of the spectrum – that is, those who feel extremely disgusted (e.g., may develop anxiety disorders) and those who are not at all or very slightly disgusted by cues to pathogens (e.g., may make worse food choices, have more sexual partners, have poor hygiene, with serious health implications; Curtis, 2011; Oaten et al., 2009).

[5] The term "disgust sensitivity" has been commonly employed with the same meaning as "disgust propensity", leading to a lack of a clear operational definition of the constructs (Melli, Chiorri, Stopani, Bulli, & Carraresi, 2017).

Individuals who are more sensitive and more prone to experience disgust are less likely to be exposed to disease-causing microorganisms and are, thus, presumably less likely to contract infectious diseases. In this vein, some researchers found that people with more propensity to disgust are also more reluctant, or less willing, to approach and/or touch things that may possibly house pathogens (e.g., a used comb, a cookie on the floor, a bedpan filled with toilet water: Deacon & Olatunji, 2007; a cockroach, a simulated greenish colored mucus, cremated ashes: Rozin, Haidt, McCauley, Dunlop, & Ashmore, 1999). People more prone to feel disgust also tend to be less open to experiences (Tybur & de Vries, 2013), to avoid new foods (Martins & Pliner, 2006), to have more constrained sexual behaviors (Oaten et al., 2009), to endorse more politically conservative ideologies (Inbar, Pizarro, & Bloom, 2009), and to exhibit more prejudicial attitudes (Terrizzi, Shook, & Ventis, 2010). Accordingly, Stevenson, Case, and Oaten (2009) found that individuals who score highly on disgust propensity had significantly fewer recent infections, supporting the idea that disgust confers protection against infectious diseases.

Recent efforts have been aimed at understanding how these differences in disgust propensity and sensitivity arise (see, for example, Tybur et al., 2013). A cost-benefit framework, according to which individuals should calibrate BIS activation to their condition and ecology, weighting costs and benefits, is a candidate explanation to address that question (see the next section of this Chapter). Chapter 6 helps to uncover whether, and how, individual variation in disgust propensity and disgust sensitivity impacts memory for contaminated items.

2.2 Benefit-cost trade-offs and the ‘functional flexibility principle’

> “Psychological adaptations are not inflexible instincts that ineluctably get expressed in behavior, but rather are flexible mechanisms whose expression is highly contingent on context.”
>
> (Meston & Buss, 2009, p. xviii)

By preemptively minimizing contact with disease-causing pathogens, the BIS has the potential benefit of reducing the risk of contracting infectious diseases (Schaller & Park, 2011). However, like physiological immune responses (see section 1.1 of Chapter 1), behavioral immune responses may incur costs as well. For example, it is energetically expensive and requires the diversion of metabolic resources away from other fitness-relevant goals (e.g., withdrawal from social interaction greatly limits opportunities for affiliate, social exchange, and mating; Murray & Schaller, 2016; Sawada, 2015; Schaller, 2011).

"Because not all situations afford identical levels of infection-related threat, nor all people identical levels of infection-related vulnerability" (Ackerman et al., 2018, p. 2), the BIS does not operate invariantly but in a functionally flexible and context-contingent manner (the 'functional flexibility principle': e.g., Murray & Schaller, 2016; Schaller & Park, 2011; Schaller, Park, & Kenrick, 2007). That is, the strength of BIS activation may vary substantially both between and within contexts, depending, respectively, "on the degree to which a disease threat is present", and "on individual differences in the calibration of sensitivity to disease cues" (Mortensen, Becker, Ackerman, Neuberg, & Kenrick, 2010, p. 441). When contextual information implies an increasing threat to human health or when individuals are more prone to infection, a more prominent activation of the BIS is likely to occur. Under such conditions, the benefits (e.g., reduced risk of infection) are likely to outweigh the costs (e.g., increased risk of missing valuable opportunities afforded through social contact; Gangestad & Grebe, 2014; Murray & Schaller, 2014).

In this line of thought, some researchers argued that the BIS may have evolved to optimally trade-off the costs and benefits of investing time, energy, and effort in pathogen defense against alternative activities (e.g., mating, food intake), and then adaptively regulate disease-avoidance behaviors accordingly (Schaller & Park, 2011). However, in the face of more pressing fitness-related problems (e.g., under conditions of starvation or dehydration), one should temporarily suppress the BIS and reallocate resources towards fulfilling a more immediate and urgent need (e.g., to find nourishment; Oaten et al., 2009). For example, spoiled, rotten, or contaminated foods might be avoided during satiate states (or when alternative foods are available) but consumed during states of hunger (or during scarcity of food resources; Hoefling et al., 2009). As pointed out by Tybur and Karinen (2018), people in the former situation can "afford" to only ingest high quality foods; thus, they would benefit more by experiencing more intense disgust than those people in the latter situation. Empirical evidence consistent with these ideas has been collected in a study by Hoefling et al. (2009), in which participants were randomly assigned to either fast for 15 h or eat a small lunch prior to a test session. Those who were hungry exhibited fewer facial expressions of disgust when exposed to pictures of unpalatable-looking foods than those who were sated. Food deprivation did not reduce disgust to other disease-salient, but unrelated to food, stimuli (e.g., body wastes, insects). Similarly, those "individuals who have been unable to secure suitable matings might downregulate their level of disgust towards a mating opportunity, thus trading the possibility of reproductive success for a higher risk of infection” (Curtis et al., 2011, p. 393).

Pathogen-driven selection pressures and the conditions known to favor the spread of diseases are not equally distributed around the world (Oaten et al., 2009). Pathogens are, in fact, one of the deadliest threats that humanity has faced throughout its history, but the magnitude of such threat differs geographically depending, for example, on the latitude (Murray & Schaller, 2014). As aforementioned, the BIS is particularly likely to be activated when the threat posed by infectious disease is salient (Schaller, 2016). To test this hypothesis, researchers compared the BIS activation in individuals situationally primed with concerns about disease transmission (e.g., by presenting news about the prevalence of infectious diseases or images and information about diseases) relative to individuals in a control condition. Compared to control-primed participants, disease-primed participants displayed increased attention to and prejudice toward individuals displaying heuristic disease cues (e.g., individuals with disfigured faces, who are obese, who are old, or who belong to foreign outgroups; Neuberg & Schaller, 2016).

Cross-population studies have also been conducted to compare the BIS activation of people living in ecologically different conditions, such as in pathogen-rich versus pathogen-poor environments (Murray & Schaller, 2014). Results from a Skolnick and Dzokoto (2013) study revealed that societies in high pathogen-stress areas (e.g., Ghana) obtained relatively high disgust-propensity scores compared to those with low pathogen-stress (e.g., USA). Other studies, however, have failed to corroborate this result (e.g., De Barra, Islam, & Curtis, 2014; Tybur et al., 2016). However, Tybur, Çınar, Karinen, and Perone (2018) provided an explanation for such results by estimating the likelihood of individuals more and less prone to experience disgust to come in contact with disease-causing agents in areas where pathogens are slightly or highly prevalent. Whereas in a pathogen-poor ecology, a more disgust-prone individual has a 7% weekly chance and a less disgust-prone individual has a 30% weekly chance of contact with pathogens, for people inhabiting a more pathogen-rich area, the risk is of 97% to 99%, respectively. Thus, higher disgust propensity leads to greater benefits in the first environment, but few or none in the latter. Rather than activating disease-avoidance strategies, people in disease-rich environments should invest more in tolerance or resistance; which in fact seems to be the case (Blackwell et al., 2016). Nevertheless, the main focus of our interest is on the up-regulation of the BIS depending of individual differences, particularly, on vulnerability to disease (which we explore next).

2.3 Compensatory up-regulation of the BIS depending on vulnerability to disease

> "The benefits offered by the behavioral immune system (reduction of infection risk) are a direct function of individuals' actual vulnerability to infection".
> (Schaller, 2011, p. 3419)

The relative benefits-to-costs ratio is thought to be a direct function of an individual's vulnerability to infection – the more prone the individual is to infections, the more benefits the activation of the BIS brings (Fessler, Eng, & Navarrete, 2005; Schaller, 2011; Schaller & Park, 2011). Therefore, the likelihood and magnitude of BIS activation is expected to vary depending on the extent to which individuals are (or merely perceive themselves to be) vulnerable to infectious diseases. That is, under circumstances in which people are relatively invulnerable to diseases few fitness benefits may accrue from activating the BIS – the benefits may be outweighed by the costs – so the BIS should produce "relatively muted responses" (Murray & Schaller, 2016, p. 88). However, BIS activation largely benefits those people with high vulnerability to diseases, for which the benefits of health-threat mitigation behaviors are most likely to outweigh the costs. In this case, the BIS should produce stronger affective, cognitive, and behavioral responses (Murray & Schaller, 2016).

2.3.1 Subjective vulnerability to disease

Humans show consistent inter-individual differences in the extent to which they view themselves as vulnerable to infectious diseases (e.g., Duncan, Schaller, & Park, 2009). Such differences have been explored in several studies through the administration of the 15-item Perceived Vulnerability to Disease Scale (PVDS). Developed by Duncan and collaborators (2009)[6], the PVDS is comprised of two subscales that assess an individual's beliefs about his/her susceptibility to infectious diseases (perceived infectability subscale) and an individual's tendency to experience emotional discomfort when exposed to pathogen-connoting cues (germ aversion subscale).

Compared to people who consider themselves relatively less vulnerable to diseases, those people with a self-perceived higher risk of being infected with pathogenic microorganisms are more likely to detect pathogen-connoting cues in their environment and to experience more exaggerated aversive affective, cognitive, and behavioral

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[6] Preliminary versions of the PVDS were described by Park et al. (2003; 2007) and by Faulkner et al. (2004).

responses to those cues (Schaller & Neuberg, 2012). For example, studies have shown that people who believe themselves to be highly susceptible to diseases exhibited more negative attitudes toward: out-group individuals (e.g., Faulkner et al., 2004), older adults (e.g., Duncan & Schaller, 2009), obese people (e.g., Park et al., 2007), physically disabled individuals (e.g., Park et al., 2003), and disease-transmitting animals (e.g., Prokop, Usak, & Fančovičová, 2010). Additionally, they expressed more ethnocentrism (e.g., Navarrete & Fessler, 2006), less agreeableness and less openness to experience (e.g., Mortensen et al., 2010), less affiliative behaviors (e.g., Sawada, Auger, & Lydon, 2018) and stronger preferences for healthy faces vs. unhealthy-looking faces (Welling, Conway, Debruine, & Jones, 2007). Furthermore, people who perceive themselves as more vulnerable to disease also inhibited social interactions (i.e., were faster in making avoidant movements to neutral faces) after being exposed to pathogen-connoting stimuli (Mortensen et al., 2010). Does the perceived vulnerability to disease impact the mnemonic tuning for contamination as well? This is an empirical question that will be addressed in an exploratory manner in Chapter 6.

2.3.2 Objective vulnerability to disease

An impairment in the physiological immune responses typically implies an increased susceptibility to and higher severity of infectious diseases (Oaten et al., 2009). Such impairment corresponds to a health status of immunosuppression, which could result, for example, from illness, pregnancy, and old age. Through activation of the BIS, people would diminish the risk of contracting infectious diseases and safeguard their health during the period of high vulnerability to diseases (Miller & Maner, 2011). In light of this, the BIS is expected to be particularly activated among individuals with a decline in their immune function, whether acute (e.g., pregnant women: Navarrete, Fessler, & Eng, 2007) or chronic (e.g., people with rheumatoid arthritis: Oaten, Stevenson, & Case, 2017). Accordingly, some studies have yielded evidence that the BIS and the BIO interact and influence each other (e.g., Fessler et al., 2005; Miller & Maner, 2011; Schaller et al., 2010); such interaction has been labeled the 'compensatory prophylaxis hypothesis' by Fessler et al. (2005).[7] In what follows, a few examples of empirical evidence consistent with this idea are presented.

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[7] Other studies support the idea of a complementary relationship (Ackerman et al., 2018). Indeed, some researchers have found that the perception of disease-connoting cues leads to an increase in salivary tumor necrotizing factor alpha (Stevenson, Hodgson, Oaten, Barouei, & Case, 2011) and of interleukin-6 (Schaller et al., 2010), cytokines involved in the inflammatory process.

An illustrative example of such a relationship is provided by studies with pregnant women. The first trimester of pregnancy is a period marked by an increased vulnerability to disease since the immunological defenses are temporarily suppressed to tolerate the semi-allogeneic fetus as half of the fetal antigens are inherited from the father rendering it ‘foreign’ to the mother immune system (e.g., Luppi, 2003; Munoz-Suano, Hamilton, & Betz, 2011). As a further consequence, in comparison to the second and third trimesters, women in the first trimester of pregnancy are more likely to have relatively greater dietary selectivity and aversion to potentially-contaminated foods, as well as to experience more nausea and vomiting, thus reducing the risk of foodborne diseases (Fessler et al., 2002; Flaxman & Sherman, 2000). Additionally, using a cross-sectional sample of 496 pregnant women, Fessler et al. (2005) found that women in the first trimester are more prone to experience disgust, compared to women in later stages of pregnancy, particularly in the food domain (see also Żelaźniewicz & Pawłowski, 2015). Navarrete et al. (2007) proposed that early stages of pregnancy are also characterized by both more negative attitudes towards foreign individuals (xenophobia), and more positive attitudes towards one’s own group (ethnocentrism). Moreover, an elevated preference for healthy over unhealthy faces has been observed in pregnant compared to non-pregnant women (Jones et al., 2005).

People with increased infection risk because of rheumatoid arthritis (Doran, Crowson, Pond, O'Fallon, & Gabriel, 2002) displayed relatively more hygiene and disease-avoidance behaviors, estimated a higher risk of contracting diseases from out-group members, and remembered more accurately the number of sick faces previously presented (Oaten et al., 2017). Other chronic vulnerable groups, such as old people, however, did not show an increased BIS activation; instead, disgust was found to decline with age (Oaten et al., 2009).

Individuals’ most recent illness may also temporarily depress physiological immune activity and increase susceptibility to new pathogens (Hendaus, Jomha, & Alhammadi, 2015). A study by Miller and Maner (2011) provide supporting evidence that, in order to compensate for a weakened BIO, the BIS is more readily engaged in people who had been recently ill. The authors found that, compared to non-recently ill participants, those who felt ill within one week previous to participating in their experiment displayed increased attention to and avoidance of perceived disease threats; specifically, they were slower to shift their attention away from the location of disfigured faces and faster to move a joystick away from themselves in response to disfigured faces compared to normal faces. Inspired by their work, we explored if the participants’ health status at the time of the experiment influenced the mnemonic tuning for contamination (see Chapter 6).

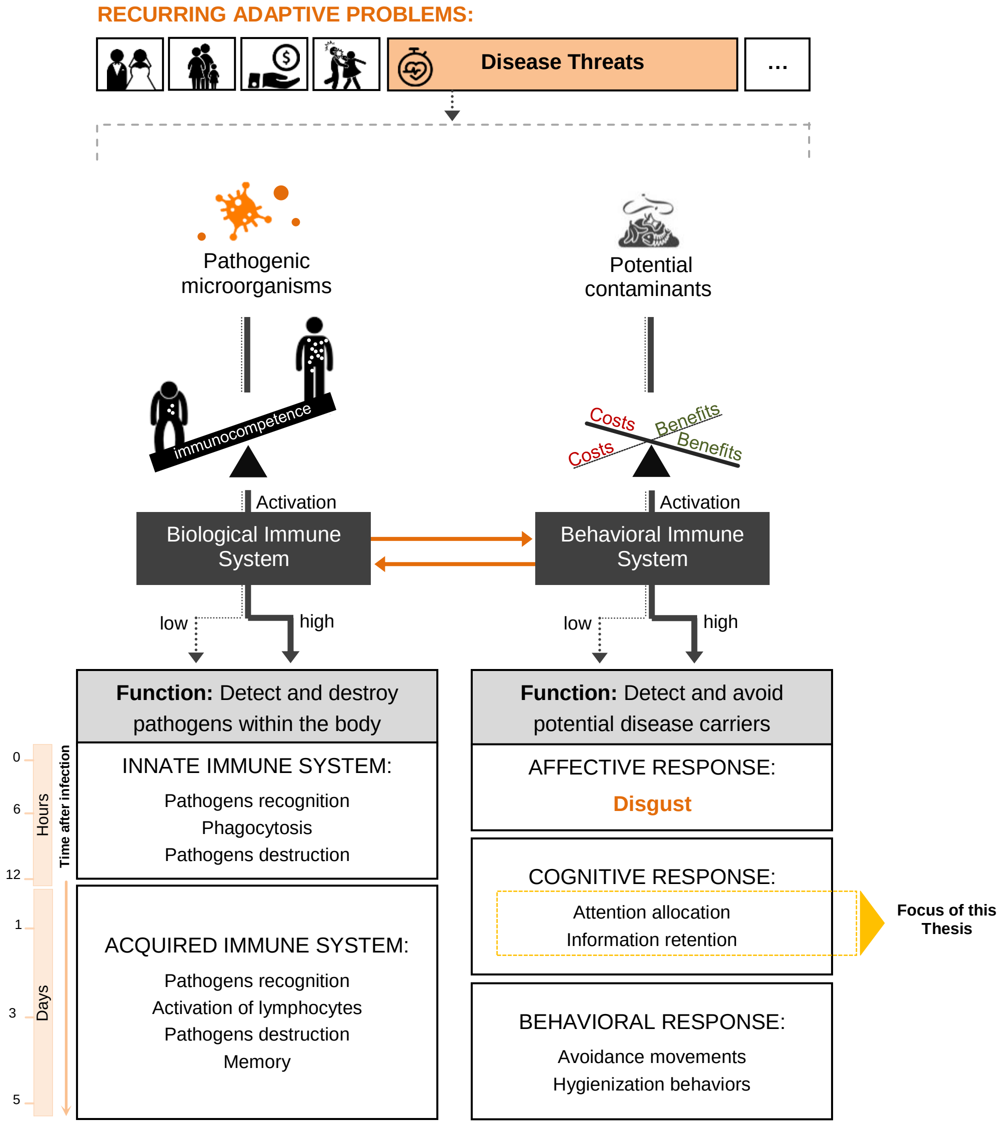
Summary of Part I:

During evolutionary history, Humans have confronted many of today's pressing challenges, including the threat posed by pathogens. Distinct strategies seem to have been tailored by natural selection to cope with such life-threatening microorganisms. Among those strategies, probably the most well-known is the BIO, that has the function to detect and eliminate invasive pathogens through the combined efforts of the innate and adaptive immune arms. More recently, a different constellation of mechanisms embodying the BIS has been postulated to play a critical role in defending us against disease-causing microorganisms. In reaction to potential contaminants, the BIS induces affective (e.g., disgust), cognitive (e.g., faster allocation of attention and better memory), and behavioral (e.g., avoidance and grooming) responses that function to shield us from exposure to pathogens. The activation of this system, however, is not without costs (e.g., refrains people from engaging in other potentially fitness-enhancing activities). Consequently, the BIS is believed to be functionally flexible, to be triggered differently and in varying degrees depending on whether the potential benefits are likely to justify the costs incurred by the activation of the system. An up-regulation of the BIS activation should be expected when the ratio of benefits to costs is high. Additionally, there seems to be a bidirectional relationship between the BIO and the BIS, which serves to maximize the survival of individuals. For example, an increased activation of the BIS would confer a significant fitness advantage when the BIO responsiveness to pathogens is compromised in individuals suffering from immunosuppression.

A schematic summary of the above-mentioned ideas is presented next:

Figure 1.

Schematic summary of the Theoretical Introduction.



Note: Examples are provided within each component box.

PART II

DEVELOPMENT OF THE STIMULI

II

DEVELOPMENT OF THE STIMULI

CHAPTER 3.

The Objects-on-Hands Picture Database

. Phase I: Development of the database
  - Objects selection
  - Stimuli presentation conditions
  - Image acquisition and processing

. Phase II: Validation of the database
  - Name agreement and familiarity
  - Arousal, disgust and emotional valence

Scientific products related to this chapter:

Empirical published work

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (2019). Presenting new stimuli to study emotion: Development and validation of the Objects-on-Hands Picture Database. *PLoS ONE, 14*(7), e0219615. doi: 10.1371/journal.pone.0219615

[**Note:** Chapter 3 is an almost exact reproduction of this article.]

Conference presentations (posters)

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (2018, April). *The Objects-on-Hands Picture Database: Development and Validation.* Poster presented at the 13th National Meeting of the APPE. Minho, Portugal.

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (2018, August). *The Objects-on-Hands Picture Database: Validation from contextual activation.* Poster presented at the BPS Cognitive Psychology Section Annual Conference. Liverpool, United Kingdom.

3.1 Introduction

Images of everyday objects have been used as stimuli in a wide array of research fields, such as perception (e.g., Eger, Henson, Driver, & Dolan, 2007), attention (e.g., Donohue et al., 2016), memory (e.g., Snow, Skiba, Coleman, & Berryhill, 2014), language (e.g., Ben-Haim, Chajut, Hassin, & Algom, 2015), and neuroscience (e.g., Horner & Henson, 2012). Over the last few decades, several sets of pictures have been created and standardized, allowing researchers to select the most suitable stimuli for their specific research needs. Snodgrass and Vanderwart (1980) developed one of the most influential and widely used set of visual stimuli – 260 black-and-white line drawings depicting mostly objects. This database has been progressively expanded and enriched with the addition of new pictures (e.g., Barbarotto, Laiacona, Macchi, & Capitani, 2002; de Beeck & Wagemans, 2001; Rossion & Pourtois, 2004; Verfaillie & Boutsen, 1995). Additionally, it has been validated and standardized for different cultures, languages and age groups (e.g., Alario & Ferrand, 1999; Raman, Raman, & Mertan, 2014; Tsaparina, Bonin, & Méot, 2011; Yoon et al., 2004). However, an increasing number of researchers have started to use photographs as their stimuli, which provide a more ecological and realistic representation of objects (e.g., (e.g., Adlington, Laws, & Gale, 2009; Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010; Foroni, Pergola, Argiris, & Rumiati, 2013; Viggiano, Vannucci, & Righi, 2004).

Line-drawings and photographs are characterized by different features, which differently affect the processing of stimuli. For example, they seem to recruit different semantic processes, which potentially impacts how the object is attended to, named and recognized (Brodeur, Guérard, & Bouras, 2014; Uttl, Graf, & Santacruz, 2006). Whereas line-drawings are simple prototypical schematic representations of objects, photographs are a more realistic depiction of objects, containing richer surface information such as color, texture, shadow, and occasionally background details (Brodeur et al., 2010). Such stimuli are particularly useful for researchers concerned with the ecological validity of their procedures, and who wish to create experimental conditions that more closely mimic real-life situations. Indeed, researchers have suggested that “using photos as the experimental stimuli increases the chances of activating the same neuronal circuits that are activated in daily tasks” (Brodeur et al., 2014, p. 2).

Despite their widespread need and broad potential use, few databases of photographs are available for researchers to use. One of the fields in which images have been increasingly and commonly used is emotion induction. Some sets of standardized emotional stimuli are available and have been frequently employed, for example, to analyze the impact of emotions on cognitive processes as well as to gain a better understanding of the dynamics and underlying mechanisms of emotional processes (Dan-Glauser & Scherer, 2011). The IAPS (Lang et al., 1997) is the most used picture database, although there has been an increasing interest in the development of other emotionally evocative databases aiming to overcome some of the limitations of the IAPS (the Geneva Affective Picture Database: Dan-Glauser & Scherer, 2011; the DIsgust-RelaTed-Images: Haberkamp, Glombiewski, Schmidt, & Barke, 2017; the Nencki Affective Picture System: Marchewka, Żurawski, Jednoróg, & Grabowska, 2014; the Set of Fear Inducing Pictures: Michałowski et al., 2017; the Emotional Picture System: Wessa et al., 2010). However, these databases only allow researchers to compare the processes that occur during the exposure to different items (e.g., disgusting vs. non-disgusting items) introducing potential item-selection concerns – that is, inherent and potentially uncontrolled item properties that could impact the processes under scrutiny. We reasoned that the best way to solve this problem would be to develop a database containing exactly the same stimuli (objects) but recorded under conditions in which the objects can be processed in domain-specific ways (e.g., as disgusting, neutral or fear-evoking). For this to be possible, one needs a dataset of stimuli that could be effectively encoded in different conditions; for example, the sauce covering the hands holding an object could be described as being pasta sauce or vomit; such different descriptors should activate low vs. high disgust and be weakly vs. strongly arousing, respectively. Thus, even though we would be able to manipulate the emotion being activated by the picture, the object of interest would be the same in the two conditions. This effectively eliminates item-selection concerns that arise when, for example, responses or processes to disgusting and non-disgusting stimuli (which might perceptually differ in many ways) are directly compared.

The law of contagion – a specific kind of sympathetic magical thinking that entails the belief that properties can be transferred through direct physical contact (Frazer, 1959; Mauss, 1972; Tylor, 1974) – can inspire many research avenues using this type of stimuli. For example, researchers could use exactly the same objects to study contamination by simply altering the description of the hands holding those objects. Following this idea, and with the goal of providing stimuli that would allow researchers to use them in multiple contexts, we created a database of photographs of different objects being held by hands under four different conditions: clean hands, hands covered with mud, hands covered with pasta sauce, and hands covered with chocolate and peanut butter spread. Each object was also photographed on its own (without the hands) sitting on a table. Even though some researchers have recently proposed alternative sets of photo stimuli (e.g., Brodeur et al., 2010; Brodeur et al., 2014; Haberkamp et al., 2017; Marchewka et al., 2014), to the best of our knowledge, none provides photographs of exactly the same stimuli (objects) recorded under presentation conditions that are capable of inducing different emotional states. A database containing pictures of the exact same stimuli (objects) in contact with different substances will open new opportunities for researchers interested in exploring, for example, the law of contagion, emotional processes, as well as other phenomena. Furthermore, by virtue of being held by hands, our stimuli convey a social dimension that does not exist in other databases which, for the most part, present the objects on their own.

The current study presents a new database of stimuli containing photographs of 126 everyday objects from six different categories: women’s accessories, fruits, kitchen utensils, office supplies, toys, and vegetables. These comprise the Objects-on-Hands Picture Database. The photographs were taken in a highly controlled environment and under two different viewpoints (frontal and top viewpoints). These two camera viewpoints could allow different conceptualizations of the object with respect to the participant. For example, the top viewpoint could represent the object as if it were being held by the participant, whereas the frontal viewpoint could be described as someone else approaching the object; these different perspectives could also be conceptualized as corresponding to the participant giving or receiving the object, respectively. Therefore, these alternative perspectives of the same object afford a set of interesting experiments in the domain of social interaction.

Furthermore, our stimuli include objects from different categories which can be used to explore organizational or relational aspects of the processing and/or effects. For example, some research has explored whether the mnemonic advantage for emotionally-valenced material, as compared to neutral material, is related to a stronger organizational structure of the former as compared to the latter (Chapman, 2018). Once again, such studies compared different stimuli and, therefore, their results are fraught with potential item confounding. With our database, such a problem could be avoided while exploring the variable of real interest: the relational processing that could be naturally afforded by using exactly the same category items but under different emotionally-activating contexts.

The Objects-on-Hands Picture Database can also be of use in several applied research areas and across tasks involving perception, attention, memory, and behavioral experiments. For example, contagion beliefs have been found across a variety of contexts (e.g., marketplace, workplace, etc.) and have proven to be highly influential in guiding cognitive and behavioral processes. In this sense, people evaluate more negatively and are unwilling to interact with objects that have been in close contact with disgusting stimuli (Morales & Fitzsimons, 2007; Rozin et al., 1986; Rozin et al., 1989). The law of contagion has inspired evolutionary researchers to study disease-avoidance strategies designed by natural selection to cope with life-threatening pathogens. For example, selection pressures imposed by pathogens are thought to have driven the evolution of the emotion of disgust, which motivates the avoidance of disease-causing microorganisms (Oaten et al., 2009). Memory seems to be biased or tuned to remember disgusting and disease-related information (Fernandes, Pandeirada, Soares, & Nairne, 2017). These are just some of the key components that have been proposed to embody a "behavioral immune system", a system that has concomitantly evolved with the "biological immune system" to protect us against pathogen threat (Schaller & Park, 2011). Our stimuli can be used to further explore the operating mechanisms and the bidirectional relationship of these two systems.

The database can also be used in clinical research. For example, our stimuli could be used to explore responses to neutral or disgust-evoking stimuli in subjects with multiple forms of maladaptive behaviors and psychopathology as well as to investigate their role in the etiology, maintenance, or treatment of such conditions (e.g., substance abuse and drug addiction: Ersche et al., 2014; eating disorders: Popien, Frayn, von Ranson, & Sears, 2015; obsessive-compulsive disorder: Whitton, Henry, & Grisham, 2015, among others). Likewise, our dataset can be used to study topics as diverse as the desirability of stimuli presented in different conditions (e.g., food items when held by hands covered with chocolate vs. by clean hands) depending on factors such as mood (e.g., Rizzato et al., 2016). In the social area, one could explore the willingness of participants to accept a given object, or the value assigned to it, when it is offered by people described with different personal characteristics. These characteristics, in turn, could be associated with more positive or negative social stereotypes (Rozin et al., 1986). By presenting the objects held by real hands potentially increases the influence of such stereotypes. Furthermore, being able to present the objects from different perspectives – from the giver's perspective (top viewpoint) or from the receiver's perspective (front viewpoint) adds other investigation opportunities. Therefore, the potential usage of this new database is as large as the numerous areas in which emotion has been shown to affect cognition and behavior.

Language and cultural differences in picture naming and rating tasks (e.g., Yoon et al., 2004) have long been acknowledged, highlighting the need for researchers to adjust the selection of stimuli as a function of the cultural background of the participants. Additionally, name agreement and familiarity are known to affect performance in different areas, such as language, perception, and memory (Alario et al., 2004; Bonin, Chalard, Méot, & Fayol, 2002; Lachman & Lachman, 2014). Therefore, besides creating the pictures database we also collected information on the naming and familiarity of the stimuli. This was done with a group of North American participants and a group of Portuguese participants. These data will allow researchers to make sure that they are selecting stimuli that are identifiable and familiar to their participants. To this end, the frontal-view photographs of the objects being held by clean hands were presented individually and participants were asked to provide a name for the object and then to rate how familiar they were with it. A comparison between groups (North American vs. Portuguese) on name agreement and familiarity ratings is presented to explore the viability of using these stimuli in cross-cultural studies.

Additionally, we aimed to demonstrate that different contextualizations of the stimuli can activate different emotional states, such as arousal, disgust and valence. To this end, the frontal-view photographs of the objects being held by hands covered with chocolate were rated on these dimensions but, in different groups, the images were framed in a disease context, a non-disease context, or presented with no context. We expected to obtain different evaluations of the same stimuli according to the provided contextualization. Such results would demonstrate that researchers can safely use the exact same stimuli in their research while, at the same time, elicit different emotional reactions.

In sum, this study aimed to create a dataset of photographs of real objects belonging to six different categories under different viewpoints and conditions; such a variety will allow a large possibility of experimental manipulations in different research contexts (Phase 1: Development of the Database). Additionally, we provide normative data (Phase 2: Validation of the Database) on the objects' name agreement and familiarity in two different countries (study 1), as well as ratings of arousal, disgust and valence of the same stimuli but presented in different context conditions (study 2).

PHASE 1: DEVELOPMENT OF THE DATABASE

3.2 Objects selection

We selected approximately 20 objects from each of six different categories: fruits (e.g., pear; *N* = 20 images), vegetables (e.g., onion; *N* = 21 images), kitchen utensils (e.g., bowl; *N* = 19 images), office supplies (e.g., tape; *N* = 21 images), toys (e.g., dices; *N* = 23 images), and women's accessories (e.g., lipstick; *N* = 22 images). These were selected considering that the objects could easily be held by hands while also being easily identifiable. Category norms for 45.2% of these stimuli can be found in (van Overschelde, Rawson, & Dunlosky, 2004)]; these could be of interest for researchers interested in taking into account categorization information.

3.3 Stimuli presentation conditions

Each stimulus was photographed under five different conditions. In four of the conditions, stimuli were held by hands with different presentations: clean hands (clean condition), hands covered with mud (mud condition), with a pasta sauce (sauce condition), or with a mixture of chocolate and peanut butter spread (chocolate condition). The latter three conditions were created as they afford the processing of different contexts. For example, images in the sauce condition can be associated with a disease context (covering described as vomit) or with a cooking situation (covering described as pasta sauce), in order to induce different affective states. In a fifth condition, objects were photographed on a table covered with a white sheet (object condition). These last photographs can be used, for example, in a final recognition test for the objects irrespectively of the condition employed at encoding. The hands holding the stimuli across all of these conditions were the same.

3.4 Image acquisition and processing

Images were recorded in a controlled environment in the audio-visual studio at the Department of Communication and Art at the University of Aveiro (Portugal). High-quality digital color photographs of 126 objects were taken against a uniform white background from two different camera viewpoints (i.e., frontal and top viewpoints). Care was taken to position the stimuli in a similar way across all of the conditions in which the object was being held by hands. We also tried to maintain the same position, as best as possible, when the objects were placed on the table. Figure 2 displays examples of pictures in each of the conditions and camera viewpoints. A total of 1260 images were collected; however, due to technical reasons (i.e., problems during the transference process from the cameras to the computer), we only have 1171 images available (see S1 Appendix for information of the stimuli available in each condition, available at https://osf.io/xn2u9/). Because neither the objects nor the necessary photo shooting conditions were met when we noted this problem, we were not able to recollect the missing stimuli. The database is freely accessible via a web-interface at https://sites.google.com/view/adaptive-memory-lab/data-databases.

The frontal-view photographs were captured with a Canon EOS 70D camera with a resolution of 5472 x 3648 pixels (CMOS sensor of 20 megapixels) in 22.5-bit color RAW format. The camera was mounted on a tripod placed at a distance of 50 cm from the stimuli. Height of the camera was 88 cm for stimuli being held by hands and 79 cm for stimuli placed on the table. Top-view photographs were acquired using a Canon EOS 60D camera with a resolution of 5184 x 2916 pixels (CMOS sensor of 18 megapixels) in 24-bit color RAW format. The camera was positioned above the stimuli on a tripod with a height of 160 cm and a distance to the object of approximately 72 cm. For both cameras focal length and focus distance was set to 50 mm. The sensor light sensitivity was fixed at 800. An exposure time of 1/60 sec and take aperture of $f/20$ were used.

Three white light-emitting diode (LED) spotlights (16x16) with a color temperature of 7000 kelvin, and two 1250-watt halogen spotlights were used to obtain optimal lighting conditions. One of the LED spotlights was located at a height of 155 cm and about 73 cm behind the frontal-view camera. The remaining two were located at a height of 110 cm, one at 60 cm on the right side and the other at 60 cm on the left side of the frontal-view camera. The halogen spotlights were positioned at a height of 164 cm and 57 cm from the frontal-view camera, one on the right and one on the left side (see Figure 3 for a schematic presentation of the setting). Frontal-view images were spatially aligned and manipulated using *Adobe Photoshop CC* so that the position of the body, hands and stimuli were as similar as possible in all conditions and for all stimuli. Furthermore, the stimuli photographed on the table were edited to remove the background of the images; thus, each photograph included the object's image only (see Figure 2).

Figure 2.

Examples of stimuli in each presentation condition and camera viewpoint.

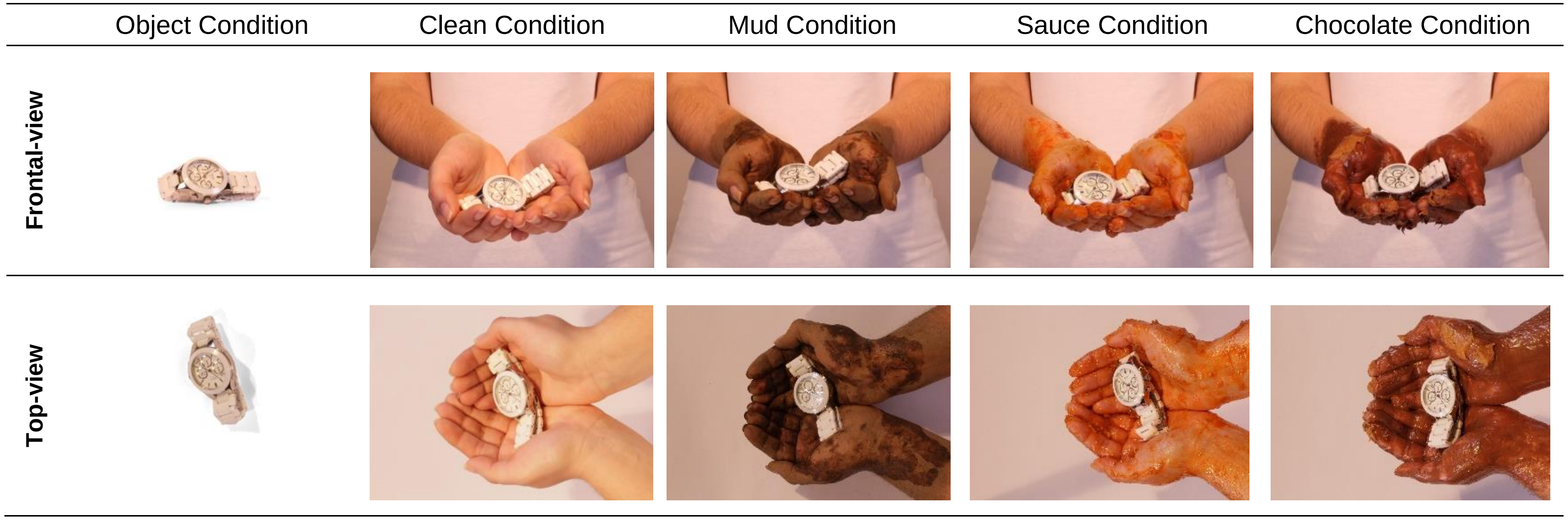
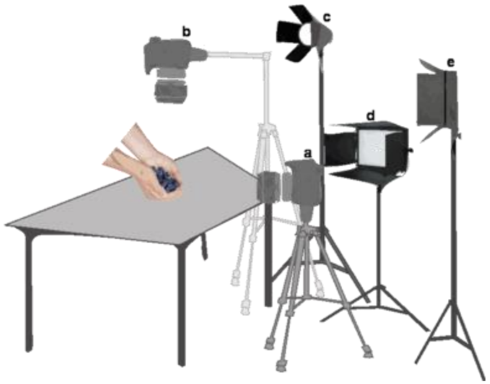


Figure 3.

Spatial arrangement of the equipment used to acquire the images.



Note: (a) frontal-view camera, (b) top-view camera, (c) halogen spotlight (a similar spotlight was positioned on the left side of the frontal-view camera but is not here represented), (d and e) LED spotlights (a spotlight similar to d was positioned on the left side of the frontal-view camera but is not here represented).

PHASE 2: VALIDATION OF THE DATABASE

3.5 Name agreement and familiarity

3.5.1 Study 1

Name agreement information and familiarity ratings (on a scale of 1-5) were collected for each of the 126 frontal-view stimuli from the clean condition from two different cultural groups: North Americans and Portuguese. Data are first presented separately for each group and then comparisons between groups were conducted. To further explore if the data collected in this presentation condition would apply for the remaining presentation conditions, we asked another Portuguese sample of participants to provide the name and familiarity ratings for the objects presented in the sauce condition (frontal-view perspective). The comparison of the data obtained in the two conditions (clean and sauce) provides preliminary evidence that the normative information can be applied to the other photo settings.

3.5.1.1 Method

Participants. The North American sample included seventy-eight psychology students (women = 25; 32.1%) from Purdue University (USA), aged between 18 and 36 years old (M_{age} = 19.65, SD = 2.37), who participated in exchange for course credits. All participants were native English-speakers (data from an additional 11 non-native English speakers were excluded). The Portuguese sample included 293 native European Portuguese speakers (women = 200; 68.0%), aged between 18 and 70 years old (M_{age} = 36.11, SD = 13.33). One hundred and seventy one participants (M_{age} = 36.86, SD = 14.16) provided the names and familiarity ratings for the objects in the clean condition, and 122 participants (M_{age} = 35.07, SD = 12.10) provided this same information for the objects in the sauce condition (data from an additional 3 non-native Portuguese speakers were excluded). The Portuguese sample participated voluntarily and no compensation was offered. Informed consent was obtained from all participants before beginning participation.

Materials. In this task, the 126 frontal-view stimuli from the clean condition were used. However, each participant only responded to a sub-group of 63 stimuli previously created in a pseudo-random manner from the initial pool of stimuli; these subgroups were created in order to avoid a lengthy questionnaire and to prevent abandonment of the task. Care was taken to ensure that each sub-group of stimuli included a similar number of objects from each of the six categories. Order of presentation of the stimuli was randomly determined for each participant. The corresponding 126 frontal-view stimuli from the sauce condition were also used and presented in these same conditions.

Procedure.

North American sample. The experiment was prepared using the *Qualtrics survey software* (Qualtrics Labs Inc., Provo, UT). The experiment was run in groups of up to four participants but each participant responded to the task in an individual workstation. This task was performed after they responded to other non-related tasks.

Objects were presented one at a time on the computer screen along with the naming question and the familiarity rating task. For the naming task, participants were asked to identify the object presented in the picture and to type the first name that came to their mind into a dialog box. When participants could not provide the name of the stimuli, they were asked to indicate whether this was because: (1) they did not recognize the object; (2) they knew the object but not its name; or, (3) they knew the name but were unable to retrieve it at that moment. These responses were provided by selecting the options “don’t know object” (DKO), “don’t know name” (DKN), or “tip-of-the tongue” (TOT), respectively. The familiarity rating task was displayed below the naming question; here, participants were asked to indicate the level of familiarity they had with the object. Responses were provided using a 5-point Likert scale (1 = very unfamiliar, 2 = somewhat unfamiliar, 3 = neither familiar nor unfamiliar, 4 = somewhat familiar, and 5 = very familiar) by clicking on the response of their choice with the computer mouse. The tasks were self-paced but participants were instructed to respond quickly and to rely on their “gut instinct”. After responding to the naming and familiarity rating tasks participants hit a “next” button which led to the presentation of the next stimuli. The questionnaire ended with the collection of information regarding sex, age, and nationality. The task lasted approximately 10 minutes.

Portuguese sample. Data was collected via the World Wide Web using the *Qualtrics survey software* (Qualtrics Labs Inc., Provo, UT). A brief description of the study along with the electronic link to access the questionnaire was sent by electronic mail to Portuguese public and private universities for dissemination. The opening page of the questionnaire provided a brief description of the study along with confidentiality information and an informed consent request. If no consent was granted, participants were thanked for their interest and the program ended; otherwise, the program moved on to the initial instructions. The procedure was as described for the North American sample but with all instructions presented in European Portuguese. No indication was given about the substance that was covering the dirty hands (sauce).

Data analysis. For each object we report the modal name, name agreement, nonmodal names and naming failures as defined next; the familiarity ratings are also provided. Some corrections to the individual entries were conducted by the first author before determining these variables. For example, misspelled names were rewritten in their orthographically correct form (e.g., from “cantelope” or “canteloup” to “cantaloupe”). When two or more names were provided by the participant to the same object, only the first one was included in the data analysis.

Modal name. This corresponds to the name assigned to each stimulus by the highest percentage of participants within each sample. Composite names (e.g., “garlic clove” and “clove of garlic”) or specifications/ adjectives presented along with the object name (e.g., “apple” and “green apple”) were considered as corresponding to the same name; among these, the most frequent name was considered the modal name. For example, for the image of “gloves” the modal name was “gloves” (*n* = 41), but the responses “winter gloves” (*n* = 1) and “women’s gloves” (*n* = 1) were considered in the total frequency of the modal name (final frequency *N* = 43).

Name agreement. Refers to the degree of agreement among participants on a specific modal name. Two measures of name agreement were computed: (1) the percentage of participants naming the stimuli with its modal name (%NA), and (2) the *H* statistic (Shannon, 1949), which measures the variability of answers across participants. The *H* value was computed using the following formula developed by Snodgrass and Vanderwart (1980):

$$h = \sum_{i=1}^{k} p_i \log_2\left(\frac{1}{p_i}\right)$$

where *k* refers to the number of different names given to each image and p_i indicates the proportion of participants giving each name. Naming failures (DKO, DKN, and TOT responses) were not taken into account when computing the *H* values (for more information see Snodgrass & Vanderwart, 1980). The %NA provides important information about which items elicit the same response from all participants and which items lead to more naming failures, whereas the *H* statistic is a more reliable measure of the distribution of names across participants. For example, “if two concepts both are given their dominant name by 60% of the subjects, but one is given a single other name and the second is given four other names, both concepts will have equal percentage agreement scores, but the first will have a lower H value” (Snodgrass & Vanderwart, 1980, p. 184). Thus, higher %NA values signify greater name agreement; in turn, higher *H* values indicate lower levels of name agreement derived from a higher variability in names given by participants. Therefore, a negative correlation is expected between these two measures. An item is given an *H* score of 0 when the same modal name is provided by all participants with a valid response (i.e., excluding naming failures), and a %NA score of 100% (i.e., perfect name agreement) when the modal name is provided by the entire sample.

Nonmodal names and naming failures. Includes the names that differed from the modal name and that were considered alternative names or nonmodal names. The nonmodal names were categorized as correct or incorrect. Correct nonmodal names refer to other ways of appropriately identifying the stimuli presented (e.g., synonyms), or to more general or specific designations of the modal name (e.g., semantic category of the object). Nonmodal names were considered incorrect when they referred to a stimulus that does not match to the one depicted in the image. Specific examples of these cases are provided in the Results section. Name frequency for each nonmodal name was calculated and converted to percentages. Frequency and percentage of naming failures (DKO, DKN, and TOT responses) were also calculated for each image.

Familiarity. Refers to the degree to which the stimulus is familiar to participants. Familiarity was computed by averaging the scores reported on the 5-points Likert scale; standard deviations are also presented. Similar to the results obtained in previous studies (e.g., Brodeur et al., 2010; Pompéia, Miranda, & Bueno, 2001), we expected familiarity to correlate positively with %NA and negatively with the H score.

Statistical analysis. Analyses were conducted on the data by stimuli. Correlations between the two-name agreement measures (%NA and H), as well as between these measures and familiarity, were evaluated using Spearman's correlation coefficient. The results obtained from the North American and Portuguese sample were compared using mixed ANOVAs where the sample was considered a within-subject variable and object category was considered as a between-subjects variable. Whenever significant interactions occurred these were followed by further analysis (e.g., comparison among categories within each sample) that assumed the necessary corrections for multiple comparisons (e.g., Gabriel's post-hoc tests). This was done on the variables related to name agreement (%NA and H), naming failures (DKO, DKN and TOT), and familiarity. To compare these same results obtained for the same objects when these were held by clean hands or by the hands covered with sauce, we also conducted mixed ANOVAs with stimulus condition as a within-subject variable and category as a between-subjects variable. The same post-hoc analyses as before were conducted to clarify interactions. The level of statistical significance was set at .05 (two-tailed). All analyses were performed using the Statistical Package for Social Sciences (IBM SPSS) version 24.

3.5.1.2 Results

The indexes obtained for each stimulus and in each sample are presented in an Excel file made available as S2 Appendix (available at https://osf.io/xn2u9/). For each stimulus, the responses coded as modal names, the different alternative names provided, along with their corresponding frequencies and percentages of occurrence, are listed in S3 Appendix (available at https://osf.io/xn2u9/). We start by presenting the data on name agreement and familiarity collected for the stimuli from the clean condition in both the North American and the Portuguese samples; data from these two samples were then compared. The same data are then reported for the sauce-condition stimuli followed by their comparison with the data from the clean condition (both obtained from independent Portuguese samples).

Data from the North American sample (clean condition). Each of the 126 stimuli was rated approximately by 42 (*SD* = 1.63) native English participants. The average percentage of participants naming the stimuli with its modal name (%NA) was 75.1% (*SD* = 27.3%; negatively skewed, with a range from 6.8% to 100%). The *H* statistic was 0.66 (*SD* = 0.75; positively skewed, with a range from 0 to 2.97), indicating relatively high name agreement (see Table 2; for an in-depth analysis see Tables 3 and 4). As expected, the two measures of name agreement (%NA and *H*) showed a high negative correlation, $r_s = -.923$, $p < .001$.

Table 2.

Summary statistics for the name agreement scores (%NA and H values) and familiarity ratings, given by the North American and the two Portuguese samples.

	%NA			**H**			**Familiarity**		
	American[a]	Port.[a]	Port.[b]	American[a]	Port.[a]	Port.[b]	American[a]	Port.[a]	Port.[b]
Mean	75.1%	84.4%	84.3%	0.66	0.51	0.50	4.20	4.54	4.49
Std. Dev.	27.3%	17.8%	17.9%	0.75	0.58	0.58	0.72	0.37	0.37
Median	86.4%	92.7%	92.5%	0.34	0.23	0.25	4.35	4.61	4.55
Q1	54.3%	71.8%	73.3%	0.00	0.00	0.00	3.94	4.34	4.29
Q3	100%	98.8%	98.4%	1.12	0.91	0.87	4.76	4.83	4.80
IQR	45.7%	27.0%	25.1%	1.12	0.91	0.87	0.82	0.49	0.51
Min	6.8%	32.1%	33.3%	0.00	0.00	0.00	1.65	3.33	3.17
Max	100%	100%	100%	2.97	2.07	2.22	5.00	5.00	4.98
Skewness	-0.87	-1.09	-1.08	1.08	1.04	1.13	-1.38	-1.23	-0.98

American = North American sample; Port. = Portuguese sample; a = clean condition; b = sauce condition; Std. Dev. = standard deviation; Q1 = 25th percentile; Q3 = 75th percentile [SPSS computation of percentiles: (w+1)*p (w is the weighted case count)]; IQR = interquartile range (Q3-Q1); Min = minimum; Max = maximum.

Table 3.

Proportion of stimuli with %NA equal to 100%, between 100% and 80%, between 80% and 50%, and below 50%, in each sample.

	American[a]	Port.[a]	Port.[b]
100%	25.4%	19.8%	22.2%
< 100% and ≥ 80%	32.5%	49.2%	46.8%
< 80% and ≥ 50%	20.6%	25.4%	26.2%
< 50%	21.4%	5.6%	4.8%

American = North American sample; Port. = Portuguese sample; a = clean condition; b = sauce condition

Table 4.

Proportion of stimuli that yielded one, two, three, four, five, or more than five names in each sample.

	American[a]	Port.[a]	Port.[b]
Single name (H = 0)	32.5%	25.4%	31.7%
Two names	18.3%	26.2%	26.2%
Three names	17.5%	16.7%	11.9%
Four names	10.3%	10.3%	11.9%
Five names	9.5%	6.3%	7.1%
More than five names	11.9%	15.1%	11.1%

American = North American sample; Port. = Portuguese sample; a = clean condition; b = sauce condition

Five (4.0%) of the obtained modal names corresponded to misidentifications of the stimuli; for example, the vegetable “chayote” was not recognized by most participants (84.1% naming failures), with the remaining participants providing an inaccurate modal name (i.e., “green pepper”) or other unrelated names. Naming failures represent 13.1% of the data with a higher percentage of DKO responses, followed by the DKN and then the TOT (see Table 5). From those participants who gave a name (i.e., excluding naming failures), 83.7% provided the modal name, 7.0% provided a correct nonmodal name and 9.3% gave an incorrect nonmodal name. The majority of the correct nonmodal names were synonyms of the modal name (e.g., “scrunchies” for the modal name “hair ties”), more general (e.g., “melon” for the modal name “cantaloupe”) or specific (e.g., “toy airplane” for the modal name “toy plane”) designations of the modal name. On the other hand, some of the incorrect nonmodal names suggest that participants did not recognize the stimulus (e.g., providing the name “onion” for the picture of a “garlic”). Some images, however, elicited names of visually and/or semantically similar stimuli (e.g., providing the name “zucchini” for the photography of a “cucumber”), suggesting that those photos might not depict very clearly the object they intended to present.

Participants reported a relatively high degree of familiarity with the stimuli presented (*M* = 4.20, *SD* = 0.71; scale: 1-5). Familiarity showed a negatively skewed distribution, reflecting the fact that few stimuli were rated as being low on this dimension (see Table 2). Familiarity was strongly and positively correlated with %NA (r_s = .812, $p <$ .001), indicating that more familiar stimuli elicited a higher name agreement. On the other hand, familiarity was negatively correlated with the *H* value (r_s = -.681, $p <$ .001), suggesting that participants assigned more alternative names to less familiar objects.

Table 5.

Proportion of naming failures (DKO, DKN and TOT responses), in each sample.

	American[a]	Port.[a]	Port.[b]
% DKO	7.8 (14.9)	1.1 (2.8)	1.3 (3.2)
% DKN	3.8 (6.0)	2.0 (3.8)	1.8 (3.2)
% TOT	1.5 (3.1)	1.6 (2.8)	1.3 (2.4)

American = North American sample; Port. = Portuguese sample; a = clean condition; b = sauce condition; DKO = don't know object; DKN = don't know name; TOT = tip-of-the tongue

Data from the Portuguese sample (clean condition). Each of the 126 stimuli was, on average, rated by 85.3 (*SD* = 3.49) native Portuguese participants. Results showed an overall high level of name agreement with 84.4% (*SD* = 17.8%) of the participants producing the modal name (range: 32.1% - 100%), and an *H* statistic of 0.51 (*SD* = 0.58; range: 0 - 2.07); see Table 2 for more descriptive results and Tables 3 and 4 for an in-depth analysis. As with the North American sample, the two measures of name agreement (%NA and *H*) were found to be strongly negatively correlated, $r_s = -.939$, $p < .001$.

All modal names were appropriate designations of the presented objects. The percentage of naming failures was 4.7%, with most referring to DKN, followed by TOT and finally by the DKO (see Table 5). A total of 88.2% of the participants who named the stimuli (i.e., excluding naming failures) provided the modal name, 7.8% provided a correct nonmodal name and only 4.0% gave an incorrect nonmodal name. Again, the majority of the correct nonmodal names were synonyms of the modal name (e.g., the names “aguça”, “afiadeira” and “apara-lápis” are regarded as synonyms of the name “afia” [“pencil sharpener”]). Correct nonmodal names can also be partly accounted for by Portuguese regional dialect variations (e.g., a bowl is called “tigela” in most of the country but is commonly known as “malga” in the northern part of Portugal) or by more general or specific designations (e.g., “esferográfica” [“ballpoint pen”] is a specific type of “caneta” [“pen”; modal name]). Incorrect nonmodal names suggest either that participants did not recognize the stimuli (e.g., the name “pepino” [“cucumber”] given to the picture of a “pimento” [“pepper”]) or were confused about what it represented (e.g., providing the name “abrunho” [“sloe”] instead of “uvas” [“grapes”]).

Participants' ratings of familiarity were negatively skewed, indicating that participants were in general very familiar with the stimuli (*M* = 4.54, *SD* = 0.37; scale: 1-5). As happened in the data from the North American sample, a significant positive correlation with the %NA (r_s = .595, p < .001), and a significant negative correlation with the H value (r_s = -.492, p < .001) was also found in this Portuguese sample.

Comparing the North American and the Portuguese data (clean condition). This section reports the comparison between the data obtained in the North American and the Portuguese sample regarding the clean condition stimuli. The former sample was less accurate in naming the stimuli, as denoted by a lower percentage of participants providing the modal name (%NA) and a higher mean H value, as compared to the Portuguese sample (see Table 2). In fact, a mixed ANOVA with sample and object category as factors revealed a significant main effect of sample for the %NA and the H value, F(1, 120) = 17.45, MSE = 0.56, p < .001, η_p^2 = .127, and F(1, 120) = 6.34, MSE = 1.62, p = .013, η_p^2 = .050, respectively; these data denote lower name agreement obtained in the North American sample as compared to the Portuguese sample. There were no significant effects of category for the %NA nor for the H value, F(5, 120) = 1.60, p = .164, and F(5, 120) = 1.97, p = .088, respectively. The interactions for the %NA and for the H value were also not statistically significant, F(5, 120) = 1.96, p = .090, and F(5, 120) = 1.64, p = .156, respectively.

There was a significant difference among categories on the DKN, F(5, 120) = 2.31, MSE = 0.01, p = .048, η_p^2 = .088 (the post-hoc analysis revealed no significant differences among categories), but not on the DKO and TOT, F(5, 120) = 1.01, p = .418 and F(5, 120) = 1.73, p = .133, respectively. The Sample x Category interaction was not significant for all of the naming failures (DKO: F(5, 120) = 1.72, p = .135; DKN: F(5, 120) < 1; TOT: F(5, 120) = 2.27, p = .052). However, as indicated by a significant main effect of sample, the North American participants committed more naming failures than the Portuguese participants, particularly with DKO and DKN responses, F(1, 120) = 30.73, MSE = 0.29, p < .001, η_p^2 = .204, and F(1, 120) = 11.91, MSE = 0.02, p = .001, η_p^2 = .090, respectively. No main effect of sample was found for TOT responses, F(1, 120) < 1. This higher proportion of naming failures from the North American sample could be due to the fact that the database was developed in Portugal containing objects that are common in Portugal but some that are somewhat uncommon to the North American participants (e.g., chayote, passion fruit, loquat).

Supporting this idea is the fact that familiarity ratings were significantly lower in the North American than in the Portuguese sample, as denoted by a significant main effect of sample, F(1, 120) = 51.75, MSE = 7.57, p < .001, η_p^2 = .301. There was no main effect of category, F(5, 120) = 1.23, p = .300, but the Sample x Category interaction was reliable,

$F(5, 120) = 4.63$, $MSE = 0.68$, $p = .001$, $\eta_p^2 = .162$. North American participants, compared to the Portuguese ones, were less familiar with objects from all categories, except for those belonging to the category of toys, for which the familiarity ratings were similar to the ones reported by the Portuguese sample. Additionally, when we compared the familiarity ratings among categories in each sample, no significant effect was obtained in the North American sample, $F(5, 120) = 1.40$, $p = .230$, but it was reliable on the Portuguese data, $F(5,120) = 4.63$, $MSE = 0.56$, $p = .001$, $\eta_p^2 = .162$. Gabriel's post-hoc tests revealed that familiarity ratings in the latter sample were significantly lower for the category of toys, as compared to the category of kitchen utensils and of office supplies; familiarity for the women’s accessories was also significantly lower relative to office supplies (see Table 6 for descriptive values by category).

Comparisons between the two samples should, however, be taken with care given some sociodemographic differences between them. For example, the North American Sample was significantly younger than the Portuguese sample, $t(246) = 10.59$, $p < .001$, $d_z = 1.453$. Also, the former sample was composed solely of undergraduate students whereas the Portuguese sample included participants with different occupations.

Data from the Portuguese sample (sauce condition). Each of the 126 stimuli from the sauce condition was, on average, rated by 60.6 ($SD = 1.08$) native European Portuguese participants. The percentage of participants who gave the modal name (%NA) was 84.3% ($SD = 17.9\%$; range: 33.3% - 100%) and the H value was 0.50 ($SD = 0.58$; range: 0 - 2.22; see Table 2, for an in-depth analysis see Tables 3 and 4). Again, %NA and H were highly negatively correlated, $r_s = -.948$, $p < .001$.

Only 4.4% of the data represent naming failures, with most referring to DKN responses (see Table 5). From those participants who named the stimuli (i.e., excluding naming failures), 87.8% provided the modal name, 7.6% provided a correct nonmodal name and 4.6% gave an incorrect nonmodal name. Nonmodal names were similar to those described previously for the clean condition from the Portuguese sample.

Participants were in general very familiar with the stimuli ($M = 4.49$, $SD = 0.37$; scale: 1-5). Familiarity was highly positively correlated with %NA ($r_s = .589$, $p < .001$), and negatively correlated with the H value ($r_s = -.501$, $p < .001$).

Table 6.

Mean (and standard deviations) for name agreement scores (%NA and H) and familiarity ratings for each category and each sample.

	%NA			**H**			**Familiarity**		
	American[a]	Port.[a]	Port.[b]	American[a]	Port.[a]	Port.[b]	American[a]	Port.[a]	Port.[b]
Women's Accessories	78.3 (21.0)	83.8 (14.9)	79.4 (18.4)	0.61 (0.62)	0.65 (0.59)	0.70 (0.64)	4.06 (0.52)	4.39 (0.30)	4.25 (0.38)
Fruits	72.2 (34.2)	88.9 (16.0)	89.1 (15.9)	0.66 (0.81)	0.33 (0.52)	0.34 (0.51)	4.07 (0.95)	4.62 (0.44)	4.59 (0.40)
Kitchen utensils	72.9 (25.2)	74.7 (23.9)	74.7 (23.5)	0.80 (0.78)	0.79 (0.73)	0.75 (0.70)	4.29 (0.66)	4.67 (0.25)	4.64 (0.26)
Office Supplies	70.5 (30.4)	86.3 (18.2)	88.5 (15.7)	0.75 (0.86)	0.45 (0.59)	0.40 (0.55)	4.31 (0.80)	4.73 (0.20)	4.68 (0.19)
Toys	87.9 (18.3)	88.4 (14.3)	91.3 (10.8)	0.31 (0.45)	0.32 (0.38)	0.28 (0.34)	4.45 (0.44)	4.33 (0.39)	4.33 (0.32)
Vegetables	66.6 (30.2)	83.3 (17.4)	81.5 (17.8)	0.90 (0.89)	0.50 (0.54)	0.58 (0.60)	3.99 (0.80)	4.52 (0.43)	4.51 (0.44)

American = North American sample; Port. = Portuguese sample; a = clean condition; b = sauce condition

Comparing data from the clean and the sauce condition. The last presented data allowed us to explore if the norming information obtained for the stimuli from the clean condition would be representative of the data one would obtain in the other presentation conditions. In what follows, we compared the data obtained for the stimuli from the clean condition with those from the sauce condition to help answer this question. Overall, the naming results obtained for the stimuli from the sauce condition were similar to those obtained when the objects were held by clean hands (see Table 2).

A mixed ANOVA with stimulus condition (clean vs. sauce) and category as factors revealed no significant main effect of stimuli condition on each of the naming variables (%NA and *H* value; both *Fs* < 1). These data provide initial evidence that the naming norms obtained for stimuli on clean hands can be generalized to the other conditions. For both naming metrics, though, we obtained a significant main effect of category, *F(*5, 120) = 2.31, *MSE* = 0.13, *p* = .048, η_p^2 = .088, and *F(*5, 120) = 2.44, *MSE* = 1.48, *p* = .039, η_p^2 = .092, for %NA and *H* value, respectively. However, the post-hoc analysis revealed no significant differences in the comparisons between the pairs of categories. The Condition X Category interaction was significant for the %NA, *F(*5, 120) = 2.73, *MSE* = 0.01, *p* = .022, η_p^2 = .102, but not for the *H* value, *F(*5, 120) < 1. When we compared the %NA among categories in each sample, no significant effect was obtained in the clean condition, *F*(5,120) = 1.72, *p* = .135, but it was reliable on the sauce condition, *F(*5, 120) = 2.96, *MSE* = 0.09, *p* = .015, η_p^2 = .110. Gabriel's post-hoc analysis revealed lower %NA (i.e., fewer participants giving the modal name) for stimuli from the category of kitchen utensils compared to those from the category of toys.

Furthermore, neither the main effects of stimuli condition or of category, nor the interaction between these variables, reached significant values on each of the naming failures (DKO, DKN and TOT; highest *F* value for the main effect of sample for the TOT: *F*(1, 120) = 3.47, *p* = .065).

Regarding familiarity, there was, however, a significant effect of stimulus condition, *F(*1, 120) = 8.68, *MSE* = 0.12, *p* = .004, η_p^2 = .067, with participants reporting less familiarity when the objects were held by hands covered with sauce as compared to when they were being held by clean hands. The main effect of category was also significant, *F*(5, 120) = 5.24, *MSE* = 1.18, *p* < .001, η_p^2 = .179, with participants reporting being less familiar with the objects from the women’s accessories and toys as compared to office supplies and kitchen utensils. These differences resemble those reported when the objects were held by clean hands (see above). The interaction between the two variables was not significant, *F(*5, 120) = 2.18, *MSE* = 0.03, *p* = .061, η_p^2 = .083.

3.5.1.3 Interim discussion

In conclusion, the results revealed high name agreement and familiarity in both the North American and the Portuguese samples for objects on clean hands, even though the Portuguese sample was more accurate in naming the stimuli and reported being more familiar with them. The data from an additional Portuguese sample for the objects held by hands covered with sauce resembled those collected with objects on clean hands.

3.6 Arousal, disgust and emotional valence

3.6.1 Study 2

Study 2 had two primary goals. The first goal was to evaluate whether participants' affective ratings of images differed depending on the condition in which the object was photographed, i.e., to analyze if the intensity of the emotional activation promoted by the stimuli varied according to the substance covering the hands. To that end, participants rated images either from the chocolate, sauce or mud condition. No context was provided for this task, that is, participants were not given any description about the nature of the pictures they were going to assess.

Secondly, we wanted to determine whether the activation of the affective dimensions afforded by the stimuli would differ depending on the encoding context in which objects were framed. Thus, photographs from the chocolate condition were described in the context of a disease situation context (hands described as being covered by diarrhea), or in a non-disease context (hands described as being covered by chocolate spread). The ratings obtained in these two contexts were also compared with those obtained previously when no context framing was presented. We expected that the participants would rate the various affective dimensions as more negative when framed in the disease than in the non-disease context.

In all procedures, the “dirty” hands were intermixed with images from the clean condition which we expected would afford lower emotional activation than hands covered with substances. Ratings for all of these cases were collected across three dimensions - arousal, disgust and emotional valence, via an online questionnaire.

3.6.1.1 Method

Participants. A total of 970 participants took part in the study. Given the high dropout rates of online questionnaires, data were considered whenever at least half of the stimuli had been rated. Five hundred and fifty-eight participants fulfilled this criterion (translating into a dropout rate of 42.5%). Participants younger than 18 years (n = 1) or with a nationality other than Portuguese (n = 19) were also excluded from the analysis. The final sample included 538 native European Portuguese speakers (women = 365; 68.6%), aged between 18 and 74 years (M = 35.90, SD = 13.15). From this sample, 313 participants (M_{age} = 35.46, SD = 12.94) provided the ratings for the objects with no context described. A total of 111 participants (M_{age} = 36.40, SD = 12.91) provided this same information for the objects from the chocolate condition described in the disease context and 114 participants (M_{age} = 36.64, SD = 14.01) for the same stimuli described in the non-disease condition. No compensation was offered to participate in the study. All participants responded in a voluntary manner and provided initial consent.

Materials. In this task, the 126 frontal-view stimuli from the clean, mud, sauce and chocolate conditions were used. However, each participant provided ratings to a set of 63 stimuli previously created in a pseudo-random manner so that: (1) a similar number of objects from each of the six categories was presented, and (2) a similar number of objects from the clean condition and from one of the “dirty” conditions was presented. This procedure created 2 sets of stimuli for each presentation condition. Within each set, half of the stimuli were presented in clean-hands and the other half in the hands covered with a substance; each object was only presented once (either in the clean or in the substance condition) to a given participant. Counterbalancing versions of the questionnaire ensured that a given object would be rated a similar number of times in the clean condition and in each of the substances conditions. In all cases, the “dirty” hands were intermixed with images from the clean condition. Order of presentation of the stimuli was randomly determined for each participant.

Procedure. The questionnaires were administered via the World Wide Web using the *Qualtrics survey software* (Qualtrics Labs Inc., Provo, UT). An electronic mail was sent to several entities (e.g., universities, professional schools and other companies across Portugal); this included a brief description of the study along with a unique electronic link to access the questionnaire. The opening page of the questionnaire consisted of further information about the study along with an informed consent request. If no consent was given, participants were thanked for their interest and the program ended; otherwise, the program moved on.

Demographic information including sex, age, and nationality were first collected. Participants were then randomly assigned to one of the three contexts (disease context, non-disease context, or no context) and to one of the counterbalancing versions of the questionnaire. The context and version of the experiment to which subjects were assigned was randomly selected by *Qualtrics.* For the assessment of the stimuli varying the substances covering the hands (mud, sauce, or chocolate condition) and with no context provided, participants were presented with the following instructions:

> ***No context:*** *"In this task, you will see pictures of objects being held by hands. You will be asked to evaluate each image in several dimensions. Each question will be followed by its response options; select your answer by clicking on the number corresponding to your choice."*

In the 'disease' and 'non-disease' encoding contexts, participants rated the stimuli presenting the hands covered with chocolate but these were framed in a disease or a non-disease context as follows:

> ***Disease context:*** *"In this task, you will see pictures of objects that have been touched by different people. One of these people is sick with a highly contagious gastrointestinal infection and is having severe and frequent episodes of diarrhea. Sometimes he/she cannot reach the toilet on time and gets diarrhea on his/her hands while handling objects. The other person is healthy and is handling objects with clean hands. Throughout the experiment, you will see pictures of objects held by hands covered with diarrhea or clean hands."*
>
> ***Non-disease context:*** *"In this task, you will see pictures of objects that have been touched by different people. One of these people has been making cakes and his/her hands are covered in chocolate spread. Sometimes he/she cannot find time to clean his/her hands and has chocolate spread on them while handling objects. The other person is handling objects with clean hands. Throughout the experiment, you will see pictures of objects held by hands covered with chocolate spread or clean hands."*

In all cases, each stimulus was presented one at a time on the computer screen; questions and their corresponding response options were shown below each image. Participants were asked to use a 9-point Likert scale to indicate (a) how calm or excited each picture made them feel (i.e. arousal: 1-very calm, 9-very excited); (b) how disgusted each picture made them feel (i.e. disgust: 1-not at all disgusted, 9-very disgusted) and, (c) how negative or positive was each image for them (emotional valence: 1-very negative, 9-very positive). A SAM (Self-Assessment Manikin) scale (Lang, 1980) was used to measure valence and arousal. Responses were provided by clicking on the response of their choice with the computer mouse. The tasks were self-paced but participants were instructed to respond quickly and to rely on their “gut instinct”. After responding to all questions participants hit a “next” button which led to the presentation of the next stimulus. The task lasted approximately 15 minutes.

Statistical analysis. To test if the participants' ratings differed depending on the substance covering the hands, a two-way univariate ANOVA was employed, with ‘image condition’ (hand covered with chocolate, sauce, and mud, generally named as “dirty hands”) and ‘state of the hands’ (dirty and clean) as between-subjects factors. When interactions were significant, follow-up one-way ANOVAs and post hoc Bonferroni tests were performed separately for each ‘state of the hands’ to pinpoint the source of the interaction.

To test if participants' ratings differed depending on the encoding context manipulation, a mixed ANOVA was performed with ‘encoding context’ (disease context, non-disease context and no context) as the within-subject variable and the ‘state of the hands’ (dirty and clean) as the between-subjects variable. When interactions were found to be significant, follow-up repeated-measures ANOVAs were additionally carried out separately for each ‘state of the hands’. When the sphericity assumption was not met (as evaluated using Mauchly's test), a Greenhouse-Geisser correction was applied. The level of statistical significance was set at .05 (two-tailed) for all reported analysis.

3.6.1.2 Results

Across all of the conditions employed here, each image was rated by approximately 25 participants (*SD* = 2.50). The average number of responses obtained for the images separated by image condition and context is presented in Tables 7 and 8; the statistical results of the overall ANOVAs are also reported in these Tables. The ratings provided for each stimulus, in each encoding context, are available as S4 Appendix (available at https://osf.io/xn2u9/).

Emotional activation as a function of the substance covering the hands (no context). For Arousal, both the main effects of substance covering the hands and of state of the hands were statistically significant. The former indicates that the different substances induced different levels of arousal and the latter reflects that the dirty hands stimuli were considered more arousing than the clean hands stimuli. However, the interaction between these two variables was also significant (see Table 7). When analyzing the data separately by *state of the hands*, a significant effect was found for the dirty hands, $F(2, 375) = 197.87$, $MSE = 51.1$, $p < .001$, $\eta^2 = .514$. Follow-up analysis showed that the stimuli from the chocolate condition elicited the highest level of arousal, followed by the stimuli from the sauce condition and then by those from the mud condition, which elicited the lowest ratings. Arousal ratings for objects on clean hands were also influenced by the type of dirty hands presented concurrently, $F(2, 375) = 23.53$, $MSE = 4.7$, $p < .001$, $\eta^2 = .112$; when these were presented along with images from the chocolate condition they were rated as being more arousing than when presented with images from the sauce and the mud conditions.

Disgust ratings also differed considerably depending on the substance covering the dirty hands, as shown by the significant main effects of substance, and of state of the hands (the dirty hands stimuli were rated as more disgusting than the clean hands stimuli). These main effects were also qualified by a significant interaction between the two factors (see Table 7). Subsequent analysis looking into each variable revealed significant effects both within the dirty hands and the clean hands, $F(2, 375) = 424.56$, $MSE = 96.9$, $p < .001$, $\eta^2 = .694$, and $F(2, 375) = 41.09$, $MSE = 2.5$, $p < .001$, $\eta^2 = .180$, respectively. These results reflect the fact that participants reported considerably and significantly higher disgust ratings for both the objects on dirty hands and objects on clean hands when the hands were covered with chocolate as compared to the sauce and mud substances; a slightly higher disgust was also obtained when the hands were dirty with sauce than with mud (see Table 7).

Finally, Valence ratings also varied significantly according to the substance covering the hands and the state of the hands (when covered with a substance, the stimuli were considered more negatively valenced than when they were clean). A significant interaction was also obtained for this variable. Follow-up analysis revealed significant differences among objects on dirty hands but not among objects on clean hands, $F(2, 375) = 172.69$, $MSE = 31.0$, $p < .001$, $\eta^2 = .479$, and $F(2, 375) = 2.28$, $p = .104$, respectively, with more negative valence ratings being assigned for the dirty hands from the chocolate condition, followed by those from the sauce condition and, finally, by those from the mud condition (see Table 7).

Table 7.

Mean number of responses (and standard deviations) obtained per image condition and mean ratings (and standard deviations) of arousal, disgust and valence in each image condition when no context was presented.

	Chocolate vs. Clean condition		**Sauce vs. Clean condition**		**Mud vs. Clean condition**		
Mean Number	23.92 (1.07)		25.67 (3.41)		23.08 (1.12)		
	Chocolate	Clean	Sauce	Clean	Mud	Clean	**Statistics**
AROUSAL	4.68 (0.45)	2.75 (0.42)	4.00 (0.34)	2.40 (0.36)	3.41 (0.68)	2.44 (0.53)	**ME subst:** $F(2, 750) = 178.03$, $MSE = 40.7$, $\eta_p^2 = .322$*** **ME SH:** $F(1, 750) = 1866.76$, $MSE = 426.8$, $\eta_p^2 = .713$*** **Interact:** $F(2, 750) = 65.99$, $MSE = 15.1$, $\eta_p^2 = .150$***
DISGUST	4.72 (0.42)	1.53 (0.32)	4.34 (0.44)	1.42 (0.21)	3.05 (0.56)	1.25 (0.19)	**ME subst:** $F(2, 750) = 449.64$, $MSE = 64.9$, $\eta_p^2 = .545$*** **ME SH:** $F(1, 750) = 9098.02$, $MSE = 1313.7$, $\eta_p^2 = .924$*** **Interact:** $F(2, 750) = 238.63$, $MSE = 34.5$, $\eta_p^2 = .389$***
VALENCE	3.79 (0.31)	6.21 (0.59)	4.08 (0.37)	6.35 (0.50)	4.75 (0.56)	6.25 (0.55)	**ME subst:** $F(2, 750) = 67.13$, $MSE = 16.1$, $\eta_p^2 = .152$*** **ME SH:** $F(1, 750) = 3366.51$, $MSE = 808.5$, $\eta_p^2 = .818$*** **Interact:** $F(2, 750) = 64.64$, $MSE = 15.5$, $\eta_p^2 = .147$***

Note: Mean number: Mean number of responses; ME subst: Main effect of substance (mud, sauce, chocolate); ME SH: Main effect of state of hands (clean, dirty); Interact: interaction between variables; *** $p < .001$

Table 8.

Mean number of responses (and standard deviations) obtained per image and mean ratings (and standard deviations) of arousal, disgust and valence in each encoding context.

	Disease context		**Non-disease context**		**No context**		
Mean Number	26.03 (2.26)		26.56 (1.87)		23.92 (1.07)		
	Dirty	Clean	Dirty	Clean	Dirty	Clean	**Statistics**
AROUSAL	5.42 (0.52)	2.00 (0.31)	4.55 (0.72)	2.26 (0.39)	4.68 (0.45)	2.75 (0.42)	**ME context:** *F*(1.7, 414.8) = 30.93, *MSE* = 9.6, η_p^2 = .110*** **ME SH:** *F*(1, 250) = 6270.44, *MSE* = 1229.1, η_p^2 = .962*** **Interact:** *F*(1.7, 414.8) = 148.86, *MSE* = 46.2, η_p^2 = .373***
DISGUST	6.22 (0.34)	1.45 (0.25)	4.72 (0.43)	1.45 (0.23)	4.72 (0.42)	1.53 (0.32)	**ME context:** *F*(2, 500) = 407.92, *MSE* = 45.2, η_p^2 = .620*** **ME SH:** *F*(1, 250) = 21517.79, *MSE* = 2651.0, η_p^2 = .989*** **Interact:** *F*(2, 500) = 452.82, *MSE* = 50.2, η_p^2 = .644***
VALENCE	3.00 (0.34)	6.95 (0.41)	3.74 (0.38)	6.68 (0.58)	3.79 (0.31)	6.21 (0.59)	**ME context:** *F*(2, 500) = 36.87, *MSE* = 4.24, η_p^2 = .129*** **ME SH:** *F*(1, 250) = 4834.12, *MSE* = 1820.6, η_p^2 = .951*** **Interact:** *F*(2, 500) = 326.49, *MSE* = 37.6, η_p^2 = .566***

Note: Mean number: Mean number of responses; ME context: Main effect of context (disease, no-disease, no-context); ME SH: Main effect of State of hands (clean vs. dirty); Interact: interaction between variables; *** $p < .001$

Emotional activation depending on the encoding context. In these analyses we compared the ratings obtained for the objects being held by hands covered with chocolate or clean hands when these were framed in three conditions: disease context, no-disease context and no-context; the data from this last condition were the same as those considered in the previous set of analysis.

Our results revealed that the manipulation of the encoding context can differently prompt Arousal, as shown by significant main effects of context and of state of the hands, but also by a significant interaction between the two. When the influence of context was analyzed for the dirty hands, a significant effect was obtained, $F(1.3, 164.6) = 71.07$, $MSE = 42.3$, $p < .001$, $\eta_p^2 = .362$. Follow-up analysis revealed that participants became more aroused when objects on dirty hands were described in the disease context as compared to when the same objects were either considered in a non-disease context or when no type of framing is given (the difference between the latter two was not significant). The contextual framework seems, likewise, even to influence the arousal level of objects on clean hands (although these images were described in the same way in the disease and the non-disease contexts), $F(1.7, 215.2) = 150.11$, $MSE = 21.4$, $p < .001$, $\eta_p^2 = .546$. Participants felt most aroused when viewing objects on clean hands with no context was provided, less aroused when viewing the same images in the non-disease context, and least aroused when viewing the images in the disease context (see Table 8). Note that this pattern is the opposite of that obtained for the dirty hands which might suggest some form of contrast effect between the two types of stimuli.

Similarly for Disgust, the results yielded significant main effects of context and state of the hands. Additionally, a significant interaction between the two variables was found. The analyses that followed the discovery of a significant main effect of context for the dirty hands, $F(2, 250) = 647.17$, $MSE = 95.1$, $p < .001$, $\eta_p^2 = .838$, revealed that the participants reported feeling significantly more disgusted when a disease context was described than when a non-disease context or no context was provided at all (the difference between the latter two was not significant). Regarding the same analysis for the significant main effect obtained for the clean hands, $F(1.6, 195.4) = 3.79$, $MSE = 0.36$, $p = .034$, $\eta_p^2 = .029$, the results revealed that, on average, disgust ratings for objects on clean hands were relatively higher when no context was given compared to a no-disease context; the latter did not significantly differ from the disease context (see Table 8).

Finally, for emotional Valence, there were significant main effects of context and state of the hands, which were qualified by an interaction between the two variables. A significant effect of context was obtained for the dirty hands, $F(1.8, 235.2) = 217.39$, MSE

= 26.6, $p < .001$, $\eta_p^2 = .635$, with stimuli being rated as more negatively valenced when framed in a disease context compared to when they were either framed in a no-disease context or when no context was given. The valence ratings for the objects on clean hands were also significantly affected by the context framing, $F(1.9, 235.2) = 147.9$, $MSE = 18.6$, $p < .001$, $\eta_p^2 = .542$; the follow-up analyses revealed that these objects prompted a more positively valenced emotion when presented in the disease context, followed by lower valence ratings in the no-disease context and even lower ratings in the no context condition (see Table 8).

3.6.1.3 Interim discussion

In sum, our data regarding the emotional activation as a function of the substance covering the hands when no context was provided revealed that the emotional responses differed by substance. Specifically, the images from the chocolate condition were rated as being the most arousing, disgusting and negatively valenced, followed by the sauce and then by the mud condition. These results seem to be consistent with the Oaten and collaborator’s (2009) proposal that disgust is likely to be evoked in proportion to the infection load (i.e., the disease risk) of a stimulus. The authors suggested that “one could potentially calculate the number of pathogen species that each disgust elicitor carried and correlate this to the degree of reported disgust that each cue evokes” (p. 307). In fact, 1 g of feces contains an estimated 10^{12} viral particles whereas 1 ml of vomit contains around 10^7 (Barker, Stevens, & Bloomfield, 2001). Therefore, the higher the likelihood of contamination, the stronger the disgust reaction.

The ratings for the clean hands stimuli which were rated when intermixed with the various dirty hands differed for the dimensions of arousal and disgust but not for valence. Regarding the first two, the pattern of results followed that obtained for the dirty hands that accompanied them: they were rated as most arousing and disgusting when intermixed with the hands from the chocolate condition. Such data suggest some form of emotional contagion from the dirty to the clean hands stimuli when no context is provided.

Regarding the contextual influence on emotion overall, our results revealed that framing the exact same stimuli in different ways (e.g., describing the same dirty hands as covered with diarrhea or chocolate, or providing no description at all) influenced the intensity of the participants’ emotional responses in the various affective dimensions evaluated here. When the objects were held by the dirty hands described as covered with diarrhea (disease context), they were consistently rated as more arousing, disgusting and negatively valenced, as compared to when the hands were described as being covered with chocolate (non-disease context) or when no context was provided. The contextual framework seems, likewise, to impact the emotional ratings of the clean hands stimuli when these were presented in the same context framings and intermixed with the dirty hands stimuli. However, here, the pattern of results followed the opposite tendency of that obtained for the dirty hands (clean hand stimuli were rated as least arousing, disgusting and most positively valenced in the disease condition) as if a contrast effect was occurring.

3.7 General discussion of the validation studies

We developed and validated a new database of stimuli that comprises high-quality color photographs of everyday objects recorded under two camera viewpoints and five presentation conditions. Even though many image datasets exist, to the best of our knowledge, none provides photographs of the exact same stimulus in different presentation conditions. The variation of the context in which objects are presented in this set of stimuli (e.g., clean hands condition, mud condition) affords new forms of manipulation while keeping the stimuli of interest (i.e., the object itself) the same, thus minimizing item-selection concerns of the type often found in research studies. Furthermore, the objects can be organized into six different categories providing an additional organizational dimension that can be of interest to researchers. Additionally, by providing two camera viewpoints, we amplify the spectrum of different scenarios that can be created, including scenarios that involve different forms of social interaction (e.g., receiving vs. giving away). There are, however, some limitations in the application of such conceptualizations that we should point out. For example, skin color typically differs from person to person: whereas Caucasians could easily accept the displayed hands as their own, the same is unlikely to happen for non-white participants. Such limitation, however, can be seen as an opportunity for further development of the database. For example, in the future, the database could be complemented with additional photographs using hands with varying skin colors. Alternatively, the already existing photos could be edited to change the skin tones according to the researchers’ goals.

This study showed high name agreement and a relatively high degree of familiarity in both North American and Portuguese samples, although some cross-cultural differences were found. By providing the data from these two samples, one can ensure the selection of stimuli that can be equally named and are equally familiar between the two groups, allowing cross-cultural studies to be conducted. The North American sample had some difficulty in naming some of the items, particularly from the fruits and vegetables categories. This could be due to the fact that the stimuli were picked in Portugal and are not necessarily common in the USA. Given this potential for idiosyncrasies across countries future studies should aim to collect normative data in other countries and cultures expanding the potential for this database to be used in cross-cultural experiments.

The results from study 2 confirmed that the different presentation conditions of our stimuli (via the different substances covering the dirty hands) can induce different emotional states. In particular, the images from the chocolate condition were considered the most arousing, disgusting, and negatively valenced, followed by the sauce, and then by the mud condition. Furthermore, we showed that the exact same stimuli can be used to afford different emotional states by simply framing them in different contexts: when the objects from the chocolate condition were described as being covered with diarrhea (disease context) they were consistently rated as more arousing, disgusting and negatively valenced as compared to when they were described as being covered with chocolate (non-disease context) or when no context was provided. A similar variety of contexts could be created for photographs from the other conditions; for example, photographs from the sauce condition could be described as belonging to a vomit or to a pasta sauce condition. Future studies should collect additional information in order to confirm that the participants' perception of the stimuli follows our framing (i.e., they believe the hands are covered with chocolate or diarrhea, for example). Nonetheless, the subjective emotional ratings we obtained seem to suggest that participants did believe in the descriptions accompanying the pictures. These initial data reassure researchers that they can keep the object of interest the same across their experiments (thus minimizing the influence of item-specific characteristics), differing only in the emotional reactions elicited by either manipulating the hands condition (e.g., hands covered with chocolate or pasta sauce) or the encoding context (i.e., the cover story provided with the stimuli). It would also be interesting for upcoming studies to complement the existing subjective data with more objective indicators of emotional reaction (e.g., physiological data).

Hence, the database comprises a suitable set of pictures of everyday objects that can be used by a large number of researchers from different knowledge domains and with various research goals. We provide subjective data regarding the variables of arousal, disgust and emotional valence but there are many other cognitive and psycholinguistic variables of potential interest to researchers that could be collected in future studies (e.g., age of acquisition, typicality, manipulability, pleasantness or naming latency). Other subjective and more objective variables regarding the perceptive aspects of the stimuli could also complement this database, such as subjective and objective indicators of visual complexity.

This database is freely available for scientific purposes after submitting formal request for research use via the database website: https://sites.google.com/view/adaptive-memory-lab/data-databases. By making our norming data available through the Open Science Framework (OSF) project we ensure their permanent availability. We aim to maintain our dataset website and OSF project updated with further developments of the database and with references of studies that have used it. Moreover, if requested by other researchers, we would be happy to also include more specific information about further norming studies on our website. We look forward to reference exciting and innovative research using our stimuli.

PART III

EMPIRICAL STUDIES

III

EMPIRICAL STUDIES

CHAPTER 4.

“Remind myself not to touch it, it is contaminated!”: Memory and contamination

. Introduction

. The mnemonic value of contamination in an Immediate-Memory Paradigm
  - Exploring faces as informative of contamination potential
  - Exploring sentences as informative of contamination potential
  - Exploring the direct transmission of contamination potential

. The mnemonic value of contamination in a Generation Paradigm
  - Exploring self-generated situations of contamination potential

. Summary and general discussion

Scientific products related to this chapter:

Overview chapter

Nairne, J. S., Pandeirada, J. N. S., & Fernandes. N. L. (2017). Adaptive memory. In John H. Byrne (Ed.) *Learning and Memory: A Comprehensive Reference* (2nd Ed., Vol. 2). Oxford: Elsevier (p. 279-293). doi: 10.1016/B978-0-12-809324-5.21060-2

Empirical work

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

Fernandes, N.L., Pandeirada, J., & Nairne, J. (under revision). The mnemonic tuning for contamination: A replication study using more ecologically-valid stimuli. *Evolutionary Psychology.*

Fernandes, N.L., Pandeirada, J., & Nairne, J. (under preparation). “If it's contaminated, you will remember it”: Direct transmission of contamination potential.

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (under preparation). “Better safe than sorry”: Mnemonic tuning for contamination extends to stimuli that resemble real pathogen-treats.

Summary of studies

Fernandes, N.L., Pandeirada, J., Soares, S.C., Nairne, J. (2018). *Adaptive memory: The mnemonic value of contamination.* In University of Aveiro (Ed.), Magazine *Research@UA 2017.* Diário do Porto (p. 44).

Conference presentations (posters)

Fernandes, N.L., Pandeirada, J.N.S., Nairne, J., & Soares, S. (2016, November). *Adaptive memory: The mnemonic value of contamination.* Poster presented at the 57th Psychonomic Society Annual Meeting. Boston, Massachusetts, USA.

Fernandes, N.L., Pandeirada, J.N.S., Soares, S., & Nairne, J. (2017, June). *“Remind myself not to touch it, it's contaminated!”: Memory and contamination.* Poster presented at the Research Day 2017@ University of Aveiro. Aveiro, Portugal.

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (2019, May). *Are health-threatening stimuli better retained? The mnemonic consequences of contamination.* Poster presented at the 14th National Meeting of the APPE. Évora, Portugal.

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (2019, June). *“If it's contaminated, you will remember it”: The mnemonic value of contamination.* Poster presented at the X Simpósio Nacional de Investigação em Psicologia. Madeira, Portugal.

Oral presentation

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (2019, May). *O Sistema Imunológico Comportamental: As consequências mnésicas da contaminação [The Behavioral Immune System: The mnemonic consequences of contamination].* Oral communication presented at the Cycle of Conferences Under Investigation: Psychology@UA (6th edition), University of Aveiro, Portugal.

Social media coverage

An interview, entitled "Objetos contaminados são mais bem recordados pela memória humana", was disseminated by LUSA: Agência de Notícias de Portugal, between January and February 2019, through print and online newspapers, such as: Diário de Aveiro, Diário dos Açores, Destak, Diário de Viseu, Diário de Viseu – Saúde, Uaveiro Research Newsletter, Expresso, Índice.eu, AuriNegra, Jornal Médico.pt, Atlas da Saúde, Medjournal, Mood Magazine, TV Europa, Saúde, Notícias ao Minuto, TSF, Sapo Lifestyle, News Farma, Rádio Terra Nova, Diário de Notícias. See, for example, http://pt.cision.com/cp2013/ClippingDetails.aspx?id=ca5ae123-b810-4293-978d-e16fd0e45500&byemail=1

In addition, an interview was conveyed through radio:

Fernandes, N.L., Pandeirada, J.N.S., & Nairne, J. (2019, September 10). Objetos contaminados são mais facilmente recordados (A. Cerqueira, Interviewer), *“90 Segundos de Ciência” - Antena 1.* Retrieved from https://www.90segundosdeciencia.pt/episodes/ep-678-josefa-pandeirada/?fbclid=IwAR1lEifFXUs3z8m5eohUNcySobzJZhZ2HopBqoZLMTPaDv02v6FVRo_sYDw

4.1 Introduction

As revised briefly in the general *Theoretical Introduction* (see section 1.4.1 of Chapter 1), there is clear evidence that people remember disgusting objects – commonly associated with transmission paths of pathogens – better than neutral objects (e.g., Chapman et al., 2013) and that the magical spread of contamination shapes people's behavior and emotional reactions (Rozin & Fallon, 1987; Rozin et al., 1986). Would the law of contagion also leave its footprints in memory? In other words, would neutral objects that had come in contact with disgusting or disease-signaling cues – potential sources of contamination – yield enhanced retention as well?

Inspired by the idea that contaminating properties of disgusting items can be transferred to neutral items through contact – law of contagion (Rozin et al., 1986) – we have recently begun investigating mnemonic tunings for potentially contaminated items by exploring if people would remember objects that had been touched by a sick person better than when the same objects had been touched by a healthy person (Nairne, 2015; Nairne & Pandeirada, 2008). Most studies have investigated memory performance for stimuli that directly trigger the emotion of disgust compared to items that elicit fear or a neutral reaction (e.g., Croucher et al., 2011). Such procedure introduces potential item concerns – that is, inherent and potentially uncontrolled differences between the to-be-remembered stimuli that could impact performance – as performance for different items is being compared. In our studies everyone is asked to recall exactly the same "neutral" items but these have acquired different fitness-relevancy via contagion with health-threatening elements. What matters is the context in which the items are presented – a context of potential contamination or not (also see Bell & Buchner, 2010). This kind of design effectively eliminates item-selection concerns that have plagued earlier research. Even though researchers have recognized this issue and have made significant attempts to equate the stimuli on a number of dimensions of interest (e.g., frequency, imagery, meaningfulness), unknown and uncontrolled dimensions might still be present. Therefore, our strategy (asking people to recall exactly the same stimuli) may be upheld as a way to potentially solve this issue.

There is certainly adaptive value in being able to successfully detect and remember possible sources of contamination (Nairne & Pandeirada, 2008). Knowing which items are contaminated helps to lessen the likelihood of coming into close contact with pathogens, maximizing our chances for survival. Accordingly, we predicted that objects that have been potentially contaminated would be better remembered than the objects that carried a lower risk of contamination. Such a mnemonic advantage for contamination – if proven to exist – is likely to operate as part of the BIS.

In an initial experiment conducted by our research team (Experiment 1a; Fernandes et al., 2017), everyday object pictures were presented along with a descriptor that specified whether that object had been touched by a sick or a healthy person. For example, a picture of a cup might be presented along with the statement "person with a runny nose" (sick condition) or the statement "person with brown hair" (healthy condition). After every third item, an immediate memory task followed in which the three preceding objects were presented again and participants were required to indicate whether each 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. Participants performed close to perfect in the immediate memory task with no differences between the sick and healthy conditions. However, in the final test, they recalled significantly more of the objects paired with descriptions of sick people than those paired with descriptions of healthy people – in other words, they retained more of the potentially contaminated objects. To our knowledge, this study provided the first empirical evidence of a memory advantage for neutral stimuli that acquired the status of potential contaminants through proximity or brief contact with a source of pathogens (i.e., sick people). With such promising results, further research was needed to establish the robustness and generalizability of this *contamination effect*. Toward this end, we conducted a set of studies using the above-described *Immediate-Memory Paradigm* (Studies 3-7)[8].

Human faces have long been known to convey information about the identity, gender, age, emotions and intentions of other individuals (Leopold & Rhodes, 2010). Importantly, they also have the potential to inform about the health status of a person (Henderson, Holzleitner, Talamas, & Perrett, 2016). In Studies 3a and 3b we explored the mnemonic tuning for contamination using faces as the source of information on the contamination potential of a series of items. Line drawings of objects were presented with faces containing signs of contagious diseases (sick faces) or faces containing no such cues (healthy faces). Critically, in Study 3a, the sick faces were described as depicting actual sick people, whereas in Study 3b they were described as actresses who were preparing to portray sick people for a TV-show. Thus, in the first case, the "sick" faces

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[8] Studies 3a, 3b and 4a are fully described in Fernandes et al. (2017) and correspond to the Experiments 2, 3, and 1b on the manuscript, respectively. Study 4b is reported in Fernandes et al. (submitted) and corresponds to Experiment 1 on the manuscript.

represented a potential source of contamination but, in the second, although the faces were exactly the same, they were described as not conveying potential for contamination.

The next couple of studies aimed to replicate and extend our previous findings using sentences as the source of information on the potential for contamination. In Study 4a, line drawings of objects were presented along with a descriptor that specified whether that object had been touched by a sick or a healthy person. In Study 4b, we added ecological validity to our procedure by using photographs of real objects being held by hands instead of object line drawings.

In the aforementioned studies, the target-item and the contamination cues (faces or descriptors) were arranged alongside each other without direct contact. Therefore, for the object to acquire the potential for contamination, participants had to imagine the contact or interaction between the object and the person with that face or with the described characteristic. In the next presented studies (Studies 5a and 5b), objects were shown in direct physical contact with (non-)contamination sources, making the pathogens' spread from the person to the object more easily attained. In these studies participants were shown objects being held by hands covered with a substance (hereafter referred to as dirty hands) described as being vomit or being held by clean hands (i.e., hands not covered with any substance). Study 6 extended this procedure by exploring the need for fitness-relevancy for the mnemonic effect to occur while using a similar procedure. Additionally, we used another substance and description to transmit the potential for contamination. Specifically, the dirty hands were covered with a substance described as diarrhea (the fitness condition, as this is likely a source of pathogens) or with chocolate spread (the non-fitness condition). The former condition posed a greater threat of disease transmission than the latter, for which the risk of infection from others is almost inexistent, even though the to-be-remembered stimuli (the objects being held by the hands) were exactly the same.

Studies 7a and 7b explored the BIS’s tendency for hypervigilance and to operate according to the smoke detector principle (Haselton & Nettle, 2006; Nesse, 2005). In Study 7a, both hands were dirty but could be described as a contamination or a non-contamination source. In the subsequent Study 7b, participants were given two cues to make their contamination decision: a face and dirty hands. Even though the stimuli were exactly the same, they were randomly described as representing a real contamination threat (i.e., diarrhea and vomit) or not (i.e., chocolate spread and pasta sauce). In all of the above-described studies, participants were given a final surprise memory task in which they were asked to recall the names of the objects associated with each cue.

We are currently exploring the mnemonic consequences of contamination in several ongoing experiments using new promising paradigms. The studies presented at the end of this chapter adopted a *Generation Paradigm* (Studies 8 and 9). In these studies, participants were asked to consider how a series of objects could be relevant to their health and then to generate a contamination situation in which each object may contribute to or prevent them from getting sick (the contamination condition). Additionally, they were asked to rate the pleasantness of objects (Study 8) or to generate autobiographical specific events from their life in which each object was relevant (Study 9), used as control conditions.

The sample sizes were selected to match those frequently used in the survival processing paradigm studies that have employed within-subject designs and free recall tasks (*Mdn* = 50, *Mo* = 48; Scofield et al., 2018), and to allow an even distribution of participants to the different counterbalancing versions. Additionally, a priori power analysis using G*Power (Version 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007) showed that a sample size of 43 participants had sufficient power ($1-\beta = .85$) at a significance level of $\alpha = .05$ to detect the medium effect size ($d = 0.47$) obtained by the initial study that gave rise to the current work (that is, Experiment 1a of Fernandes et al., 2017 which was conducted previously to the studies here reported).

THE MNEMONIC VALUE OF CONTAMINATION IN AN IMMEDIATE-MEMORY PARADIGM

4.2 Exploring faces as informative of contamination potential

Human faces are a rich and easily accessible source of information, including information about a person’s health status. Several facial traits (e.g., symmetry, averageness, masculinity/femininity, adiposity, skin color, skin texture) are reliably and systematically used in the detection of poor health and potential presence of infectious disease (Axelsson et al., 2018; Henderson et al., 2016; Matts, Fink, Grammer, & Burquest, 2007). People infected with pathogenic microorganisms commonly manifest visible morphological changes (e.g., rashes, skin lesions, jaundice), which can be easily detected (Neuberg et al., 2011).

Conspecifics play a critical role in transmitting disease-causing agents. In our everyday life we are constantly observing other people interacting directly with objects with which we might need to contact in the future. These objects can be a potential vehicle of disease if touched by sick people, coughed on, sneezed on, and so on. It is important to cope with such threats in an adaptive manner by orchestrating adaptive responses aimed at shielding us from contracting diseases. Memory is probably a key component in such behaviors. In particular, we predicted that possible vehicles of contamination should be preferentially retained allowing for future avoidance behaviors toward such stimuli. Relying on the idea that some disease signals can be observed directly on a person’s face, we designed an experiment using photographs of faces displaying (or not) disease-connoting cues, which will inform about the potential of contamination of a set of objects with which those people interacted previously.

4.2.1 Study 3a

In Study 3a, participants were shown pictures of everyday objects along with faces containing cues indicative of contagious diseases (sick faces) or containing no such cues (healthy faces). For example, a picture of a ball might be shown along with someone's face with herpes (sick condition) or along with a healthy-appearing face (healthy condition). After every third item, the three preceding items were shown again and participants were asked to identify whether each had been touched by a sick or a healthy person. This immediate test was included simply to guarantee that participants were paying attention to the stimuli, while allowing us to ensure that the faces were being correctly interpreted as corresponding to a sick or a healthy person. 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 Figure 6 for a schematic illustration of the procedure). Of main interest was whether people would remember more of the items touched by someone with a sick face as compared to those touched by someone with a healthy face.

4.2.1.1 Method

Participants. Forty-eight undergraduate psychology students (females = 42; 87.5%) from the University of Aveiro (Portugal) participated in exchange for course credit (M_{age} = 22.25, *SD* = 5.58; age range: 19-53 years old). Data from two other participants were excluded, one due to low performance on the immediate memory task (< 60%

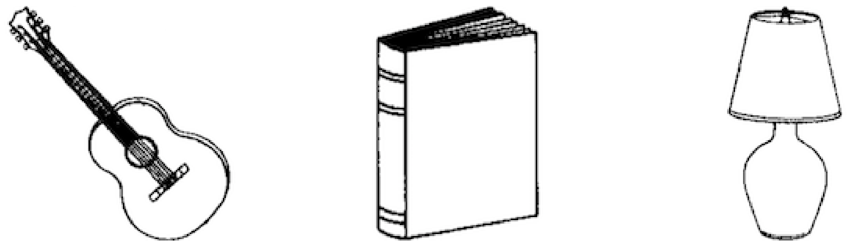
correct), and another due to a technical error that prevented data from being saved. Informed consent was obtained from all participants.

Materials.

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 (see Figure 4 for examples). According to the same norms, the average name agreement for these objects was 95.9% (*SD* = 6.99)[9].

Figure 4.

Examples of object stimuli used in Studies 3a, 3b, and 4a.



Faces. Twenty-eight female faces from the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998) and 19 from the Radboud Facial Database (RaFD; Langner et al., 2010) were manipulated using Adobe Photoshop CC to display conspicuous disease-connoting cues, namely perioral dermatitis, conjunctivitis, eczema, herpes, Sweet syndrome, dermatophytosis and butterfly-shaped rash (see Figure 5 for examples).

We then conducted a pilot study in which an independent sample of 38 female participants (M_{age} = 20.05, *SD* = 2.14; age range: 18-26 years old) was 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. The 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). A total of 48 faces were rated per participant, with a total of 38 ratings collected per face and 19 ratings collected

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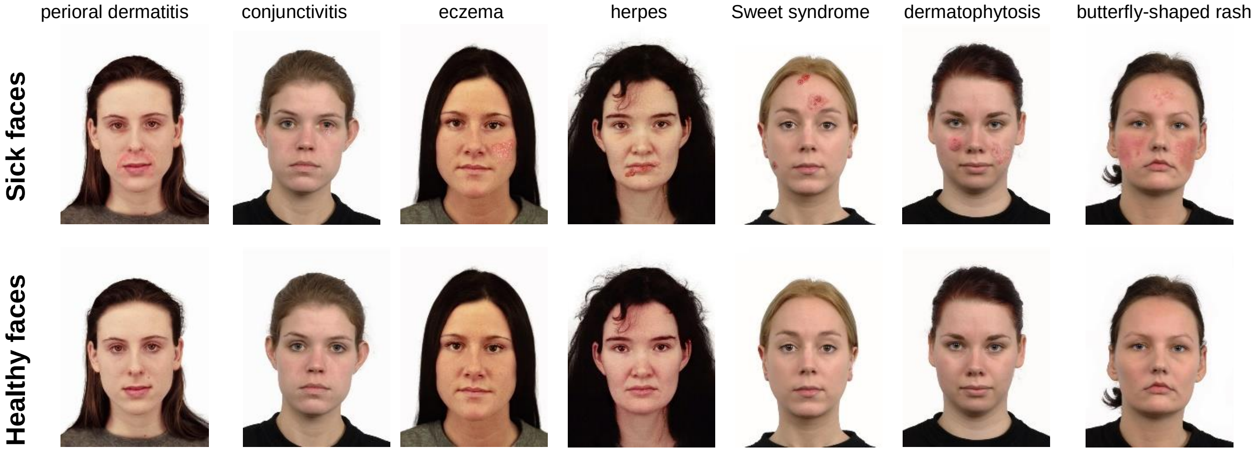
[9] Although these norms were collected from a North American sample of participants (no norms exist for the Portuguese population), the objects used were easily nameable and participants did not mention difficulty in identifying them.

per manipulation condition. All decisions were provided using a visual analog scale ranging from 0 (not at all) to 100 (very much) and were self-paced. This task was implemented in groups of up to six participants in individual computers running the *software E-prime 2.0 Professional* (Schneider, Eschman, & Zuccolotto, 2002). Each session lasted about 20 minutes.

Figure 5.

Examples of face stimuli used in Studies 3a and 3b, in its manipulated form (sick faces) and in its normal state (healthy faces).



Based on results from the pilot study, the five sick condition manipulations that were found to have the highest rates on all the evaluated scales were selected to be used as stimuli material (the perioral dermatitis and butterfly-shaped rash were the excluded manipulations). From each of these selected manipulations, we picked the six faces that caused the highest disgust and discomfort; these same faces elicited low levels on those dimensions when the corresponding non-manipulated (healthy) version was 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 9. 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 hypothetical situation of close contact, as compared to the same faces in their healthy appearance.

Using the selected faces (17 from the KDEF and 13 from the RaFD), we created four counterbalancing versions of the experiment making sure that, across participants, each face appeared an equal number of times in its healthy and sick version, and that each condition (sick vs. healthy) appeared an equal number of times in each position of the list during encoding. Participants were not given any sort of verbal description (e.g., “sick” or “healthy”) nor were they enlightened about the type of illness suffered by each person.

Table 9.

Mean ratings (and standard deviations) obtained from the pilot study for each version of the face stimuli used in Studies 3a and 3b.

	Healthy faces	**Sick faces**	***t*-tests 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)	$t(58) = -29.32$***

*** $p < .001$

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

Procedure. Participants were tested in individual computers running the *software E-prime 2.0 Professional* (Schneider et al., 2002) in sessions that included up to six people. Each session lasted approximately 30 minutes. On arrival at the laboratory, and after consenting to participate, participants were randomly assigned to one of the counterbalancing versions of the experiment.

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

> *“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 a 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."

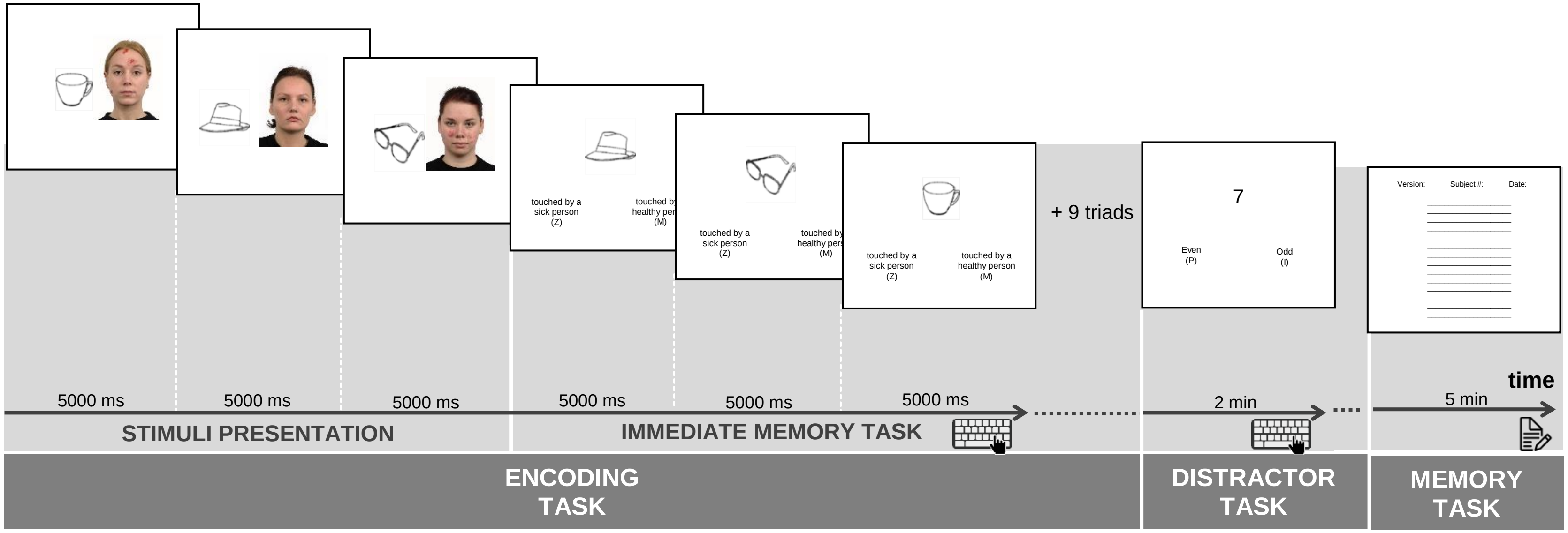
Throughout the experiment, participants saw 10 sets of three stimuli each (object + face), for a total of 30 stimuli. A brief practice phase containing three additional stimuli preceded the presentation of the scored trials to ensure understanding of instructions. Data collected during the practice phase were not analyzed. After the practice phase, participants were again presented with the instructions. Each object picture was displayed on the screen with the face presented on its right side for 5 s each. Stimuli were presented one at a time, in sets of three (stimuli presentation phase). After each third stimulus, the just three preceding objects were again presented individually on the screen and participants had 5 s to identify if the item had been touched by a "sick" or a "healthy" person by pressing the "Z" or the "M" key, respectively (immediate memory task). Participants were warned they would have only 5 s to view each stimulus and 5 s to make their memory decision. To ensure that the exposure time was constant for all participants, the stimuli remained on the screen until 5 s had elapsed, even if a judgment was completed within the time frame. When no response was given within this time interval, the program advanced to the presentation of the next item. An inter-trial interval of 250 ms preceded both the stimuli presentation and the immediate memory phases. The objects were randomly assigned to each condition and the order of presentation of the objects during the immediate memory task was randomized; therefore, in the latter, the objects were not necessarily presented in the same order as in the presentation phase (see Figure 6 for an illustration of the procedure). However, we pre-established the condition presentation in each initial presentation triad to make sure that: 1) both conditions were present in each triad of stimuli (e.g., two objects were presented with a sick face and one with a healthy face; this was counterbalanced in two versions of the experiment); 2) the first two trials presented different conditions (to prevent guessing of the condition of the last stimulus of the triad); 3) and, in each half of the task an approximately equal number of sick and healthy faces was presented. Performance in the immediate memory task allowed us to ensure participants were correctly identifying the faces as belonging to a sick or a healthy person and also were associating the items with the corresponding condition.

After the encoding phase, a distractor task followed for about 2 mins. 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 “P” or “I” keys in 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 5 min period; everyone was told that they could recall the objects in any order. The response sheet was only provided after the recall instructions. Participants were encouraged to spend the full time trying to remember as many objects as they can. 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). The Perceived Vulnerability to Disease Scale (PVDS: Duncan et al., 2009; Portuguese version by Ferreira et al., Under preparation), the health status questionnaire, the Disgust Propensity and Sensitivity Scale-Revised (DPSS-R: Olatunji, Cisler, Deacon, Connolly, & Lohr, 2007; Portuguese version by Ferreira et al., 2016) and some demographic questions were then administered. Full description of these instruments as well as the obtained results will be presented in Chapter 6. Participants were fully debriefed at the end of the experiment, thanked for their participation, and excused.

Experimental design and statistical analysis. Study 3a employed a single-factor within-subject design, in which the Independent Variable (IV) was the condition (i.e., sick vs. healthy) and the Dependent Variables (DVs) were the performance indicators on each memory task (proportion of free recall, source memory performance). Analyses were performed using the IBM SPSS version 24. The statistical level of significance was set at $p < .05$ (two-tailed) for all analyses. Paired-samples t-tests were used to determine whether there were significant differences between conditions for each of the DVs. Accuracy during the immediate memory task was also analyzed to ensure the correct association was occurring equally in both conditions. The effect of contamination on free recall was examined at both the subject-level (averaged for each participant) and item-level (averaged for each object). We also report the pluses, minuses and ties for each comparison which correspond to the number of cases in which a contamination advantage was obtained, the opposite result occurred, or no difference between conditions was obtained, respectively.

Figure 6.

Schematic representation of the procedure used in Study 3a.



Note: For the encoding task, the sequence of events was repeated 10 times for a total of 30 presented stimuli. The same procedure was adopted in Studies 3b, 4a, 4b, and 5a with some adjustments (which will be fully described in the procedure section of each study).

4.2.1.2 Results

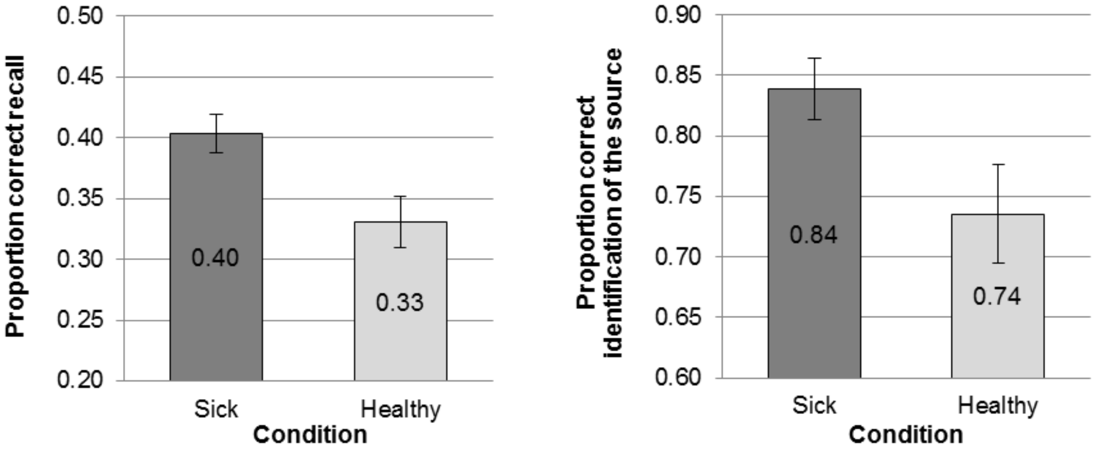
Immediate memory. In both conditions, participants performed at about 95% (M_{sick} = .95, *SD* = .08; $M_{healhty}$ = .95, *SD* = .07), indicating they were identifying the faces correctly as corresponding to a sick or a healthy person and also associating the objects with the corresponding condition, *t*(47) = 0.38, *p* = .705. On average, participants took about 1 s to identify if the item had been touched by a sick or a healthy person (M_{sick} = 1039 ms, *SD* = 257; $M_{healhty}$ = 1088 ms, *SD* = 247), *t*(47) = -1.51, *p* = .138.

Free recall. Free recall was assessed by counting up the number of object names participants were able to recover from each condition. A response was considered correct if the modal name or any alternative names (e.g., synonyms) was used by the participant. This number was then divided by the number of objects presented in each condition (*n* = 15 objects per condition).

Participants recalled more objects associated with faces of sick people than those associated with faces of healthy people (see Figure 7). A paired-samples *t*-test revealed that this mnemonic advantage for the potentially contaminated items was statistically significant, both in the subject, *t*(47) = 2.82, *p* = .007, d_z = 0.407 (plus = 31; minus = 15; ties = 2), and item analyses, *t*(29) = 2.34, *p* = .026, d_z = 0.427 (plus = 20; minus = 10; ties = 0).

Figure 7.

Mean proportion of correct free recall (on the left) and of correct source identification (on the right) for each condition in Study 3a. Error bars represent Standard Errors of the Mean (SEM).



Source memory. In this task, we calculated the percentage of times participants correctly identified the source for the objects they recalled. Source memory was calculated by dividing the number of correct source memory responses in each condition by the number of correctly recalled items from that same condition.

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 s/he recalled only items from the sick condition; s/he correctly identified the source memory for all of these items. One additional participant did not provide a response for 54% 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 the source for the other half of the recalled items was identified.

The results revealed that participants were significantly better at identifying the source of the objects that had been previously paired with a sick face as compared to those previously paired with a healthy face, $t(42) = 2.15$, $p = .038$, $d_z = 0.327$ (Figure 7).

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 ($M = 0.58$ 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.

4.2.1.3 Interim discussion

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 healthy person. Results support previous findings suggesting a mnemonic advantage for fitness-relevant information; in this specific case, we found better memory for “contaminated” objects that may potentially threaten people’s health. This study also provides 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.

4.2.2 Study 3b

Study 3b tested whether the attribution of fitness-relevance is an important determinant of the mnemonic effect. This study is an exact replication of Study 3a, 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 show. 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.

4.2.2.1 Method

Participants. Forty-eight undergraduate students (female = 36; 75.0%) from the University of Aveiro (Portugal) took part in this experiment (M_{age} = 22.27, *SD* = 7.08; age range: 18-55 years old). Participants received a monetary compensation or course credits for their participation. Data from 13 additional participants were excluded due to low performance in the immediate memory task (< 60% correct; *n* = 8) or to failure to follow instructions (*n* = 5). Informed consent was attained prior to participation.

Materials. The stimuli were the same as those used in Study 3a.

Procedure. With the exception of the instructions and response options of the immediate memory test, participants went through a procedure identical to that described in Study 3a. The instructions were adjusted as follows:

> *"In this task, you will be asked to remember objects that have been touched and handled by different people. 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 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. (…).”

Experimental design and statistical analysis. A single-factor within-subject design was also used in Study 3b (IV = condition: actress vs. TV-show viewer; DVs = performance on memory tasks). The statistical analyses carried out in the previous study were also performed in this study.

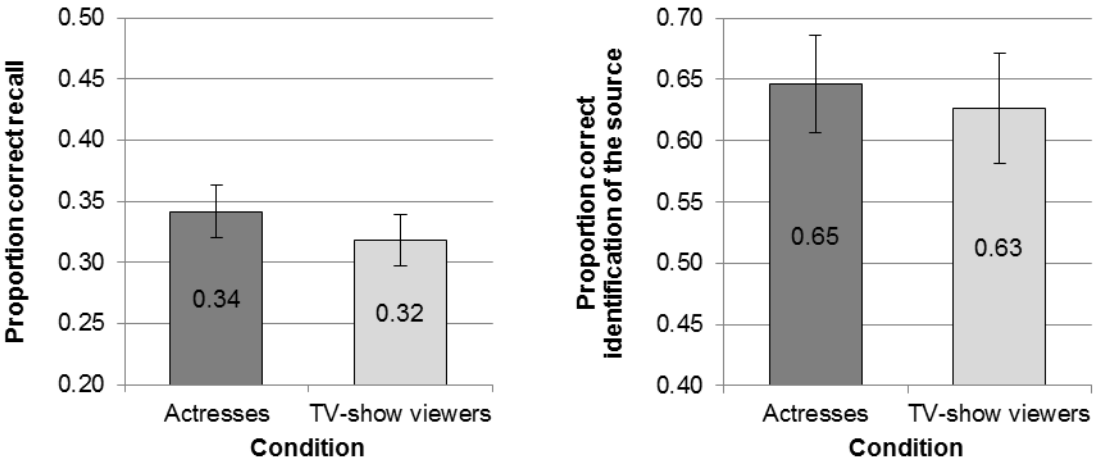
4.2.2.2 Results

Immediate memory. As in the previous experiment, performance in the immediate memory task was high, with an average percentage of 93% correct responses in both conditions ($M_{actresses}$ = .93, *SD* = .08; $M_{TV\text{-}show\ viewers}$ = .93, *SD* = .08), *t*(47) = 0.17, *p* = .868, certifying that participants were relating the objects with the corresponding faces during the encoding phase. Participants needed approximately 1 s to identify if the object had been touched by an actress or a TV-show viewer ($M_{actresses}$ = 1098 ms, *SD* = 331; $M_{TV\text{-}show\ viewers}$ = 1123 ms, *SD* = 328), *t*(47) = -0.53, *p* = .596.

Free recall. The data presented in Figure 8 indicate that participants remembered about the same percentage of objects previously paired with the actresses’ or TV-show viewers’ faces; this observation was confirmed by the non-significant difference obtained in the paired-samples *t*-test, at both the subject, *t*(47) = 0.76, *p* = .452 (plus = 26; minus = 17; ties = 5), and the item-level, *t*(29) = 0.87, *p* = .393 (plus = 15; minus = 15; ties = 0).

Figure 8.

Mean proportion of correct free recall (on the left) and of correct source identification (on the right) for each condition in Study 3b. Error bars represent SEM.



Source Memory. Performance in this task was determined as detailed in Study 3a. Data from one participant were not included as no responses were provided in this task. Data from another participant were also not included as s/he recalled only items from the TV-show viewer condition; s/he correctly identified the source memory for 40.0% of these items. Some participants (*n* = 6) did not provide a source memory response for about 21% (*SD* = 13.43) of their recalled items, seeming reluctant to guess a response. More than half of the items without a source memory response were from the TV-show viewer condition (62.8%). Because these participants assigned a source memory response to recalled items from both conditions, their data were still included in the analyses.

Participants did not differ in their ability to identify the source of the objects that had been previously paired with actresses' faces as compared to those previously paired with TV-show viewers' faces, *t*(45) = 0.35, *p* = .731 (see Figure 8). As in the previous experiment, we explored the possibility of response bias by looking at the source memory assignment to the intrusions. As before, a small number of intrusions occurred (*M* = 0.65 per participant) with a similar percentage of these being attributed to the TV-show viewer condition (48.4%) and the actress condition (45.2%); for the remaining 6.4% of the intrusions no source memory response was provided. These results do not suggest any response bias.

4.2.2.3 Interim discussion

In this experiment, participants were asked to remember exactly the same objects, associated with exactly the same faces as in Study 3a; what differed was the fitness-relevancy of the context associated with the faces: Whereas in Study 3a these were described as potential sources of contamination, in Study 3b, even though they contained exactly the same disease-connoting cues, 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 are processed within a fitness-relevant context.

4.2.3 Discussion of studies using faces as cues of disease threat

Infectious agent's overgrowth leads to noticeable changes on facial morphological characteristics. Because pathogens can be easily transmitted through physical contact with infected conspecifics, people must be vigilant to behavioral and morphological cues signaling the possible presence of disease. The faces presented in Studies 3a and 3b tried to reproduce some of these morphological changes on people's faces. It was hypothesized that people would remember more objects previously touched by people whose faces contained disease-connoting cues (i.e., objects that became potential disease-carriers, consistent with the operation of the magical “law of contagion") than objects touched by people with healthy faces (i.e., objects that do not pose an immediate threat to health). Results from Study 3a confirmed this hypothesis.

The same “sick” faces were presented again in Study 3b along with the same objects, but participants were led to believe that the facial cues were actually from the application of make-up 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. Therefore, the contamination memory effect obtained in Study 3a seems not to rely on the visual cues of the faces accompanying the objects, but rather on whether the context presented establishes a real opportunity for contamination.

A direct comparison of the two studies using an Analysis of Variance including experiment (3a vs. 3b) as a between-subjects variable and condition (manipulated faces vs. normal faces) as a within-subject variable, revealed no main effect of experiment, $F(1, 94) = 3.27$, $MSE = .020$, $p = .074$, no main effect of type of face, $F(1, 94) = 1.42$, $MSE = .018$, $p = .236$, but a significant interaction, $F(1, 94) = 6.57$, $MSE = .117$, $p = .012$, $\eta_p^2 = .065$. This interaction was qualified by the memory advantage found for the objects associated with the sick faces in Experiment 3a but not in Experiment 3b. Of note is also the fact that the overall memory performance in the latter was similar to that obtained for the healthy faces in Experiment 3a; thus, the effect derives from an increased memory performance for the “sick” condition.

Notably, everyone was remembering exactly the same information; what varied was the context with which the object was associated. Such a methodology eliminates item selection issues that have been a concern in some previous work on memory for disgusting and non-disgusting stimuli (e.g., Chapman et al., 2013).

4.3 Exploring sentences as informative of contamination potential

The BIS seems to be automatically triggered by perceptual cues connoting potential infection risk (Schaller & Duncan, 2007). However, such cues are not always available in the immediate environment. Tybur et al. (2013) highlighted the adaptive benefits of gathering information about possible sources of pathogens through social communication, particularly under circumstances of uncertainty or ambiguity. The authors gave as an example the propensity to ask others' opinion about something that does not taste right (e.g., "Does this milk taste spoiled to you?"; Tybur et al., 2013, p. 70).

Others may be indeed a valuable source of information, especially in the absence of sensory and perceptual cues. Often times in our daily lives we become aware of the health status of people by sharing information. In the next studies, instead of using visual cues, we presented objects paired with sentences. Since diseases can cause not only anomalous morphological changes on skin (e.g., rashes, skin lesions) but also behavioral signals (e.g., vomiting, coughing, sneezing) and symptoms (e.g., fever), the selected sentences included both. We predicted a mnemonic enhancement for contamination due to the likely activation of the BIS in such situations; specifically, we expected that items associated with descriptors of sickness would be better retained than those associated with "healthy" descriptors. The immediate-memory paradigm described in the previous studies was used in these experiments.

4.3.1 Study 4a

Study 4a was designed to replicate an initial experiment previously conducted by our research team with a sample of undergraduate students at Purdue University (USA) (Experiment 1a; Fernandes et al., 2017). In that study, participants were shown line-drawings of objects along with descriptors denoting the health state of people that had been in contact with each object. The present study was run in a sample of students from the University of Aveiro (Portugal) in an effort to replicate and help establish the generality of the mnemonic tuning for contamination. The replication of studies, deemed foundational to science, lies at the "heart of scientific progress" (Walker, James, & Brewer, 2017, p. 1221). 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.

4.3.1.1 Method

Participants. A sample of 106 participants[10] (females = 95; 89.6%) was recruited

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[10] In this study we were also interested in exploring if the participants' health status (situation of sickness or healthy) would influence the pattern of results. Considering the scarceness of "sick" participants, and in an effort to recruit a large enough sample of this type of participants, we ended up running a higher number of participants as compared to the remaining experiments).

at the University of Aveiro (Portugal) to participate in this study. Participants received course credits for their participation. All participants consented to participate voluntarily before starting the experiment. Data from one additional participant were excluded due to low immediate memory performance (< 60% correct).

Materials.

Objects. The same black-and-white line drawings of objects used in Studies 3a and 3b were used in this study.

Sentences. A set of 10 sentences of equivalent length, $t(8) = 0.81$, $p = .442$, was created; five of these sentences described signs and/or symptoms of a sick person and the other five described "neutral" characteristics of a person (see Table 10); the latter were indicated to the participants as being descriptors of a "healthy" person.

Table 10.

Sick and healthy descriptors used in Studies 4a and 4b.

Sick	Healthy
person with a high fever	person with a round face
person with a sore throat[a]	person with a straight nose[a]
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

[a] Descriptors used in Study 4a only.

Stimulus. Each stimulus was comprised of an object picture and a descriptor. Objects and descriptors were randomly combined for each participant.

Procedure. The procedure was very similar to that used in the previous studies, including the presentation and response timings. Up to eight participants were tested in each session using individual computers. The experiment was controlled with the *software E-prime 2.0 Professional* (Schneider et al., 2002). The specific instructions were as described next:

> *"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 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 informed about the time available to view each stimulus and to make their memory decision (5 s each stimulus). As before, the procedure described in the instructions was repeated 10 times for a total of 30 trials. The experiment began with a practice phase comprising three additional stimuli.

Each object picture appeared individually in the center of the screen, with the descriptor presented below. 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. The distractor task that followed the encoding phase was as described in the previous experiments (an even-odd discrimination task). For the surprise final free recall task participants were allowed 10 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. The health status questionnaire and some demographic questions were finally employed (see Chapter 6). Participants were fully debriefed upon study completion. The source memory task was not performed in this study nor in the following ones.

Experimental design and statistical analysis. A simple within-subject design was used to assess whether the two conditions (i.e., sick vs. healthy; IV) differed significantly in their effect on immediate memory and free recall performance (DVs). To that end, paired-samples *t*-tests were conducted both on the subject and item levels.

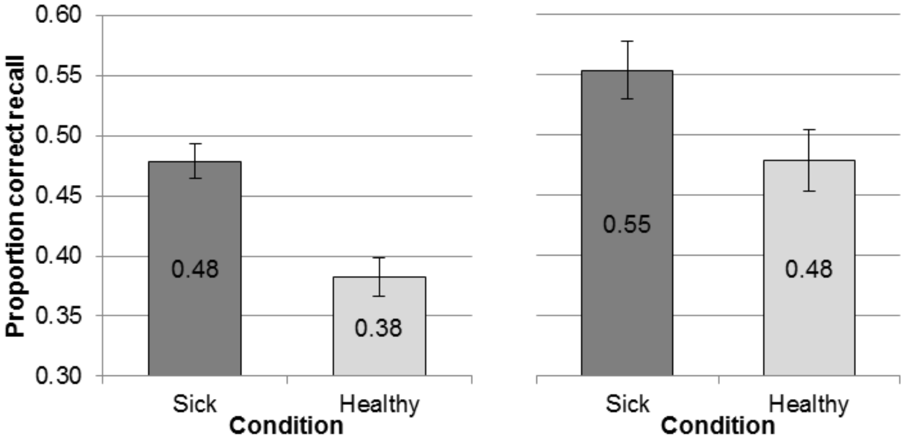
4.3.1.2 Results

Immediate memory. Performance in the immediate memory task was around 93% in both conditions (M_{sick} = .93, SD = .10; $M_{healhty}$ = .93, SD = .09), $t(105) = -0.60$, $p = .547$, indicating participants were correctly relating the condition (sick and healthy) with the objects. Participants took less than 2 s to identify the person who touched the item; however, they were significantly faster to identify the objects touched by sick people than those touched by the healthy individuals (M_{sick} = 1042 ms, SD = 296; $M_{healhty}$ = 1111 ms, SD = 302), $t(105) = -2.69$, $p = .008$, $d_z = -0.261$.

Free recall. The results obtained in this study are displayed in Figure 9 and reveal, as in previous studies, significantly better memory for the items described as having been previously touched by sick people, at both the subject, $t(105) = 5.74$, $p < .001$, $d_z = 0.557$ (plus = 65; minus = 15; ties = 26), and item levels, $t(29) = 4.51$, $p < .001$, $d_z = 0.826$ (plus = 23; minus = 7; ties = 0).

Figure 9.

Mean proportion of correct free recall for each condition in Study 4a (on the left) and in Study 4b (on the right). Error bars represent SEM.



4.3.1.3 Interim discussion

The present data largely confirm our main hypothesis that items who are likely carriers of harmful pathogens are remembered particularly well compared to non-contaminated items: line drawings of objects associated with descriptors of sick people were remembered better than objects associated with descriptors of healthy people. The effect seems to be robust as it was obtained in two different samples from two different countries.

4.3.2 Study 4b

Study 4b was an attempt to replicate and extend the just reported findings using different stimulus. Notwithstanding the contribution of the just reported study (and of those that preceded it), one could argue that the stimuli that were used (line drawings of objects) lack ecological validity. Thus, rather than using line-drawing, the current study used more realistic stimuli – photographs of objects being held by hands. Recently, researchers have noted the benefit of using more ecologically valid stimuli, as it can affect the way stimuli are processed. As noted by Brodeur et al. (2014), using photographs "increases the chances of activating the same neuronal circuits that are activated in daily tasks" (p. 2), mimicking more closely real-life conditions. We expected to replicate previous findings with more ecologically valid stimuli, establishing the generality of the mnemonic tuning for contamination previously found. Stimuli were selected from the Objects-on-Hands Picture Database (see Chapter 3).

4.3.2.1 Method

Participants. Forty-eight students (female = 21; 43.8%) from the University of Aveiro (Portugal) took part in the experiment (M_{age} = 21.92, *SD* = 3.21; age range: 18-32 years old). Data from six additional participants were excluded from the analysis for having reported expecting a surprise final recall test and trying to memorize the stimuli during the immediate memory task to that latter memory test (*n* = 5), or for having low immediate memory performance (< 60% correct, *n* = 1). As a compensation for their participation, participants became eligible to win a ticket for the Academic Festivities' week of the University of Aveiro or a small gift. All participants gave informed consent.

Materials.

Objects. A new dataset of pictures – the Objects-on-Hands Picture Database – was purposely developed by our research team to be used as stimulus materials (for a detailed description of the database see Chapter 3). Twenty-four frontal-view pictures of objects being held by clean hands (plus six to be used in practice trials) were selected from the pool of 126 (4 items selected per category; see Figure 10 for examples). The selected items obtained high name agreement (%NA = 99.3%, *SD* = 2.04), and a high degree of familiarity (*M* = 4.82, *SD* = 0.18; on a scale of 1-5) on the Portuguese norming data (see Chapter 3).

The objects were then divided in two sets with identical name agreement and familiarity (all *t*s(22) < |1|), to be presented in the sick and healthy condition in a counterbalanced manner across participants during the experiment. The two sets of images contained an equal number of items from each category.

Figure 10.

Examples of object stimuli used in Study 4b.

Sentences. A set of 8 sentences selected from those used in the previous study was used (see Table 10); no significant length differences occurred between the sick and healthy sentences, $t(6) = 0.28$, $p = .787$.

Stimulus. Each stimulus was composed of an object photograph and a descriptor. For each participant, the object-descriptor dyads were obtained randomly.

Procedure. All aspects of the procedure from Study 4a were employed here (including the previously presented instructions) with the exception that only eight sets of three stimuli each were now presented throughout the experiment, for a total of 24 stimuli. With this number of stimuli, only four items from each category were presented limiting the possibility of the participants using a category-recall strategy in the final task. The experimental task was preceded by two extra sets of three stimuli each that worked as practice trials. In addition, to ensure the incidental nature of the encoding, after completing the free recall task participants were asked the following questions: 1) if they anticipated being asked to recall all of the objects; and 2) if they tried to memorize them during the immediate memory task to a latter memory test. The exclusion of the participants saying "yes" to both questions allowed us to be more confident that the obtained results were due to the nature of the encoding task and not to the memorization strategies used by the participants.[11] As in the previous experiments, the experiment ended with the application of the PVDS, the health status questionnaire, the DPSS-R and some demographic questions (see Chapter 6).

Experimental design and statistical analysis. The study design and the statistical analyses were the same as in the previous study, that is, a simple within-subject

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[11] These questions were also applied in the following studies.

design and paired-samples *t*-tests were adopted.

4.3.2.2 Results

Immediate memory. Participants performed at about 94% in both conditions (M_{sick} = .95, *SD* = .07; $M_{healhty}$ = .94, *SD* = .09), *t*(47) = 0.85, *p* = .402. This result indicates that 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. The identification of the person who touched the items was performed in approximately 1 s in both conditions (M_{sick} = 1083 ms, *SD* = 324; $M_{healhty}$ = 1116 ms, *SD* = 318), *t*(47) = -0.63, *p* = .532.

Free recall. Participants remembered significantly more of the items previously associated with the sick descriptors compared to those previously associated with the healthy descriptors (see Figure 9), at both the subject, *t*(47) = 2.31, *p* = .025, d_z = 0.334 (plus = 27; minus = 13; ties = 8), and the item-level, *t*(23) = 2.40, *p* = .025, d_z = 0.490 (plus = 15; minus = 7; ties = 2).

4.3.2.3 Interim discussion

The results of this study reveal that the mnemonic advantage for contamination still held when using more ecologically valid stimuli[12], attesting to the robustness of the effect.

4.3.3 Discussion of studies using sentences as cues of disease threat

People rely on perceptual cues to detect the presence of potential disease-causing microorganisms. However, knowledge about disease sources is sometimes obtained at a social level through social sharing of information. Because the evolutionary success of the BIS depends on the detection of potentially harmful pathogenic agents, information about vehicles of disease should be extracted from different possible sources of information. In Studies 4a and 4b we tested whether verbal information about people that had handled a set of objects would influence the way those objects were remembered. Across the two studies we found that objects associated with descriptors of sick people were more memorable than objects associated with descriptors of healthy people. The effect

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[12] Study 3a was also replicated using more ecologically valid stimuli (i.e., photographs instead of line drawings of objects). A contamination effect was again observed; the full description of the replication study was not included in this thesis but can be found in Fernandes et al. (submitted).

occurred using both line drawings of objects (Study 4a) and more ecologically photographs of objects (Study 4b), reinforcing the robustness of the contamination effect.

4.4 Exploring the direct transmission of contamination potential

In the previously presented studies, the potential for contamination had to be somehow imagined by the participants as the object and potential source of contamination (faces: Studies 3a and 3b; or descriptors: Studies 4a and 4b) were arranged alongside each other without a visible direct contact. In the next studies, we manipulated the potential for contamination using another type of stimuli: photographs of hands holding objects – in some cases the hands were clean whereas in others they were dirty, conveying a potential source of contamination. Thus, rather than presenting the objects along with cues about the person who had touched it, we presented them in direct physical contact with a contamination or a non-contamination source, making the potential spread of contamination from the people’s hands to the objects more readily intelligible to participants. Using this new type of stimuli we expected to replicate the previous findings of enhanced retention to potential contaminated objects compared to non-contaminated objects. Furthermore, this study used real photographs of hands holding real objects affording higher ecological validity. As in our previous studies, everyone was asked to remember exactly the same items; what differed was whether the object had been in contact with a potential source of contamination or not.

4.4.1 Study 5a

Bodily secretions such as vomit serve as a reservoir of pathogens with just 1 ml of vomit from a sick person containing around 10^7 viral particles (Barker et al., 2001). People tend to experience disgust when witnessing others' vomiting or when there is vomit spread out (Curtis & Biran, 2001). In Study 5a, participants were presented with a set of objects being held either by dirty hands covered with a vomit-looking like substance described as belonging to sick people or by clean hands described as belonging to healthy people. As in the previous experiments, participants performed an immediate memory task in which they were asked to discriminate if the just presented object were touched by a sick or a healthy person. Participants then completed a distractor task followed by a final surprise free recall test for all of the presented objects. We expected to obtain better memory for objects when these were held by the “sick person” than by the “healthy person”.

4.4.1.1 Method

Participants. Forty-eight undergraduate psychology students (females = 25; 52.1%) from Purdue University (USA) took part in the experiment in exchange for course credits (M_{age} = 19.13, *SD* = 1.10; age range: 18-23 years old). Seven other participants were non-native English speakers and, thereby, were excluded from the sample. An additional seven participants were excluded for having reported expecting a recall test and trying to memorize the stimuli during the encoding phase for a latter memory task. Informed consent was obtained from all participants.

Materials. Twenty-four stimuli (plus six to be used in the practice trials) were selected from the Objects-on-Hands Picture Database. The stimuli included frontal-view pictures of each object being held by clean hands, by hands covered with a vomit-looking pasta sauce, and on its own (see Figure 11 for examples).

Figure 11.

Examples of stimuli used in Studies 5a and 5b: items being held by sick and healthy people (used in the presentation phase), and items on their own (used in the immediate memory test).

According to the American norms collected for the pictures of the objects being held by clean hands (see Chapter 3), the selected stimuli had high name agreement (%NA = 96.9%, *SD* = 4.65), and high degree of familiarity (*M* = 4.63, *SD* = 0.31; on a scale of 1-5). The images were arranged in two identical sets, with similar name agreement and familiarity, *t*s(22) < |1|. Four counterbalancing versions were created to ensure that each set appeared an equal number of times in its contaminated and non-contaminated version across participants. Each participant saw each stimulus in only one of the conditions.

Procedure. Up to four participants were tested in each session in individual workstations; the session lasted approximately 30 min. The procedure was similar to that used in the previous studies (i.e., an encoding task followed by a distractor and finally by a free recall task). Some adjustments were made in the encoding instructions considering that clean and dirty hands were now being presented rather than faces or descriptors. Instructions were as follow:

> *"In this task, you will be asked to remember items that have been touched by different people. Some of these people are sick with a highly contagious disease and have recently thrown up while handling the items, whereas others are healthy people with clean hands. Throughout the experiment, you will see pictures of items being held either by hands covered with vomit or by clean hands. You will need to decide whether the item was touched by a sick or a healthy person and then remember this information for a memory test. (…)"*

Pictures of objects being held by hands were presented centrally on the screen, one at a time, in sets of three. After each triad, the just three presented objects were again displayed on the screen (on their own, that is, without the hands) and participants had to indicate if the object had been touched by a "sick" or a "healthy" person. Participants were given 5 s to see the stimuli and 5 s to make a decision. This procedure was repeated 8 times for a total of 24 trials. The distractor task was as described in the previous studies (an even or odd discrimination task). Responses were now made by selecting the "E" or "O" keys in the keyboard, respectively. For the surprise final free recall task, participants were asked to recall the names of as many objects as they could during an 8 min period irrespective of the condition in which the object had been presented. Also, they were told that they could write down the items in any order they wished. Responses were written on a recall sheet provided by the researcher.

After the recall test, participants were asked whether they had anticipated a final memory test and/or had tried to memorize all the objects during the immediate memory task to a latter memory test. Participants then viewed all of the photographs that had been presented during the encoding part of the experiment (i.e., the objects being held either by the dirty or the clean hands) and rated how calm or excited each picture made them feel using a 9-point Likert-type scale, ranging from 1 (very calm, relaxed, sleepy, or some other similar feeling) and 9 (very excited, jittery, wide-awake, or some other similar feeling). After making these arousal ratings, participants completed the Pathogen Disgust Subscale of the Three Domain Disgust Scale (PDS; Tybur et al., 2009), the health status questionnaire, and some demographic questions (see Chapter 6). Participants were fully debriefed at the end of the experiment.

Experimental design and statistical analysis. Study 5a used a simple within-subject design. Paired-samples *t*-tests were conducted to test differences between conditions (i.e., sick vs. healthy; IV) on task performance (immediate memory and free recall; DVs), and on arousal ratings.

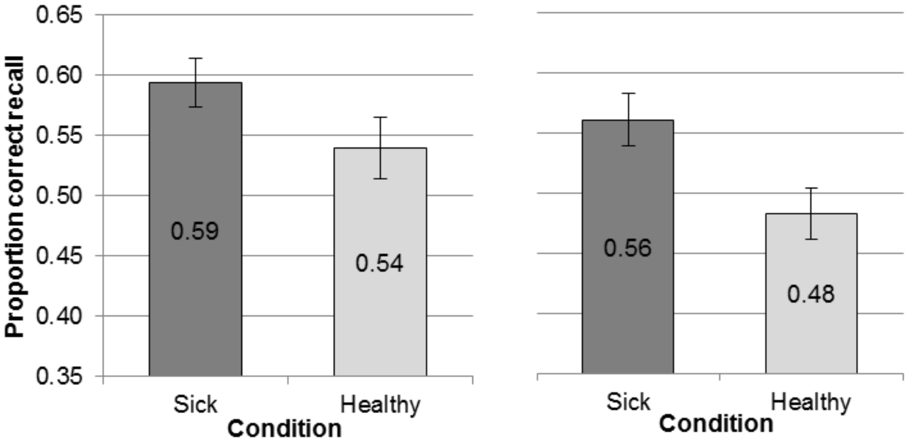
4.4.1.2 Results

Immediate memory. Performance in the immediate memory task was close to perfect with an average of 97% correct responses in both conditions (M_{sick} = .97, *SD* = .05; $M_{healhty}$ = .98, *SD* = .05), *t*(47) = -0.57, *p* = .569. This result suggests that participants were successful in associating the objects to the sick and the healthy conditions as intended. On average, participants took about 1 s to identify if the item had been touched by a sick or a healthy person, (M_{sick} = 1094 ms, *SD* = 342; $M_{healhty}$ = 1046 ms, *SD* = 388), *t*(47) = 1.04, *p* = .303.

Free recall. Participants remembered more of the items previously “touched” by sick people (i.e., those presented on dirty hands) compared to those previously touched by healthy people (i.e., those presented on clean hands; see Figure 12). However a paired-samples *t*-test revealed that this mnemonic advantage for the potentially contaminated items was only marginally significant at both the subject, *t*(47) = 1.82, *p* = .075, d_z = 0.263 (plus = 28; minus = 14; ties = 6), and item levels, *t*(23) = 1.74, *p* = .096, d_z = 0.355 (plus = 13; minus = 8; ties = 3).

Figure 12.

Mean proportion of correct free recall for each condition in Study 5a (on the left) and in Study 5b (on the right). Error bars represent SEM.



Arousal ratings. Images of objects held by the dirty hands were significantly more arousing than the images of objects held by clean hands (*M* = 4.83, *SD* = 2.01 and *M* = 2.74, *SD* = 1.28, respectively), *t*(47) = 5.90, *p* < .001, d_z = 0.851.

4.4.1.3 Interim discussion

Descriptively, the objects that have been potentially contaminated by a sick person were better remembered than those that carried a lower risk of contamination. This finding, though in the expected direction, was only marginally significant.

A possible explanation for our results is that the presented stimuli might have been too disgusting, inducing participants to attend away (i.e., withdrawing gaze) in an attempt to reduce the emotional reactivity typically elicited by stressful or threatening situations (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Thus, even in spite of the descriptive advantage for contamination in this procedure, it might have failed to reach statistical significance due a visual avoidance of the stimuli. Accordingly, some researchers have found that participants responded to disgust-inducing pictures with eye-gaze avoidance (e.g., Armstrong, McClenahan, Kittle, & Olatunji, 2014; Calvo & Lang, 2004). However, a close look at the arousal ratings provided by our participants at the end of the experiment, which might be used as a subjective measure of their emotional state, suggests that the images of objects held by the dirty hands were not considered as highly arousing (the obtained average rating was positioned on the middle of a 1-9 scale), even though they induced more arousal than the objects held by clean hands. This leads us to a second possible explanation. Studies have revealed enhanced allocation of attention to disgusting stimuli compared to neutral stimuli (e.g., van Hooff et al., 2013). Thus, it is possible that participants were mainly looking to the dirty hands and were not paying that much attention to the object itself. In this way, the processing of the object may have been, in some way, reduced. Even though attention could certainly be involved in these results, our procedure does not allow us to draw conclusions regarding this process. Further studies using oculometric measures (captured, for example, through eye-tracking devices), for example, are needed to clarify these hypotheses.

4.4.2 Study 5b

Study 5b was intended to be a replication of the previous study, but with a minor change in the encoding procedure aimed at ensuring that participants paid attention to the object. Thus, in the current experiment, the object was first presented on its own, and, only later, being held by hands, instead of being presented exclusively being held by hands at encoding.

4.4.2.1 Method

Participants. A sample of 48 undergraduate students (females = 17; 35.4%) enrolled in an introductory psychology course at Purdue University (USA), consented to participate in the experiment in return for course credits (M_{age} = 18.92, *SD* = 1.10; age-range: 18-22 years old). Data from an additional 11 non-native English speakers and 12 participants who, at the end of the experiment, reported that they expected a final recall test and, therefore, tried to memorize the stimuli, were excluded.

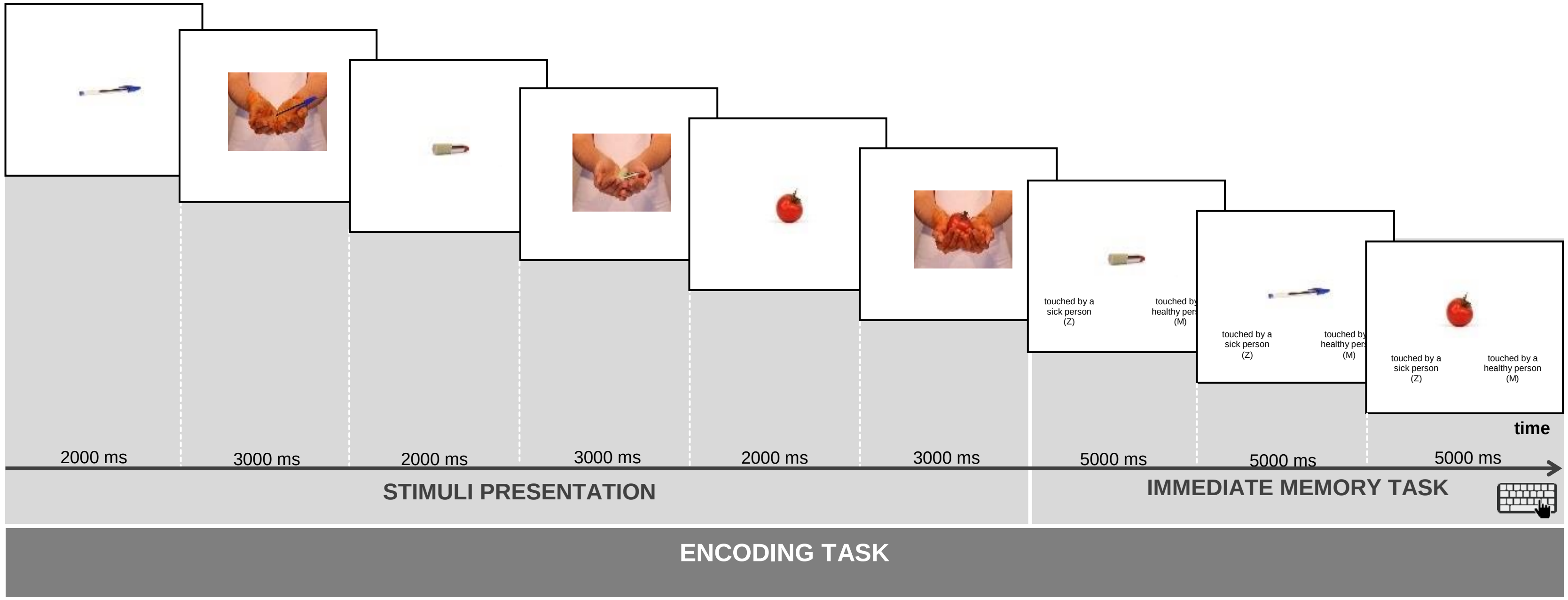
Materials. Materials were the same as those used in Study 5a.

Procedure. All aspects of the procedure from Study 5a were employed here with the exception of the stimuli presentation phase. In this experiment, each object was presented first on its own during 2 s and then being held by hands during 3 s (see Figure 13 for a schematic illustration of the new encoding procedure).

Experimental design and statistical analysis. The experimental design and the statistical analyses were the same as in Study 5a.

Figure 13.

Schematic representation of the encoding procedure used in Study 5b.



Note: This same procedure was adopted in Studies 6, 7a and 7b with some adjustments (which will be fully described in the procedure section of each study).

4.4.2.2 Results

Immediate memory. Participants performed at about 95% in both conditions (M_{sick} = .95, *SD* = .08; $M_{healhty}$ = .95, *SD* = .09), *t*(47) = 0.001, *p* > .99, suggesting an effective association of the object to its condition (sick/healthy). Approximately 1 s was spent by participants to identify if the item had been touched by a sick or a healthy person, (M_{sick} = 1048 ms, *SD* = 342; $M_{healhty}$ = 1056, *SD* = 341), *t*(47) = -0.19, *p* = .852.

Free recall. There was a significantly better memory performance for the items being held by sick people (i.e., dirty hands) than those being held by healthy people (i.e., clean hands; see Figure 12), at both the subject, *t*(47) = 2.91, *p* = .006, d_z = 0.419 (plus = 27; minus = 12; ties = 9), and item levels, *t*(23) = 2.88, *p* = .009, d_z = 0.587 (plus = 17; minus = 5; ties = 2).

Arousal ratings. At the end of the experiment, participants were significantly more aroused by images of objects held by dirty hands than when the same objects were held by clean hands (*M* = 5.35, *SD* = 1.72 and *M* = 2.46, *SD* = 1.31, respectively), *t*(47) = 8.03, *p* < .001, d_z = 1.159.

4.4.2.3 Interim discussion

The present data confirm, once again, our main hypothesis: potentially contaminated items are remembered particularly well compared to non-contaminated items. When participants were allowed to attend more closely to the objects and, only later, to analyze the nature/ degree of the contamination threat, the memory advantage to contamination reached significant levels. Therefore, it is possible that attentional processes were mediating the results obtained in Study 5a.

4.4.3 Study 6

The purpose of the study 6 was twofold. Firstly, we sought to replicate the findings of Study 5b using another vehicle of contamination: diarrhea. Feces are another potential source of infection (feces contain at least 20 known bacterial, viral, and protozoan pathogens that pose a high risk of infection; 1 g of feces contain an estimated 10^{12} viral particles) and strongly induce the emotion of disgust (Barker et al., 2001; Curtis & Biran, 2001). Speculating that the BIS must be adaptable to different sources of pathogens, we expected to replicate the results of the last-reported experiment.

The procedure of the previous experiment was followed here but, rather than presenting objects being held by hands covered with a sauce-looking vomit, they were presented on hands covered with a chocolate and peanut-butter spread that looked like diarrhea (dirty hands). Secondly, we wanted to explore memory for the exact same stimuli but when processed within a non-disease context; this allowed us to test whether the attribution of fitness-relevance is required to obtain the mnemonic effect for potentially contaminated items (i.e., those being held by dirty hands, similarly to Study 3b). Towards that end, two groups of participants took part in this experiment. Importantly, for one of the groups, the dirty hands were described as covered with chocolate spread (non-disease context) and for the other group they were described as being covered with diarrhea (disease context). Thus, memory for the same objects being held by the same hands was tested, but the context (disease vs. non-disease) in which they were described varied.

4.4.3.1 Method

Participants. Eighty undergraduate psychology students[13] (females = 34; 42.5%) from Purdue University (USA) took part in the experiment in exchange for course credits (M_{age} = 19.60, *SD* = 1.31; age range: 18-23 years old). Half of the participants (*n* = 40) were assigned to the disease context and the other half to the non-disease context. A further 32 participants were excluded for the following reasons: being non-native English speakers (*n* = 18), not indicating their nationality (*n* = 1), expecting the final recall test and trying to memorize the stimuli (*n* = 9), being underage (*n* = 1), or having low immediate memory performance (< 60% correct, *n* = 3). Written informed consent was granted by all participants.

Materials. A total of 24 images were selected from the Objects-on-Hands Picture Database to be used in the experiment (see Chapter 3). Photographs of an additional six objects were used in practice trials. All pictures selected had high name agreement (%NA = 97.9%, *SD* = 5.48) and familiarity scores (*M* = 4.76, *SD* = 0.19; on a scale of 1-5) according to the American norms for the objects being held by clean hands (see Chapter 3). The stimuli were comprised of frontal-view pictures of each object being held by clean hands, by hands covered with a mixture of chocolate spread and peanut butter, and on its own (see Figure 14 for examples).

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[13] Running of this experiment occurred at the end of the period spent at Purdue University which also coincided with the end of the academic semester. Therefore, we were unable to run the 48 participants initially intended in each group.

Two lists of stimuli were created, one to be assigned to the clean condition and the other to the dirty condition; this assignment was counterbalanced across participants. The order of stimuli presentation was also counterbalanced across participants, yielding four counterbalancing versions for each context (i.e., disease and non-disease contexts). Thus, each object was only presented once to a given participant, either being held by the dirty or the clean hands.

Figure 14.

Examples of stimuli used in Study 6: items being held by dirty and clean hands (used in the presentation phase), and items on their own (used in the immediate memory test).

Note: The dirty hands were described as covered with chocolate spread (non-disease context) or as covered with diarrhea (disease context).

Procedure. The procedure used in this experiment was analogous to that described in Study 5b, including the presentation time, but with some adjustments. On arrival at the laboratory, participants were randomly assigned to one of two contexts: a disease (i.e., diarrhea vs. clean) or a non-disease (i.e., chocolate vs. clean) context. The specific instructions for each context were as follows:

Initial encoding instructions common to the two groups: *“In this experiment, you will be asked to remember items that have been touched by different people. First you will see a description of each person. Then, items on hands will be presented one at a time, in sets of three. After each set of three, the items will appear again and you will be asked to remember who touched it.”*

Disease Context: *Zonia has a highly contagious gastrointestinal infection and is having severe and frequent episodes of diarrhea. Sometimes she cannot reach the toilet on time and gets diarrhea on her hands while handling objects. Marin has a newborn child and is having to stay at home to take care of him. Sometimes she cannot help but worry about her child’s safety and is careful to have clean hands while handling objects.*
Throughout the experiment, you will see pictures of items being held either by Zonia, whose hands are covered with diarrhea, or by Marin, whose hands are clean. You will need to decide whether the item was touched by Zonia or Marin and then remember this information for a memory test.

Non-Disease Context: *Zonia bought lots of groceries and is having to make cakes and organize the house for a birthday party. Sometimes she cannot find time to clean her hands and has chocolate spread on them while handling objects. Marin has a newborn child and is having to stay at home to take care of him. Sometimes she cannot help but worry about her child’s safety and is careful to have clean hands while handling objects.*
Throughout the experiment, you will see pictures of items being held either by Zonia, whose hands are covered with chocolate spread, or by Marin, whose hands are clean. You will need to decide whether the item was touched by Zonia or Marin and then remember this information for a memory test.

Final encoding instructions common to the two groups: *If the person who touched the item was Zonia, press the "Z" key at that time. If the person was Marin, press the "M" key. The hands will not be presented at the moment you have to make this decision, so you will need to remember who touched and manipulated each of the items. After you have entered your responses for each item, a new set of three items will be presented and this sequence of tasks will be repeated.”*

As in our previous studies, participants completed an encoding phase consisting of the presentation of the stimuli and the immediate memory test, a distractor task, and finally a free recall task for the objects, in which they were asked to write down the objects they recalled on a recall sheet. After the completion of the recall task, participants indicated whether they had anticipated the final memory test and/or had tried to memorize the objects. Next, participants responded to some question using a 9-point Likert-type scale. Specifically, they were asked to rate: (1) how calm or excited the items touched by each person made them feel (1-very calm, relaxed, sleepy, 9-very excited, jittery, wide-awake), (2) how disgusted the items touched by each person made them feel (1-not at all disgusted, 9-extremely disgusted), and (3) how likely would someone be to get sick if s/he touch or interact with items previously touched by each person (1-extremely unlikely, 9-extremely likely). Finally, participants provided responses to the PDS, the health status questionnaire, and some demographic questions (see Chapter 6). The experiment ended with the debriefing.

Experimental design and statistical analysis. Given that a mixed design was used, with encoding context (i.e., disease context vs. non-disease context) manipulated between subjects and type of hands (i.e., dirty vs. clean) as a within-subject variable, two-way mixed ANOVAs were carried out. Paired-samples *t*-tests were also conducted separately for each context, irrespectively of the statistical significance of the interaction effect because we expected a priori a mnemonic advantage in the disease context but not in the non-disease context (based on the results of Studies 3a and 3b).

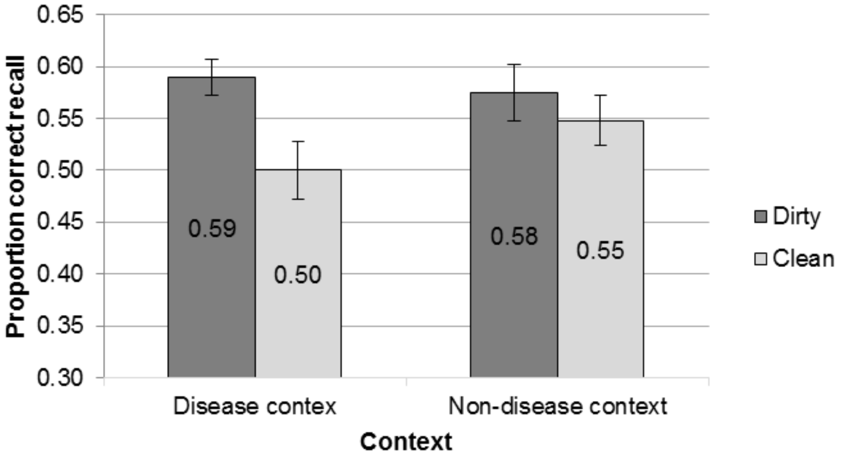
4.4.3.2 Results

Immediate memory. Participants performed close to perfect in the immediate memory task, with no main effect of type of hands, $F(1, 78) = 2.50$, $MSE = 0.003$, $p = .118$, no main effect of context nor interaction between variables, both $Fs(1, 78) < 1$ (Disease context: $M_{dirty} = .98$, $SD = .04$; $M_{clean} = .96$, $SD = .06$; Non-disease context: $M_{dirty} = .98$, $SD = .04$; $M_{clean} = .97$, $SD = .04$). Participants were fast (less than 2 s) at identifying the person who touched each item. Again, none of the main effects nor the interaction approached significance, $F(1, 78) = 1.37$, $MSE = 207164.773$, $p = .245$ for the main effect of context, remaining $Fs(1, 78) < 1$ (Disease context: $M_{dirty} = 966$ ms, $SD = 288$; $M_{clean} = 958$ ms, $SD = 316$; Non-disease context: $M_{dirty} = 1046$ ms, $SD = 321$; $M_{clean} = 1022$ ms, $SD = 302$).

Free recall. A mixed ANOVA revealed a significant main effect of type of hands, $F(1, 78) = 8.18$, $MSE = 0.136$, $p = .005$, $\eta_p^2 = .095$, denoting a better memory for items held by dirty hands than those held by clean hands. Neither the main effect of context, $F(1, 78) < 1$, nor the interaction between the two variables was statistically significant, $F(1, 78) = 2.35$, $MSE = 0.039$, $p = .129$. Analyses were conducted separately for each context as we expected different patterns in each context. Paired-comparisons revealed a significant mnemonic advantage for the dirty objects in the disease but not in the non-disease context. That is, in the disease context, participants remembered more of the items previously touched by sick people (i.e., those presented on hands described as being covered with diarrhea) compared to those previously touched by healthy people (i.e., those presented on clean hands). This effect was obtained in both the subject and item analyses, $t(39) = 3.25$, $p = .002$, $d_z = 0.514$ (plus = 22; minus = 9; ties = 9), and $t(23) = 2.46$, $p = .022$, $d_z = 0.501$ (plus = 15; minus = 9; ties = 0), respectively. On the other hand, in the non-disease context, the percentage of remembered objects previously touched by people with hands covered with chocolate spread was not significantly different from that obtained when objects were touched by people with clean hands (see Figure 15), at both the subject and item levels, $t(39) = 0.90$, p = .373 (plus = 18; minus = 12; ties = 10) and $t(23) = 0.81$, $p = .425$ (plus = 12; minus = 7; ties = 5), respectively.

Figure 15.

Mean proportion of correct free recall for each condition by participants assigned to the disease and the non-disease context in Study 6. Error bars represent SEM.



Ratings. Participants subjectively rated themselves as feeling significantly more aroused by pictures of objects held by dirty hands than by pictures of objects held by clean hands, irrespectively of the context. Dirty hands were also reported as significantly more disgusting than the clean hands, particularly when described as diarrhea in the disease context. People believed that an interaction with items previously touched by dirty hands would more likely result in illness than an interaction with items touched by clean hands. Again, this was especially strong in the disease context (see Table 11 for the descriptive data and accompanying statistical results).

Table 11.

Mean ratings (and standard deviations) of arousal, disgust and likelihood of becoming sick obtained for each context and each type of hand in Study 6.

	Disease context		**Non-disease context**		
	Dirty	Clean	Dirty	Clean	**Statistics**
AROUSAL	5.05 (1.63)	3.60 (1.79)	4.75 (1.78)	3.68 (1.87)	**ME hands:** *F*(1, 78) = 19.71, *MSE* = 63.756, η_p^2 = .202 *** **ME context:** *F*(1, 78) < 1 **Interact:** *F*(1, 78) < 1
DISGUST	6.58 (2.23)	1.43 (0.98)	5.00 (2.41)	1.43 (1.08)	**ME hands:** *F*(1, 78) = 244.92, *MSE* = 761.256, η_p^2 = .758 *** **ME context:** *F*(1, 78) = 7.42, *MSE* = 24.806, η_p^2 = .087 ** **Interact:** *F*(1, 78) = 7.98, *MSE* = 24.806, η_p^2 = .093 ** Disease Context: *t*(39) = 14.00, d_z = 2.214*** Non-disease Context: *t*(39) = 8.53, d_z = 1.348***
DISEASE	7.93 (1.53)	2.88 (2.00)	5.10 (1.84)	2.83 (1.60)	**ME hands:** *F*(1, 78) = 186.89, *MSE* = 536.556, η_p^2 = .706 *** **ME context:** *F*(1, 78) = 25.32, *MSE* = 82.656, η_p^2 = .245 *** **Interact:** *F*(1, 78) = 26.82, *MSE* = 77.006, η_p^2 = .256 *** Disease Context: *t*(39) = 13.21, d_z = 2.089*** Non-disease Context: *t*(39) = 6.06, d_z = 0.956***

Note: ME hands: Main effect of type of hands (clean, dirty); ME context: Main effect of context (disease, non-disease); Interact: interaction between variables; ** $p < .01$; *** $p < .001$

4.4.3.3 Interim discussion

In this study, participants were required to remember exactly the same objects being held by exactly the same hands; what differed was the fitness-relevancy of the context in which they were described: Whereas in the disease context they were considered potential vehicles of pathogens, in the non-disease context, no risk of contamination by pathogens exists.

As expected, individuals assigned to the disease context recalled significantly more contaminated (i.e., dirty hands) than non-contaminated items (i.e., clean hands), whereas no difference between conditions (dirty vs. clean hands) was found in the non-disease context. Taking a closer look at the results it is noteworthy, however, that participants' memory for items on dirty hands did not differ significantly as a function of the context, *t*(78) = 0.45, p = .657. This could be an evolved response of the BIS which follows the ‘smoke detector principle’. The failure to detect a real threat (a false-negative error) usually has consequences that are far more costly than the misinterpretation of an innocuous stimulus as noxious (a false-positive error). Living in a group implies interacting frequently with others, resulting in higher exposure to certain pathogens; thus, people must flexibly adjust signal-detection thresholds to ensure risky disease-threats do not go unnoticed (Kurzban & Leary, 2001; Park et al., 2003). It is possible, though, that participants assumed that there was some degree of contamination afforded by the hands covered with chocolate spread. This assumption was somehow confirmed by the data obtained when participants were asked to estimate the likelihood of someone getting sick in case of a future interaction with items touched by each type of hands. Even though items held by hands with diarrhea were clearly assessed as being more likely to contaminate other people, there was still a relatively higher probability of items held by hands covered with chocolate to contaminate people compared with those held by clean hands. Additionally, participants could be disgusted by the behavior of handling objects without washing the hands (adopted by the person with hands covered with chocolate spread), which failed to conform to conventional norms of health and practices of hygiene. Historically, adherence to cultural norms was likely to be an efficient way to prevent the spread of infectious diseases (Murray & Schaller, 2012). Accordingly, items held by hands covered with chocolate induced significantly more disgust compared to when the same objects were held by clean hands.

Likewise, participants may be behaving consistently with the *law of similarity.* According to this law of sympathetic magic, a harmless stimulus resembling something disgusting can acquire the infectious threat value of the disgusting stimulus, summed up by the idea that “appearance is reality” (for example, if it looks like feces, it must share some of the disgusting properties of feces). This was illustrated in a well-known study wherein people showed reluctance to try a piece of chocolate when it was shaped in the form of dog feces (Rozin et al., 1986).

4.4.4 Study 7a

Just as smoke detectors occasionally misrepresent harmless situations as dangerous ones (Nesse, 2005), the BIS has been argued by some researchers to be “prone to activation even in cases where pathogen threats are absent” (Ackerman et al., 2018, p. 2). Study 7a aimed to test such bias to overperceive or overgeneralize cues of contamination. Specifically, this study explored whether the mnemonic tuning holds when the stimuli only resemble real pathogen-threats (but pose no real threat) as compared to when they indeed represent such threat (e.g., objects held by hands covered with chocolate spread vs. covered with diarrhea, respectively). Each participant saw pictures of objects being held by hands covered with two substances. One of those substances was described as a potential source of contamination (i.e., diarrhea or vomit) and the other as a non-source of contamination (i.e., chocolate spread or pasta sauce). Even though the hands were exactly the same, across participants, they were equally described as posing a real contamination threat or not. Thus, all stimuli were now held by dirty hands but for half of the stimuli these hands were described in a contamination context and the other half in a non-contamination context.

4.4.4.1 Method

Participants. Sixty-four female participants from University of Aveiro (Portugal) consented to participate in the study (M_{age} = 21.50, *SD* = 3.32; age range: 18-35 years old). For half of the sample (*n* = 32) the hands were described as covered with vomit and chocolate spread (context 1); for the second half of the sample the same hands were described as covered with pasta sauce and diarrhea (context 2), respectively. Eighteen additional participants were excluded from analysis because they anticipated being asked to recall all the objects and tried to memorize them during the encoding phase for a latter memory test (*n* = 13), or because they showed very low performance in the immediate memory test (< 60% correct, *n* = 5). As a compensation for their participation, participants became eligible for a 5 euros gift card (50% chance).

Materials. Twenty-four frontal-view pictures of everyday objects (plus six to be used in the practice trials) from the Objects-on-Hands Picture Database (see Chapter 3) were used. The selected objects had high name agreement (%NA = 99.3%, *SD* = 1.06) and familiarity scores (*M* = 4.83, *SD* = 0.13; on a scale of 1-5) according to the Portuguese norms collected for the stimuli held by clean hands (see Chapter 3). The stimuli encompassed objects being held by hands covered with a mixture of chocolate spread and peanut butter, being held by hands covered with pasta sauce, and on their own. Each participant saw each stimulus in only one of the dirty hands condition.

Procedure. Participants were tested individually in groups of one to six students per session, which took roughly 20 min to complete. The procedure followed was, again, very similar to the ones described above (i.e., an encoding task followed by a distractor and finally by a free recall task). Participants were randomly assigned to one of the two ways stimuli were described (i.e., context 1: vomit vs. chocolate spread; or context 2: pasta sauce vs. diarrhea). The specific instructions for each context were as follow:

> ***Initial encoding instructions common to the two groups:*** *“In this experiment, you will be asked to remember items that have been touched by different people. First you will see a description of each person. Then, items on hands will be presented one at a time, in sets of three. After each set of three, the items will appear again and you will be asked to remember who touched it.”*
>
> **Context 1:** *Drusila has a highly contagious gastrointestinal infection and is having severe and frequent episodes of vomiting. Sometimes she cannot contain the vomit in and throws up while handling objects. Leonisa bought lots of groceries and needs to bake cakes and organize the house for a birthday party. Sometimes she cannot find time to clean her hands and has chocolate spread on them while handling objects.*
> *Throughout the experiment, you will see pictures of items being held either by Drusila, whose hands were covered with vomit, or by Leonisa, whose hands were covered with chocolate spread. You will need to decide whether the item was touched by Drusila or Leonisa and then remember this information (…)”*
>
> **Context 2:** *Drusila bought lots of groceries and is having to organize them in her pantry at home. Sometimes she cannot reach the top shelf and breaks jars of pasta sauce while handling objects. Leonisa has a highly contagious gastrointestinal infection and is having severe and frequent episodes of diarrhea. Sometimes she cannot reach the toilet on time and gets diarrhea on her hands while handling objects.*
> *Throughout the experiment, you will see pictures of items being held either by Drusila, whose hands were covered with pasta sauce, or by Leonisa, whose hands were covered with diarrhea. You will need to decide whether the item was touched by Drusila or Leonisa and then remember this information (…)”*

Similar to the previous studies, participants completed an encoding phase consisting of the presentation of the stimuli and the immediate memory test, in which they had to decide whether each object was a potential contaminant or not (5 s each phase). An even or odd discrimination task served again as a distractor task. Finally, a free recall task was conducted in which participants wrote down, on a lined piece of paper, as many objects as possible from the encoding phase, irrespective of the condition in which the object had been presented. Participants had 8 min to complete the recall task. The experiment ended with a debriefing.

Experimental design and statistical analysis. Study 7a used a simple within-subject design. To examine differences between conditions (i.e., sick vs. healthy; IV) on task performance (immediate memory and free recall; DVs), paired-samples *t*-tests were conducted.

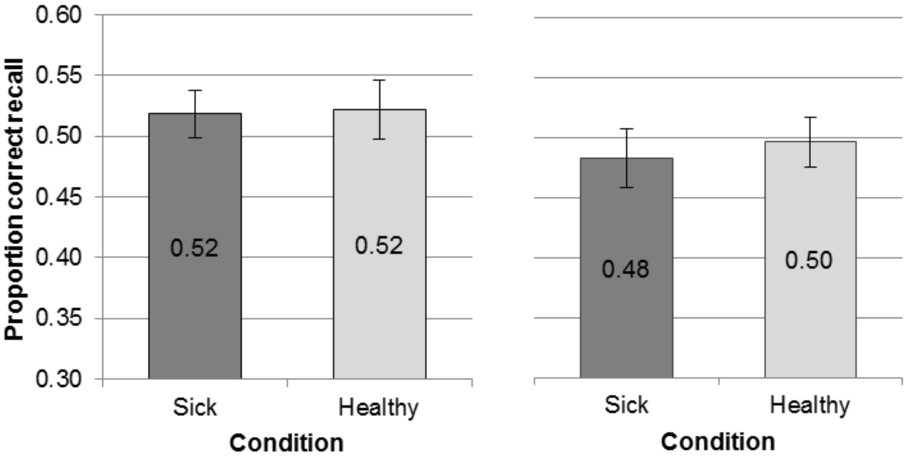
4.4.4.2 Results

Immediate memory. Performance was at about 92% with no differences between conditions (M_{sick} = .92, *SD* = .09; $M_{healhty}$ = .92, *SD* = .10), *t*(63) = 0.78 *p* = .439. Participants made their decisions in approximately 1 s (M_{sick} = 1100 ms, *SD* = 372; $M_{healhty}$ = 1136, *SD* = 380), *t*(63) = -0.87, *p* = .390.

Free recall. Participants remembered about the same percentage of objects being held by sick people and objects being held by healthy people[14] (see Figure 16), at both the subject, *t*(63) = -0.18, *p* = .855 (plus = 26; minus = 24; ties = 14), and item levels, *t*(23) = -0.19, *p* = .849 (plus = 12; minus = 10; ties = 2).

Figure 16.

Mean proportion of correct free recall for each condition in Study 7a (on the left) and in Study 7b (on the right). Error bars represent SEM.



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[14] Because the norming results of Study 2 (see Chapter 3) suggested that the different presentation conditions of our stimuli can induce different emotional states (i.e., images from the chocolate condition were considered the most arousing, disgusting, and negatively valenced, followed by the sauce condition), we conducted a mixed ANOVA, with encoding context (i.e., context 1 vs. context 2) entered as a between-subjects variable and condition (i.e., sick vs. healthy) as a within-subject variable. None of the main effects, nor their interaction, were significant [*effect of condition: F*(1, 62) < 1; *effect of context: F*(1, 62) = 3.53, *MSE* = 0.164, *p* = .065; *interaction: F*(1, 62) = 2.79, *MSE* = 0.040, *p* = .100].

4.4.4.3 Interim discussion

The contamination effect was not found when participants were shown objects held by hands covered with two substances. Given the fact that infectious diseases have been acting as one of the most important selective pressures shaping the evolution of organisms, there is an overperception bias to cues that connote the threat of disease (Haselton et al., 2015). Thus, the two substances were possibly associated with a disease threat, despite knowledge that one of the substances was not a carrier of pathogens. Consequently, objects being held by hands covered with noninfectious substances (e.g., pasta sauce, which looks like a real pathogen-threat even though it is being described as not representing one) and infectious substances (e.g., vomit) might become equally memorable. In this way, people are steered away from the costs that might arise from failing to detect a real pathogen threat.

It might also be the case that memory performance was influenced by task difficulty. Whereas in previous studies participants had to discriminate between a contamination and a non-contamination source which were easily distinguishable from each other (e.g., a sick and a healthy face, a dirty and a clean hand), in Study 7a participants had to distinguish between two dirty-hands stimuli. This task was possibly more demanding, requiring a higher discrimination effort. In fact, an eye inspection of the performance during encoding suggested that, compared to the previous studies, participants took a little longer to decide if the item had been touched by a sick or a healthy person and were also slightly less accurate in their judgments.

4.4.5 Study 7b

Study 7b was designed to replicate the previous study, but with a slight modification of the cues used to signal the potential of contamination. To facilitate the discrimination task, we increase the number of cues participants could use to classify the objects as “contaminated” or “non-contaminated”. Participants were presented with both a picture of the hands and a picture of the face of the person who touched the object. The hands were covered with two substances (similar to Study 7a). In the initial instructions, one of the faces was described as depicting a sick person and the other as depicting a healthy person, even though none of the faces contained signals of sickness. Thus, either the face or the substance could serve as cues of contamination status. Similar to the previous study, even though the cues (face + substance) were exactly the same, they were described as posing a real contamination threat or not.

4.4.5.1 Method

Participants. Forty-eight students (females = 30; 62.5%) from University of Aveiro (Portugal) participated in the study (M_{age} = 20.10, *SD* = 4.76; age range: 18-39 years old; one participant did not provide information about his/her age). Half of the sample (*n* = 24) was randomly assigned to the context 1; the remaining half was assigned to the context 2. Three additional participants were excluded from analysis because they expected a recall test and tried to memorize the stimuli for a latter memory test. Some participants were randomly rewarded with a Power Bank battery. All participants were offered a candy as a token of appreciation. Written informed consent was obtained from all participants.

Materials.

Objects. Objects stimuli were the same as those used in Study 7a: objects being held by hands covered with a mixture of chocolate spread and peanut butter, objects being held by hands covered with pasta sauce and the objects on their own.

Faces. Two frontal-view colored young adult female facial photographs, displaying direct eye gaze and a neutral facial expression, were selected from RaFD (Langner et al., 2010). The two faces are moderately attractive (*M* = 4.75, *SD* = 0.01; on a scale of 1-7) according to the Portuguese norms from Pandeirada, Fernandes, and Vasconcelos (Under revision). These two faces were described as corresponding to a sick and a healthy person in a contrabalanced manner.

Stimulus. Each stimulus contained an object picture and a face.

Procedure. After being informed about the nature of the study and providing consent to participate, participants completed the experiment using individual computers. Each session included up to 6 participants and lasted approximately 20 minutes. The procedure was analogous to the one employed in Study 7a, except that, in addition to the two dirty hands, participants were also presented with faces (see Figure 17 for a schematic illustration of the encoding procedure). Participants were randomly assigned to one of the two ways stimuli were described (i.e., context 1: vomit vs. chocolate spread; or context 2: pasta sauce vs. diarrhea). Slight modifications in the instructions were also made. Next, we present the specific instructions for each context:

> ***Context 1:*** *In the center of the screen images of objects that have been touched by two different people will be presented. One of these people is SICK with a highly contagious gastrointestinal infection and is having severe and frequent episodes of vomiting. Sometimes she cannot contain the vomit and throws up while handling objects. The other person is HEALTHY and has been preparing desserts for a party, which included topping cakes with chocolate spread. This task delayed her and so she had to arrange some objects scattered around the house in a hurry while still having chocolate spread in her hands. Throughout the experiment, you will see pictures of items being held either by hands covered with vomit or by hands covered with chocolate spread, along with the photo of the person who handled the item. You will need to decide whether the item was touched by a sick or a healthy person and then remember this information (…)"*
>
> ***Context 2:*** *In the center of the screen will appear images of objects that have been touched by two different people will be presented. One of these people is SICK with a highly contagious gastrointestinal infection and is having severe and frequent episodes of diarrhea. Sometimes she cannot reach the toilet on time and gets diarrhea on her hands while handling objects. The other person is HEALTHY and has been organizing grocery products in her pantry at home. However, he accidentally spilled pasta sauce from a half-open jar while handling other objects. Throughout the experiment, you will see pictures of items being held either by hands covered with diarrhea or by hands covered with pasta sauce, along with the photo of the person who handled the item. You will need to decide whether the item was touched by a sick or a healthy person and then remember this information (…)"*

In the presentation phase, each object picture was presented individually in the center of the screen, with the face displayed above. Thus, two cues (faces + substance) were used to inform participants if the objects were contaminated or not.

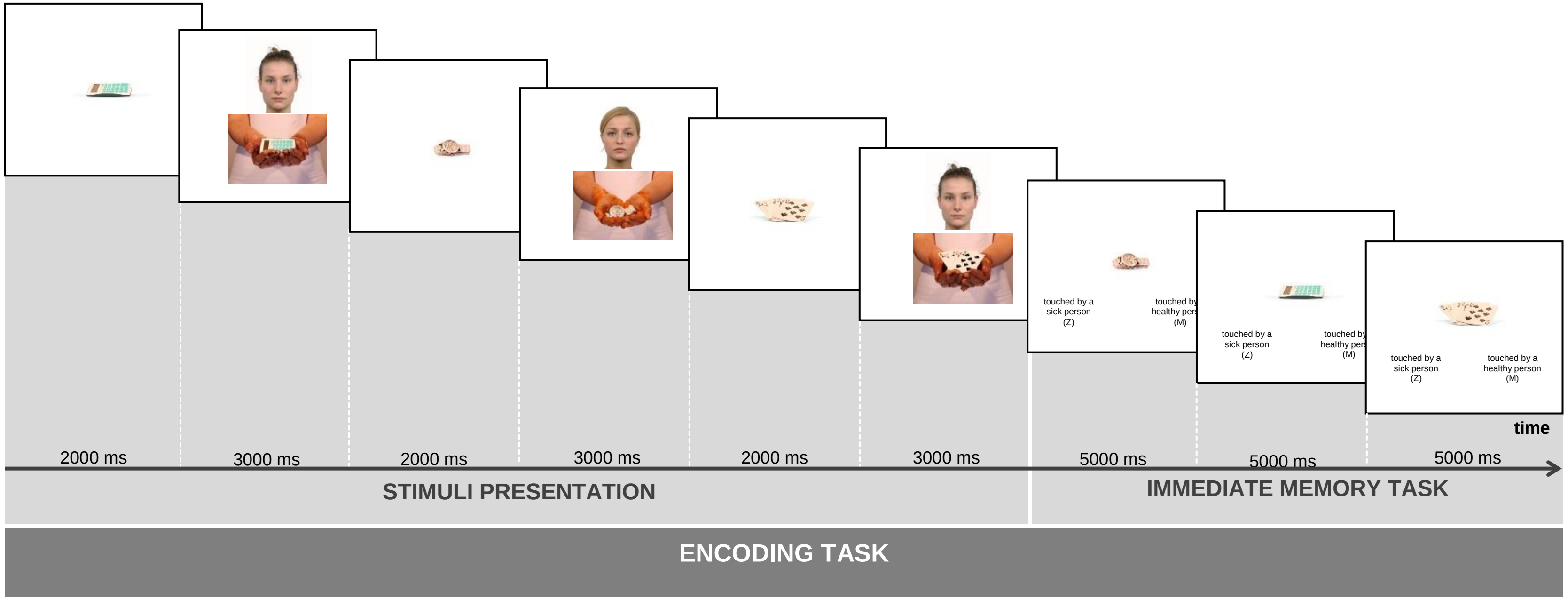
Experimental design and statistical analysis. The experimental design and the statistical analyses were the same as in Study 7a.

4.4.5.2 Results

Immediate memory. Performance was close to ceiling at the immediate memory test and did not significantly differ between conditions (M_{sick} = .95, *SD* = .08; $M_{healhty}$ = .95, *SD* = .07), *t*(47) = 0.27 *p* = .792. Participants made their decisions in approximately 1 s (M_{sick} = 1152 ms, *SD* = 283; $M_{healhty}$ = 1143, *SD* = 342), *t*(47) = 0.24, *p* = .811.

Figure 17.

Schematic representation of the encoding procedure used in Study 7b.



Free recall. Participants remembered about the same percentage of objects being held by sick people and objects being held by healthy people (see Figure 16), at both the subject, *t*(47) = -0.45, *p* = .653 (plus = 18; minus = 21; ties = 9), and item levels, *t*(23) = -0.48, *p* = .635 (plus = 10; minus = 14; ties = 0).

4.4.5.3 Interim discussion

The results obtained in the previous study were replicated: that is, when participants were told that objects were touched by dirty hands (covered with either a contagious or a noncontagious – but still disgusting – substance), the mnemonic performance did not differ between the two conditions.

4.4.6 Discussion of studies using dirty hands as cues of disease threat

Studies 5-6 found some evidence of a mnemonic tuning for contamination using photographs of objects in direct physical contact with a contamination or a non-contamination source (dirty and clean hands, respectively). Although the stimuli used were more ecologically valid, it also seems to introduce some complexity. As a result, the effect obtained in Study 5a was not as pronounced as expected (only marginally significant). We could ponder that participants needed to allocate more time and attentional resources to fully assess the potential health threat implied by the hands. Were participants focusing mostly on the hands and ignoring the object? In fact, when they were given the opportunity to process the object individually previously to the presentation of the source of contamination (Study 5b), the retention pattern was as expected, that is, participants remembered significantly more objects touched by sick people than when the same objects were touched by healthy people. Such results suggest that attentional resources might be involved and need further exploration.

Similar to what was found in Study 3a and 3b, the results from Study 6 suggested that the contamination mnemonic effect depends on fitness attribution: There was a memory advantage for objects potentially contaminated with diarrhea compared to non-contaminated items (disease context); however, when dirty hands were framed in a non-disease context (that is, when they were described as covered with chocolate spread instead of diarrhea), the mnemonic advantage no longer occurred.

Nevertheless, when only dirty hands were presented as stimuli during the experiment, and participants were somehow primed to a potential for contamination, memory performance for the objects did not differ as a function of the context provided (disease vs. non-disease). In fact, and in accordance with studies that suggest that the

BIS might be activated in the absence of a pathogen threat, Study 7a and 7b found no differences on memory performance for objects presented on hands either covered with a substance representing a contamination threat or covered with an innocuous substance resembling (but not posing) a real pathogen-threat. Therefore, adaptively, our memory seems to be calibrated to react to potential contaminants even when they might not be real ('smoke detector principle').

THE MNEMONIC VALUE OF CONTAMINATION IN A GENERATION PARADIGM

4.5 Exploring self-generated situations of contamination potential

New techniques and methods are essential to attain a better understanding of the mnemonic consequences of contamination and to help establish the robustness and generality of the effect. In our previous studies, participants were presented with a unique scenario of contamination: objects became contaminated due to previous contact with sick people. In the next studies, participants were free to elaborate their own contamination scenarios, as varied and complex as they were capable of elaborating. We raised the question of whether or not neutral objects for which participants generated situations in which the objects may threaten their health would yield enhanced retention as well when compared to alternative non-contamination conditions. This novel paradigm has been recently introduced by our research team to explore survival processing (see Nairne, Coverdale, & Pandeirada, 2019).

The generation of situations is likely to activate elaborative processing and a deeper-level of organization of information in memory, wherein people link the to-be-remembered items to other information in memory (e.g., Craik & Tulving, 1975). This should result in a larger number of retrieval cues available for retrieving the target stimuli. We expected that objects for which people generate contamination situations would be better remembered than when the same objects were processed in other highly effective encoding conditions. In the next studies, the to-be-remembered stimuli were words instead of object pictures.

4.5.1 Study 8

In Study 8 participants were required to consider how a series of objects could be relevant to their health and to generate a contamination situation in which each object could contribute to or prevent them from getting sick (contamination condition). This condition was compared to a standard deep processing control, largely known to yield enhanced retention: participants were asked to rate the pleasantness of objects (pleasantness condition). Memory performance in both tasks was then compared. We expected to replicate previous findings of enhanced retention in the contamination condition compared to the pleasantness condition. The data for this study were collected from volunteers who responded to the task on an online task.

4.5.1.1 Method

Participants. Forty-eight participants from several Portuguese universities (females = 39; 81.3%) took part in the study (M_{age} = 38.48, *SD* = 13.20; age range: 19-66 years old). All subjects participated voluntarily in response to an invitation sent by email. The data from 149 additional participants were not included in the analysis because they dropped out of the study before completing the task (*n* = 146), provided more than 25% of invalid responses (*n* = 2) or reported that they had not provided accurate answers and, thus, we should not keep their data (*n* = 1). Informed consent was given prior to the experiment in all cases.

Materials. Twenty-four words (plus three practice words) with very high familiarity (*M* = 1.53, *SD* = 0.34; scale 1-very familiar to 5-nothing familiar), according to Portuguese norms from Marques (2004), and high concreteness and imageability (*M* = 6.59, *SD* = 0.15 and *M* = 6.11, *SD* = 0.31, respectively; scale 1-low to 7-high), according to Portuguese norms from Soares, Costa, Machado, Comesaña, and Oliveira (2017), were used as stimuli. Words were divided into four sets of six words, to be presented in four different blocks (two per condition; see procedure below); these sets of words did not differ in the aforementioned variables (all *Fs*(3,20) < 1). Presentation of words within each block was randomly determined for each participant.

Procedure. The experiment was administered electronically via the World Wide Web, using the Qualtrics survey software (Qualtrics Labs Inc., Provo, UT). An invitation email was sent to Portuguese public and private universities, describing the study and providing an electronic link that gave access to the experiment.

On the opening page of the experiment participants were provided information on confidentiality, freedom to participate and the right to withdraw from the study at any point. After consenting to participate, participants were given the initial instructions. If no consent was provided, participants were thanked and the program ended.

Four different blocks of nouns of objects were presented in an alternated manner, two assigned to the generation of contamination situations (C) and the other two to the pleasantness ratings (P). Order of the blocks was counterbalanced across participants such that half received the blocks in the order CPCP and the other half in the order PCPC, ensuring that each word was evaluated under both conditions an equal number of times.

In the contamination blocks, participants were asked to consider how each of the presented objects could be relevant to their health, and then to describe a contamination situation in which each object may contribute to or prevent them from getting sick. Examples were provided to make the task clearer. Specific instructions were as follow:

> *"We are going to show you a series of object names. We would like you to consider how each object could be relevant to your health – that is, we want you to think of a contamination situation in which each object could contribute to or prevent you from getting sick. For example, if the following objects are presented to you, you can think of situations like the ones described below:*
>
> *Pen: "Someone with flu sneezed on my pen."*
> *Keys: "I accidentally dropped my keys on a dirty public toilet."*
> *Lipstick: "I avoid sharing my lipstick with other people."*
> *Sandals: "I use sandals in the gym shower to prevent contracting a fungal infection."*
>
> *Keep in mind that several infectious diseases are spread through contact with objects contaminated by pathogens. In our daily life we are in constant contact with these contaminated objects, which can dramatically harm our health and compromise our survival. Please try to imagine yourself in a situation where you are interacting directly with each object, and describe how this situation could contribute to or prevent you from getting sick."*

Participants were free to generate a situation for as long as necessary. Responses were typed directly on the computer. After answering, participants could move on to next item by pressing the "Next" button.

In the pleasantness blocks, participants were required to rate the pleasantness of the presented objects using a 5-points Likert scale that ranged from "totally unpleasant" (score of 1) to "extremely pleasant" (score of 5). Participants had 5 s to make the pleasantness rating of each word. The program automatically proceeded to the next word after 5 s had elapsed. Instructions were as follow:

> *"We would like you to rate the pleasantness of each object. Some of the objects may be pleasant, others may not – it's up to you to decide. The scale will range from "totally unpleasant" to "extremely pleasant". Make your decision by clicking on the option that you wish to select. Please try to use the whole scale."*

A short practice trial of three items preceded the first block of each task (pleasantness rating and generation situation). Words were presented one at a time in the center of the screen. Accompanying each word was a question specifying the required task ("How pleasant is this object?" or "Describe a contamination situation in which this object may be involved."). Each block was composed of 6 words, for a total of 24 trials.

Participants then engaged in a distractor task – even or odd discrimination task (similar to what was done in the previous experiments) – that lasted 3 min. Finally, participants were given 8 min to remember the names of as many objects as they could; this task came as a surprise to participants affording the intended incidental learning. The responses were typed into a text box in the browser window. After the recall task, participants were asked whether they had anticipated the final memory test and/or had tried to memorize the words during the task. This question allowed us to identify cases in which encoding was not incidental (as intended).

The last section of the experiment contained a few demographic questions, the PVDS and the health status questionnaire. The experiment ended with the question "Did you pay attention and answer honestly?", for which participants selected one of the two forced-choice responses: "Yes, keep my data" or "No, delete my data". At the end, participants were fully debriefed and thanked for their participation.

Experimental design and statistical analysis. A within-subject design was used. The data were statistically analyzed with paired-samples *t*-tests.

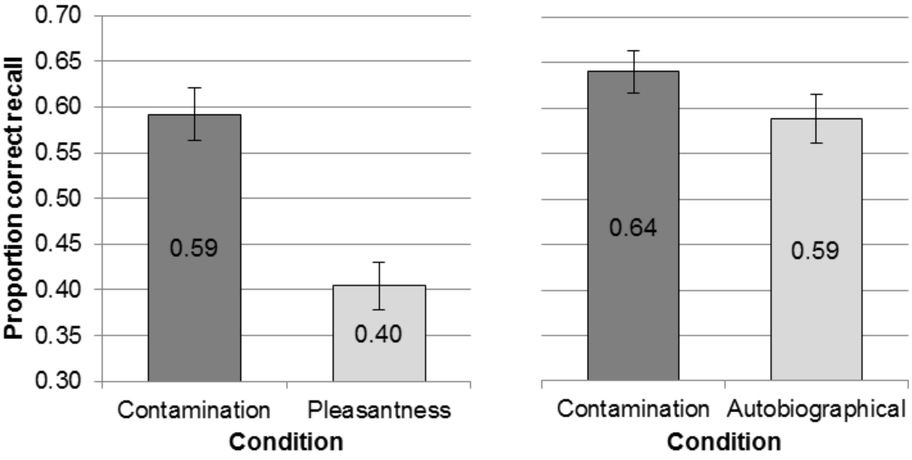
4.5.1.2 Results

***Encoding*.** Participants took about 42 s (M = 41.50, SD = 36.38) to generate a contamination situation with an average length of 51 characters (SD = 31). On the other hand, participants took less than 2 s to make the pleasantness rating (M = 2.68, SD = 0.47); still, the stimuli remained on the screen for 5 s, $t(47) = 7.41$, $p < .001$, $d_z = 1.069$.

Free recall. A highly significant mnemonic advantage was found for the objects for which participants described a contamination situation as compared to those objects for which participants provided pleasantness ratings (see Figure 18), at both the subject, $t(47) = 5.17$, $p < .001$, $d_z = 0.747$ (plus = 35; minus = 8; ties = 5), and the item-level, $t(23) = 6.83$, $p < .001$, $d_z = 1.393$ (plus = 21; minus = 1; ties = 2).

Figure 18.

Mean proportion of correct free recall for each condition in Study 8 (on the left) and in Study 9 (on the right). Error bars represent SEM.



4.5.1.3 Interim discussion

This study provides ample and robust evidence for the mnemonic advantage of contamination using this generation procedure, as revealed by a large difference in the proportion of objects recalled between conditions. Such data are consistent with previous studies showing an enhanced retention for information processed in terms of its survival value compared to several deep processing control conditions, including pleasantness (Nairne et al., 2007).

However, the obtained results should be considered with caution, as other variables may also have been involved. For example, the generation of contamination situations is clearly more effortful than pleasantness decisions. Indeed, participants took, on average, 42 s to generate the contamination response but only 2 s to produce a pleasantness rating and a maximum of 5 s of exposure to the stimuli. Such difference could account for the obtained difference in retention, even though previous studies have reported that effort is a poor predictor of retention overall (Craik & Tulving, 1975).

To our knowledge no studies have previously compared memory for objects for which people rated pleasantness – typically thought to be one of the best encoding conditions (Packman & Battig, 1978) – with memory for objects for which people generate situations of contamination, so one might wonder if the former was a deep enough encoding strategy. Nairne et al. (2008) directly compared a self-reference task, in which participants were asked to rate how easily a set of words brought to mind personal experiences, a deep encoding task considered to be one of the best ways to boost memory performance (e.g., Symons & Johnson, 1997), with a pleasantness rating task and no recall differences were found; memory performance was actually descriptively better for words rated for pleasantness than for self-reference, suggesting that the former is an effective encoding manipulation. In this case, however, participants were not asked to actually write down the personal experience that came to mind and decisions were also made within a 5 s time frame.

To help establish this effect, the next experiment used another highly effective encoding condition: a self-reference task, in which participants were asked to generate specific events from their lives; such a condition more closely matches the generation of contamination situations as it asks participants to generate responses in written form rather than to do a single rating score.

4.5.2 Study 9

Study 9 was designed to compare memory performance for our contamination-generation condition with a control condition well known to be a very effective encoding technique: self-reference (see Symons & Johnson, 1997 for a meta-analytic review). Researchers have long acknowledged the powerful memory advantage conferred by processing information in relation to the self, known as the self-reference effect in memory. It has been suggested that the self functions as a superordinate schema, by which encoding and retrieval processes are facilitated (e.g., Rogers, Kuiper, & Kirker, 1977). Thus, we wanted to ascertain whether generating information for a contamination context would promote superior retention compared to encoding information in terms of self-reference. Towards that end, participants were required to describe, in separate blocks, possible ways in which each object could lead them to or prevent them from getting sick (contamination condition) and specific instances from their lives in which each object had been involved (autobiographical condition).

Even though both conditions are likely to afford a similar potential for elaboration, it is possible that participants would come up with more similar situations in the contamination than in the autobiographical condition. For example, they could generate distinct life episodes for each object but only a given disease transmission vehicle for various objects. Consequently, the amount of retrieval cues for the to-be-remembered objects would differ between conditions, making the information more or less accessible in memory. Thus, an informal and exploratory qualitative analysis of the generated situations was also conducted. Responses were categorized and evaluated by two independent researchers, regarding complexity and variability of the generated situations. Additional data were collected for a subset of the generated sentences regarding complexity, arousal, and valence, using an independent sample of participants (see Supplementary Material 1 for a detailed description).

4.5.2.1 Method

Participants. Fifty students (females = 37; 74.0%) attending two Portuguese universities (University of Aveiro and OPorto Global University) participated in this study (M_{age} = 22.06, *SD* = 5.45; age range: 18-38 years old). Some participants were rewarded with a 50% chance of receiving a 5 euros gift card and others received no compensation. All participants gave informed consent.

Materials. The same stimuli as in Study 8 were used.

Procedure. The experiment was carried out with groups of up to ten participants at a time, in regular classrooms at the University of Aveiro and OPorto Global University. The experiment was run in individual computers using the Qualtrics survey software (Qualtrics Labs Inc., Provo, UT). The procedure was similar to that used in Study 8, except that participants were asked to generate autobiographical episodes (A) instead of rating the pleasantness of words. As before, the generation task was organized in alternating blocks with condition order counterbalanced across subjects (CACA or ACAC). In both conditions, responses were self-paced and participants typed their responses directly on the computer. Some adjustments were also made in the instructions as follows:

> ***Contamination condition:*** *"In this task, we are going to show you a series of object names. We would like you to consider how each object could be relevant to your health – that is, we want you to think of a contamination situation in which each object could lead you to or prevent you from getting sick. Please specify the type of contamination involved in each situation or the type of illness you may catch. For example, if the following objects were presented, you might think of situations like the ones described below:*
>
> > *Pen: "Someone with the flu sneezed on my pen, which became contaminated with the Influenza virus."*

> *Keys: “My keys fell into a public toilet and became contaminated with bacteria that could cause gastrointestinal diseases.”*
> *Sandals: “I use sandals in the gym shower to prevent catching a fungal infection like athlete's foot.”*

Keep in mind that several infectious diseases are spread through contact with objects contaminated by pathogens. In our daily life we are in constant contact with these contaminated objects, which can dramatically threaten our health and survival. Please try to imagine yourself in a situation where you are interacting directly with each object, and describe how this situation can lead you to or prevent you from getting sick.”

Autobiographical condition: *“In this task, we are going to show you a series of object names. We would like you to think about a specific event in your life in which each object was relevant – that is, we want you to think of a specific instance from your life in which each object was involved. Please specify the time and place, and describe how this object was present in the event. For example, if the following objects were presented to you, you can think of situations like the ones described below:*
Pen: “In September of last year, I used my dad's pen to fill out the registration form at the university's academic services.”
Keys: “Last Thursday, I went to the store to duplicate the keys of my new apartment.”
Sandals: “When I was five years old, I had sandals with dinosaur pictures that I always wore to go to the beach.”

Keep in mind that each object may be involved in our life in different ways. In our daily life, we are in constant contact with different objects that can be more or less important in any given instance. Please try to imagine yourself in a specific experience from your life with each object, and describe the details of the event, including when and where it took place.”

Experimental design and statistical analysis. Study 9 used a within-subject design. Memory performance was analyzed with paired-samples *t*-tests.

4.5.2.2 Results

***Encoding*.** Participants took significantly longer to generate a contamination situation than to generate an autobiographical situation (M = 47.87, SD = 17.50 and M = 40.12, SD = 18.07, respectively), $t(49) = 3.09$, $p = .003$, $d_z = 0.436$. Accordingly, the contamination situations generated had higher length (number of characters) compared to the autobiographical ones (M = 88.42, SD = 35.82, and M = 71.06, SD = 24.10, respectively), $t(49) = 3.64$, $p < .001$, $d_z = 0.515$. The recall difference scores (defined as the difference between recall of words for which participants generated contamination situation vs. for which participants generated autobiographical episodes) were not significantly correlated with the RT difference scores (defined as RT in the contamination condition minus RT in the autobiographical condition; *r* = .10, *p* = .495) nor with the length difference scores (length of sentences generated in the contamination condition minus length of sentences generated in the autobiographical condition; *r* = .08, *p* = .573).

Free recall. A paired-samples *t*-test on the proportion of object names correctly recalled resulted in a marginally significant advantage for objects for which participants described a contamination situation as compared to those objects for which participants described an autobiographical episode (see Figure 18), at the subject-level, $t(49) = 1.79$, $p = .080$, $d_z = 0.253$ (plus = 25; minus = 17; ties = 8). At the item-level, in turn, the contamination effect reached conventional levels of statistical significance, $t(23) = 2.40$, $p = .025$, $d_z = 0.491$ (plus = 16; minus = 6; ties = 2).

4.5.2.3 Interim discussion

Nairne et al. (2008) have shown that survival processing produces a mnemonic advantage over a multitude of deep-processing conditions, including a self-reference condition. In this study, we tested whether memory for contamination would be better as well. Although descriptively this was the case, the difference between the contamination and autobiographical conditions was only marginally significant at the subject level but significant at the item level. Remarkably, we did not find enhanced retention for objects for which participants generated autobiographical episodes, even though such situations were more complex and variable than the contamination situations (See Supplementary Material 1). Therefore, even when a highly effective control condition is used, one that is typically found to promote high retention, a memory advantage for contamination still exists.

4.5.3 Discussion of studies using self-generated situations of contamination

Studies 8 and 9 introduced a new way of exploring the mnemonic value of contamination. At issue was how retention after the generation of contamination situations would compare with retention obtained after other deep processing control conditions known to be highly effective: rating items for pleasantness (Study 8), or generating an autobiographical experience (Study 9). As expected, we found a highly significant mnemonic advantage for the objects for which participants described a contamination situation as compared to those objects for which participants provided pleasantness ratings. This mnemonic advantage was only marginally significant at the subject level, though in the expected direction, when participants described autobiographical episodes (but was significant at the item level).

4.6 Summary and general discussion of studies exploring memory and contamination

Table 12 provides a summary of the reported memory studies. Our data have yielded consistent findings in the predicted direction – that is, better memory performance for potentially contaminated items than non-contaminated items. We obtained statistically significant differences and small-to-medium effect sizes in the majority of the experiments. In two of the experiments (Study 5a and 9), the contamination effect, though in the expected direction, was only marginally significant.

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 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 contacted a healthy person. The data obtained in experiments adopting an immediate-memory paradigm provided some 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 faces containing signs of potentially contagious diseases (Study 3a), sentences describing signals and symptoms of disease (Studies 4a and 4b), as well as when they were associated with dirty hands described as being covered with vomit (Studies 5a and 5b) or with diarrhea (Study 6). Results from Studies 3b and 6 also seem to suggest that the stimuli have to be put in a fitness-relevant context – a contamination threat – for the memory advantage to occur.

Table 12.

Summary of studies exploring the mnemonic effect of contamination.

STUDY	SAMPLE	TO-BE-REMEMBERED STIMULI	ENCODING CONTEXT	CONTAMINATION CONDITION	NON-CONTAMINATION CONDITION	RESULTS
IMMEDIATE MEMORY PARADIGM						
Exploring faces as informative of contamination potential						
3a	*N* = 48 PT	black-and-white line drawings	Disease	Sick people [sick faces]	Healthy people [healthy faces]	Sick > Healthy**
3b	*N* = 48 PT	black-and-white line drawings	Non-Disease	Actresses [faces with make-up]	TV-show viewers [faces without make-up]	Actresses ≈ TV viewers
Exploring sentences as informative of contamination potential						
4a	*N* = 106 PT	black-and-white line drawings	Disease	Sick people [descriptors of a sick person]	Healthy people [descriptors of a healthy person]	Sick > Healthy***
4b	*N* = 48 PT	photographs of objects on clean hands	Disease	Sick people [descriptors of a sick person]	Healthy people [descriptors of a healthy person]	Sick > Healthy*
Exploring the direct transmission of contamination potential						
5a	*N* = 48 AM	photographs of objects on hands	Disease	Sick people [hands covered with vomit]	Healthy people [clean hands]	Sick > Healthy+
5b	*N* = 48 AM	photographs of objects on hands	Disease	Sick people [hands covered with vomit]	Healthy people [clean hands]	Sick > Healthy**

6	*N* = 80 AM (40 per context)	photographs of objects on hands	Disease	Zonia [hands covered with diarrhea]	Marin [clean hands]	Zonia > Marin**
			Non-Disease	Zonia [hands covered with chocolate spread]	Marin [clean hands]	Zonia ≈ Marin
7a	*N* = 64 PT	photographs of objects on hands	Disease	Drusila/Leonisa [hands covered with diarrhea or vomit]	Drusila/Leonisa [hands covered with chocolate spread or pasta sauce]	Drusila ≈ Leonisa
7b	*N* = 48 PT	photographs of objects on hands	Disease	Sick people [faces + hands covered with diarrhea or vomit]	Healthy people [faces + hands covered with chocolate spread or pasta sauce]	Sick ≈ Healthy
GENERATION PARADIGM						
Exploring self-generated situations of contamination potential						
8	*N* = 48 PT	object words		Contamination situations	Pleasantness ratings	Contamination > Pleasantness***
9	*N* = 48 PT	object words		Contamination situations	Autobiographical episodes	Contamination > Autobiographical^{+}

Notes: PT – Portuguese sample; AM – North American sample; + $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$

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 better the location of disfigured faces but that 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); we remind that these last studies tested recognition memory for faces whereas we tested memory for objects. 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). Note that, as already mentioned, previous studies explored memory for disgust-eliciting stimuli as compared to neutral stimuli. In our studies people were required to recall exactly the same “neutral” items but these have acquired distinct fitness-relevancy via contagion with disgusting stimuli. 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 BIS 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 et al., 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 also motivated arm avoidance movements toward photographs of faces, thereby reducing potentially harmful social interaction (Mortensen et al., 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 disgusting cues (the faces which contained the disfigurative elements or the dirty hands, which could capture more of the participants' attention), but rather for the objects that accompanied the cues. According to this idea, memory for the objects could actually be worsened by the simultaneous presentation of the disgusting cues (e.g., sick faces); yet, we obtained the opposite result. Nevertheless, complex photographs of dirty hands holding objects seem to demand more time and attentional resources, probably to vouch that the substance covering the hands was actually a potential threat. 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 procedures designed properly to address this issue (e.g., manipulating the presentation timings or using shorter presentation times; e.g., van Hooff et al., 2013) or using oculometric measures should be conducted to explore these hypotheses.

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; L. J. Levine & Pizarro, 2004; Sharot & Phelps, 2004). In most studies, however, the items representing each condition differ 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 from 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 Studies 3a and 3b, and the same stimuli were used in the disease and non-disease contexts in Study 6, 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. In fact, the arousal did not differ between the disease and the non-disease contexts of Study 6 (in both contexts, participants felt significantly more emotionally aroused by pictures of objects on dirty hands than pictures of objects on clean hands). Disgust ratings, however, confirmed that stimuli framed in different contexts induce differential emotional states despite the fact that the stimuli were exactly the same (see also Chapter 3 for similar findings).

Nevertheless, people recall about the same percentage of objects touched by hands covered with diarrhea (disease context) and objects touched by hands covered with chocolate (non-disease context), even though the potential risk of contamination was rated as being lower in the latter case. Accordingly, Studies 7a and 7b found no memory advantage when participants were shown objects on dirty hands covered with different substances, which were randomly described as contagious (i.e., diarrhea or vomit) or noncontagious (e.g., chocolate spread or pasta sauce). In these studies, participants recalled stimuli regardless of whether they were presented as actually posing a contagion risk. This is likely to be an evolved response of the BIS, governed by what has been called 'the smoke detector principle’. Although participants could be “erroneously” inferring the harmless chocolate spread and pasta sauce as vehicles of contamination (a false-positive error), it is still less risky than failing to detect a truly harmful source of diseases (a false-negative error). Similarly, researchers have been proposing that the BIS tends to be hypervigilant by setting a low threshold for pathogen detection, in that it is triggered heuristically by any deviation from typical morphology and behavior (features unrelated to contagious), in order to minimize the risk of contracting diseases (Park et al., 2003; Schaller & Park, 2011). Physical disabilities (Park et al., 2003), facial disfigurements (Ackerman et al., 2009; Miller & Maner, 2011), obesity (Park et al., 2007), elderly aspects (Duncan & Schaller, 2009) and mental illness (Lund & Boggero, 2014) are some examples of such features. Even when people have rational knowledge of the noncontagious nature of these conditions, they still experience disgust and react in an aversive way. As highlighted by Ryan et al. (2012), “disgust-based disease avoidance should be both automatic and fairly impenetrable to cognition to ensure that all disease signals, false or real, are acted upon” (p. 640).

Surprisingly, these findings are not in line with those of Study 3b. Even though the risk of infection from people using makeup is supposedly low, in light of the error management theory (Haselton et al., 2015; Johnson et al., 2013) we should also expect a boost in memory for objects touched by actresses. However, this was not the case. Although the results are inconsistent across studies, this difference may stem from the cues and the framing adopted in each study. For example, in contrast to the remaining studies, in which the threat of disease was temporarily salient, in Study 3b objects were touched by actresses and TV-show viewers, which, in principle, pose little or no threat to human health. Because mounting a behavioral immune response entails costs (e.g., inhibits other fitness-related goals by limiting social exchange and mating opportunities), activation of the BIS needs to be flexible, depending on the extent to which the available environmental information signals the presence of life threatening diseases (Duncan & Schaller, 2009). Consequently, people adaptively tune their responses to such environmental cues in a way that optimizes fitness. It is possible that in the actresses' condition, people were not concerned with disease threats, feeling no need to trigger the BIS.

In addition, our results generally suggest that contamination seems to spread according to the laws of sympathetic magic, whereby an object that has been in contact with a disgusting item (diarrhea; law of contagion) or resembles a disgusting item (chocolate spread; law of similarity) could be believed to be contaminated (Rozin & Fallon, 1987) and, consequently, to be better remembered. Moreover, the BIS should be activated by disgusting behaviors that deviate from the culturally accepted health practices. The behavior of handling items without washing hands could, in itself, induce disgust or contagion thoughts. This is in line with a study by Bell and Buchner (2010) who found better source memory performance for faces associated with disgusting behaviors. Our 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 (Study 3a); when they were presented in the non-fitness relevant context of Study 3b, no differences were found between 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 that 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 does 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.

Continued efforts were directed towards designing new paradigms to provide a more thorough investigation of the mnemonic consequences of contamination. Using a generation paradigm, participants generated contamination situations involving presented objects (the to-be-remembered stimuli) that could lead them to or prevent them from getting sick. Two control conditions thought to prompt deep encoding of information were used: pleasantness ratings and autobiographical processing. We found again some evidence of enhanced retention of material relevant to our health, particularly relative to pleasantness ratings. The effect was only marginally significant at the subject level when participants generated autobiographical episodes but significant at the item level. Nevertheless, the advantage for contamination remained (even only descriptively) despite the fact that the pleasantness and self-reference conditions represented two well-known deep and elaborative encoding procedures.

Efficient detection, processing, and memorization of stimuli that potentially threaten an individual's health, compared with other non-threatening stimuli, constitute adaptive features of the cognitive component of the BIS, as each potentially promotes individuals' survival. The current results provide demonstration of a memory tuning for potentially contaminating objects and add to the growing body of evidence supporting the robustness and universality of the 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, et al., 2017), we present some evidence for a mnemonic tuning for another domain that certainly played a role during evolution: contamination.

III

EMPIRICAL
STUDIES

CHAPTER 5.

“Watch out for that disgusting thing!”: Attention and contamination

5.1 Introduction

Stimuli inducing the emotion of disgust have been shown to preferentially “capture” one’s visual-attention, even when we should ignore (or inhibit attention to) these stimuli to attend to other stimuli that are presented simultaneously on screen (see section 1.4.2 of Chapter 1 to a brief *Theoretical Introduction*). In other words, capture of exogenous attention by disgusting-distractors (i.e., elements that are irrelevant to the ongoing task) causes subsequent disruption of task performance by inhibiting the processing of targets to which endogenous attention must be directed to accomplish the task. This results in significantly longer reaction times and higher error rates (e.g., Chapman et al., 2013; Krusemark & Li, 2011).

In Chapter 5, attentional biases towards contamination-related stimuli were tested by adopting the paradigm of van Hooff et al. (2013). In their study, a task-irrelevant stimulus (neutral, fear- or disgust-inducing) was presented at fixation, followed by the presentation of a target in its vicinity (the letter Z or N); the participants’ task was to identify the target as soon and accurately as possible. The authors found that, compared to fear-inducing and neutral pictures, disgust-eliciting pictures delayed and impaired subsequent target discrimination at short (100 and 200 ms) cue-target intervals (van Hooff et al., 2013; van Hooff, van Buuringen, El M'rabet, de Gier, & van Zalingen, 2014). Their results suggest a difficulty in diverting attention onto another stimulus once attention is allocated to a disgust-related stimulus, particularly at early sensory processing stages.

In our next study, objects being held by dirty hands or by clean hands were presented in the center of the screen as distractors while participants carried out a letter-identification task. Thus, participants would need to disengage covert attention from the central distractor-stimulus to search for the peripherally-presented target-letters. Difficulty with disengaging attention from the central cue would lengthen target identification times and/or lower accuracy.

Previous studies analyzing attentional biases to contamination-related stimuli typically compare stimuli that directly trigger the emotion of disgust with stimuli that elicit fear or a neutral reaction. The disgusting stimuli used in those studies broadly varied in content (e.g., dead animals, dirty toilets, rotten food), likely demanding extensive perceptual processing in order to identify each source of infection and the disease-risk associated with it. In our study, a single vehicle of contamination was used during the entire experiment (i.e., dirty hands), not calling for a constant evaluation effort. Indeed, images only differed on the object in contact with the substance covering the hands (the potential vehicle of contamination). Furthermore, participants were previously informed about the pictures they would be seeing – that is, they already knew that the pictures depicted dirty and clean hands holding objects. However, in order to avoid pathogenic threats, one should be attentive not only to the primary source of contamination but also to other things that, by being in close physical contact with a source of disease, may harbor pathogenic microorganisms as well (law of contagion; Rozin et al., 1986). Thus, we hypothesized that attentional processes would take longer to disengage from the pictures of objects when these were being held by dirty hands (vs. when held by clean hands).

To evaluate whether the attribution of fitness-relevancy is an important determinant of the attentional effect, one half of the participants were randomly assigned to a disease context, whereas the other half responded to a non-disease context. That is, following Study 6 (see Chapter 4), the dirty hands were presented covered with a substance described as diarrhea or described as chocolate spread – the fitness and non-fitness condition, respectively. If participants were made to believe that there is a real disease-threat only in the disease-context then the bias in the attentional system would be expected to be more pronounced in such a context. However, if the BIS is governed by the 'smoke detector principle' then the attention bias should be equally observed in both the disease and the non-disease context; such result would reflect a tendency to avoid false-negative errors to ensure the correct identification and avoidance of disease-vehicles (see also Chapter 4).

Previous studies (e.g., van Hooff et al., 2013; van Hooff et al., 2014) have shown that disgusting stimuli capture (or not) people's attention depending on the time interval between the presentation of the cue and the onset of the target (i.e., cue-target stimulus onset asynchrony: SOA). Thus, in our studies, the SOA was varied allowing us to assess the time course of attentional biases toward potentially contaminated items. A SOA of 200 ms was selected because van Hooff and collaborators (2013, 2014) only found an attention bias for disgust-related stimuli at early sensory processing stages. An additional SOA of 350 ms was used in our experiment, so as to analyze whether the object-hands association requires a longer encoding interval.

We also explored if performance changed throughout the task due to possible habituation effects. Habituation is likely to occur in our study since the same disgusting component of the stimulus (dirty hands) was used in the entire experiment. Previous studies have shown that the attentional bias for disgust-related stimuli became progressively smaller throughout the course of the experiment, with participants being faster at detecting a target stimulus towards the end of the experiment (van Hooff et al., 2013). In a similar vein, we expected the attentional bias to be more pronounced at the beginning of the task and to lessen towards the end due to habituation. Finally, memory was tested at the end of the experiment.

5.2 Exploring attentional biases for contaminated-related stimuli

5.2.1 Study 10

In Study 10 a letter-identification task was employed in which participants were required to identify which of two target letters (Z or N) was presented shortly after a picture of an object being held by dirty hands or by clean hands was displayed. The substance covering the dirty hands was described as diarrhea (in the disease context) or as chocolate spread (in the non-disease context). The letters were presented at 200 or 350 ms after the onset of the central stimulus (object being held by hands), either on the left or on the right side of it. After the attention task, participants were given a distractor task followed by a surprise free recall task. In order to assess the effectiveness of the context manipulation (disease vs. non-disease context), participants assessed their emotional state before and after the attentional task. We were particularly interested in the emotional experience of disgust; we expected an increase in disgust from the pre- to the post-task in the disease context, but not in the non-disease context.

5.2.1.1 Method

Participants. Eighty-eight participants (females = 57, 64.8%; 44 per context: disease vs. non-disease context) from the University of Aveiro (Portugal) took part in the experiment (M_{age} = 20.69, *SD* = 2.73; age range: 18-37 years old). Data from an additional 10 participants were excluded from analysis; these include seven participants who indicated not having normal or corrected-to-normal eyesight and three participants whose accuracy levels in the attentional task was below or only slightly above chance level (< 60% correct). Participants were rewarded by entering on a prize draw for one of the three tickets for the Academic Festivities' week of University of Aveiro. All participants gave written informed consent.

Materials. Thirty-six stimuli (plus six to be used in practice trials) were selected from the Objects-on-Hands Picture Database. The selected pictures had good name agreement (%NA = 89.3%, *SD* = 13.4), and high degree of familiarity (*M* = 4.61, *SD* = .29; on a scale of 1-5), based on Portuguese norms for the objects being held by clean hands (see Chapter 3). The stimuli included frontal-view pictures of objects being held by clean hands and by hands covered with a mixture of chocolate spread and peanut butter (i.e., dirty hands). Within each stimuli category (i.e., women's accessories, fruits, kitchen utensils, office supplies, toys, and vegetables), six items were selected on the basis of having the lowest and highest ratings, respectively, on arousal, disgust and valence; that is, those that presented the highest absolute difference between scores obtained for the same objects when these were being held by clean and by dirty hands, to ensure optimal separation between conditions.

Two identical lists of stimuli were constructed, matched for name agreement, familiarity, arousal, disgust and valence ratings (*ts*(34) < 1). Each list had the same number of stimuli per category (i.e., three pictures for each of the six categories). Two counterbalancing versions were created such that each object appeared an equal number of times in its dirty and clean version across participants. These two versions were applied in both contexts. Each participant saw each stimulus in only one of the conditions (clean or dirty).

Procedure. Each session included up to six participants and lasted approximately 30 min. After consenting to participate in the study, participants were randomly assigned to one of the contexts (disease or non-disease context) and to one of the counterbalancing versions of the experiment. The experiment was run on individual computers using the software *E-prime 2.0* (Schneider et al., 2002), using a 22 inch Dell P2214H LED-backlit LCD monitor at a resolution of 1920 × 1080 pixels, and a refresh rate of 60 Hz (476 × 267 mm, 32-bit color depth). For half of the sample, a chin-rest was used to ensure a constant viewing distance and minimize head movements (the number of participants that used or did not use the chin-rest was equated across versions and contexts).

An attentional task was performed using a procedure adapted from van Hooff and collaborators (2013, 2014). Firstly, a brief scenario was provided, which differed according to the context participants were randomly assigned to. Specific instructions for each context were as follow:

> ***Disease Context:*** *"In this task, you will see pictures of objects that have been touched by different people. One of these people is sick with a highly contagious gastrointestinal*

> *infection and is having severe and frequent episodes of diarrhea. Sometimes she cannot reach the toilet on time and gets diarrhea on her hands while handling objects. The other person is healthy and is handling objects with clean hands. Throughout the experiment, you will see pictures of objects held by hands covered with diarrhea or clean hands."*
>
> **Non-disease Context:** *"In this task, you will see pictures of objects that have been touched by different people. One of these people has been baking cakes and her hands are covered in chocolate spread. Sometimes she cannot find time to clean her hands and has chocolate spread on them while handling objects. The other person is handling objects with clean hands. Throughout the experiment, you will see pictures of objects held by hands covered with chocolate spread or clean hands."*

Each trial began with a fixation cross at the center of the screen (Arial 55pt font size, subtended a visual angle of 1.6°), followed after 1000 ms by a cue stimulus (521 x 365 pixels; subtending 11.3° × 7.9° of visual angle at a viewing distance of 65 cm). After 200 or 350 ms of the cue stimulus onset, a target stimulus (letter Z or N, Arial 23pt font size, subtended 0.7° of visual angle) was presented in a random order for 50 ms either on the left or right side of the centrally located image (approximately 8 cm; 7° of visual angle from the center of the screen). The time interval between trials was 500 ms. This sequence of events is illustrated in Figure 19.

Participants were instructed to indicate, as accurately and quickly as possible, which target letter was being presented (Z or N), by pressing the corresponding keyboard button. The cue stimulus remained on the screen until a response was given or for a maximum period of 1200 ms. Participants were required to keep their eyes fixated on the center of the screen and to refrain from moving them during the task.

The experimental task consisted of 8 non-randomized blocks, each composed of 36 trials for a total of 288 trials, with a brief rest period between each block (20 s). Each of the 36 images (18 dirty and 18 clean) were presented once in each block and, therefore, repeated eight times during the entire task. In this way, it was ensured that each image was paired with both target letters (Z and N), which were presented on both sides (left and right), and on both SOA (200 and 350 ms). The SOA varied randomly within each block as well as the presented target letter and respective position, with the constraint that each SOA, target letter and position of presentation occurred the same number of times within each block. Participants were also given a set of 6 practice trials prior to the experimental trials, in which feedback regarding their performance was provided ("Correct", "Incorrect" or "You didn't answer, please be faster").

Emotional state was measured before and after the attentional task by asking participants to indicate to what extent they felt a set of emotions at that moment (that is, disgust, sadness, happiness, anger, and fear); their response was provided using a visual analogical scale ranging from 0 (none) to 100 (very) presented on the screen. Additionally, at the end of the attentional task, participants were asked to what extent they were concerned about potential sources of contamination and how strongly they felt the need to wash their hands.

Participants were then given two minutes to solve paper and pencil mazes[15] (distractor task), after which a final surprise free recall task followed. In this task, participants were asked to remember the names of as many objects as they could remember from the initial task. Responses were written on a recall sheet during a 5 min period. Participants were fully debriefed at the end of the experiment, thanked for their participation, and excused.

Experimental design and statistical analysis. A mixed design was employed in this study. A 2x2 mixed ANOVA was conducted to analyze the impact of the attentional task on the participants' emotional state, with time (i.e., pre- and post-task) as a within-subject factor and context (i.e., disease and non-disease) as a between-subjects factor. Accuracy and mean response times (RTs) were each analyzed using a 2x2x2 mixed ANOVA, with SOA (i.e., 200 and 350 ms) and type of hands (i.e., dirty and clean) as within-subject factors and context (i.e., disease and non-disease) as a between-subjects factor. RTs were calculated on the basis of correct responses only (1.3% of responses were incorrect). Following van Hooff et al. (2013), RTs shorter than 200 ms were considered errors (i.e., response anticipations) and were excluded from the analysis (in total, these occurred in less than 1% of responses). To assess habituation effects, data were split into first and second half of the task, each containing 4 blocks. A 2x2x2x2 mixed ANOVA was performed with one between-subject factor (i.e. context: disease and non-disease) and three within-subject factors (i.e., SOA: 200 and 350 ms; type of hands: dirty and clean; half: first and second half of the attention task). The mean proportion of correct recall was examined with 2x2 mixed ANOVA, which comprised type of hands (i.e., dirty and clean) as the within-subject factors and context (i.e., disease and non-disease) as the between-subjects factor. Whenever necessary, these analyses were followed up by independent or paired *t*-tests (according to the variables under scrutiny) to clarify the

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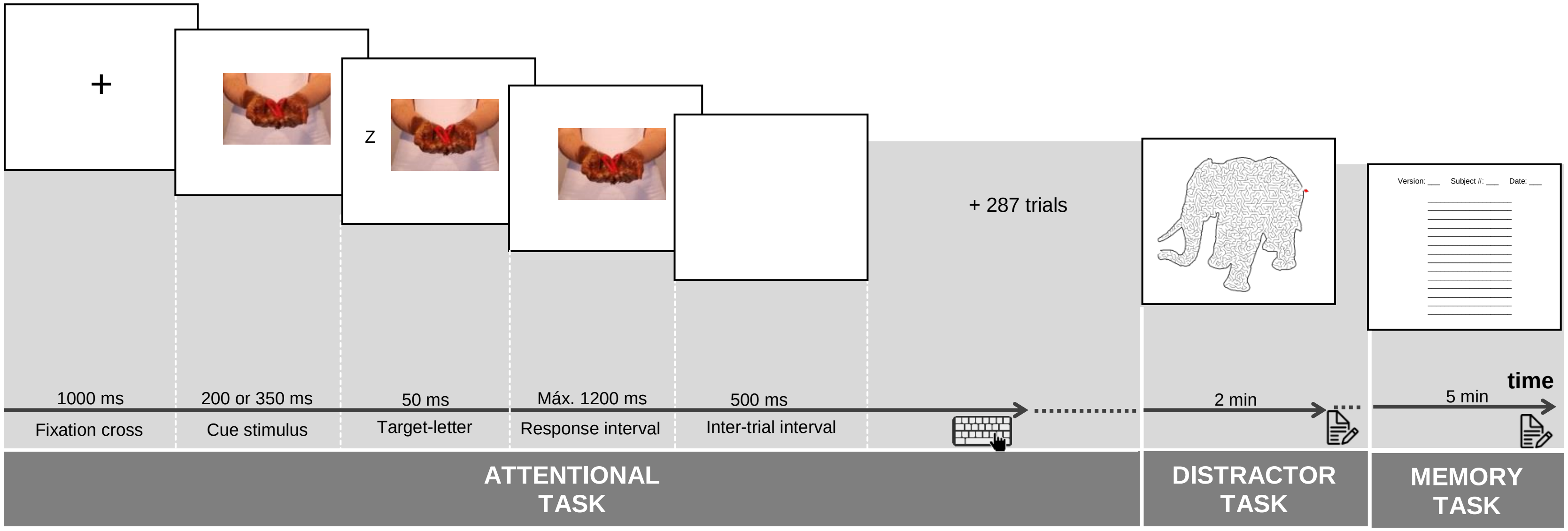
[15] The mazes were obtained from krazydad and are freely available at: https://krazydad.com/mazes/index.php?sv=AnimalMazes.

Figure 19.

Schematic representation of the procedure used in Study 10.



the pattern of results. Analyses were performed using the IBM SPSS version 24. The statistical level of significance was set at $p < .05$ for all analyses.

5.2.1.2 Results

Emotional State. A mixed ANOVA conducted on the emotion of disgust revealed no main effect of context, but a significant main effect of time and a significant interaction between the two variables (see Table 13). Participants in the disease context experienced increased disgust after performing the attentional task compared to their baseline level, $t(43) = -4.67$, $p < .001$, $d_z = -0.790$; on the other hand, the disgust levels obtained from the participants in the non-disease context, did not differ significantly between the pre- and post-task, $t(43) = 0.02$, $p = .987$. These results suggest that the context activation influenced the level of experienced disgust according to our predictions. Nevertheless, the overall level of disgust was very low (maximum 18% on a scale 0-100).

Table 13.

Mean ratings (and standard deviations) for each emotion before (pre) and after (post) the attentional task for each context.

	Disease context		**Non-disease context**		
	Pre	Post	Pre	Post	**Statistics**
DISGUST	3.70 (10.03)	18.93 (22.28)	7.93 (17.19)	7.89 (14.75)	**ME time:** $F(1, 86) = 12.27$, $MSE = 2535.364$, $\eta_p^2 = .125$ ** **ME context:** $F(1, 86) = 1.47$, $MSE = 511.364$, $\eta_p^2 = .017$ **Interact:** $F(1, 86) = 12.41$, $MSE = 2565.818$, $\eta_p^2 = .126$ **
HAPPINESS	52.89 (18.40)	48.25 (20.67)	51.98 (26.20)	38.34 (27.07)	**ME time:** $F(1, 86) = 24.69$, $MSE = 3672.818$, $\eta_p^2 = .223$*** **ME context:** $F(1, 86) = 1.364$, $MSE = 1287.364$, $\eta_p^2 = .016$ **Interact:** $F(1, 86) = 5.991$, $MSE = 891.00$, $\eta_p^2 = .065$ *
FEAR	13.91 (20.69)	7.66 (14.14)	14.75 (25.70)	6.20 (13.88)	**ME time:** $F(1, 86) = 11.77$, $MSE = 2407.960$, $\eta_p^2 = .120$ ** **ME context:** $F(1, 86) < 1$ **Interact:** $F(1, 86) < 1$
SADNESS	18.57 (20.41)	17.68 (18.85)	22.23 (29.62)	16.23 (26.10)	**ME time:** $F(1, 86) = 3.74$, $MSE = 521.642$, $\eta_p^2 = .042$ **ME context:** $F(1, 86) < 1$ **Interact:** $F(1, 86) = 2.062$, $MSE = 287.642$, $\eta_p^2 = .023$
ANGER	11.00 (18.62)	13.16 (21.71)	12.43 (22.10)	16.52 (24.78)	**ME time:** $F(1, 86) = 1.97$, $MSE = 429.688$, $\eta_p^2 = .022$ **ME context:** $F(1, 86) < 1$ **Interact:** $F(1, 86) < 1$

Note: ME time: Main effect of time (pre-, post-task); ME context: Main effect of context (disease, non-disease); Interact: interaction between variables; * $p < .05$; ** $p < .01$; *** $p < .001$

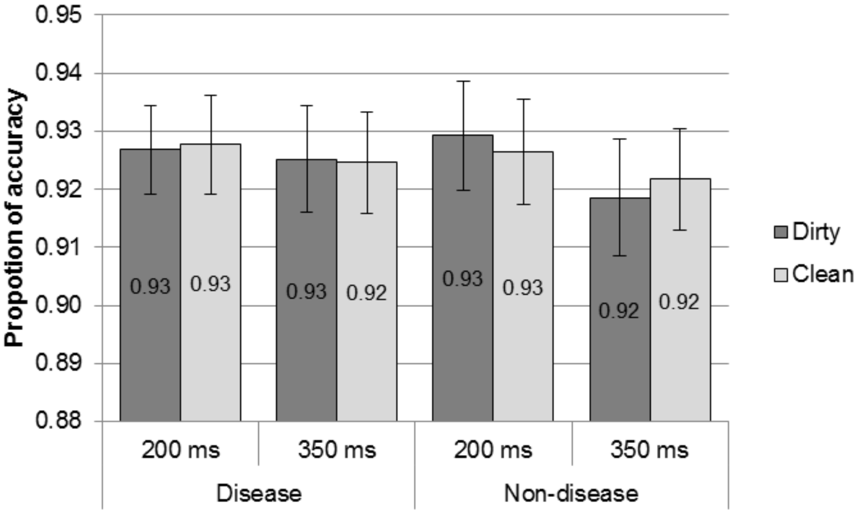
The attentional task also impacted the experience of fear and happiness, which reduced significantly from the pre- to the post-task moment in both contexts, as revealed by significant main effects of time. The interaction was also significant for the emotion of happiness. Follow-up analyses revealed that the reduction of happiness from the pre- to post-task was only marginally significant in the disease context, $t(43) = 1.91$, $p = .063$, $d_z = 0.288$, but statistically significant in the non-disease context, $t(43) = 4.93$, $p < .001$, $d_z = -0.744$. No main effects or interactions were found for the emotions of sadness and anger (see Table 13).

There were no significant differences between contexts on concerns regarding potential sources of contamination ($M_{Disease\ context} = 36.00$, $SD = 29.90$ and $M_{Non\text{-}disease\ context} = 36.25$, $SD = 31.79$, on a scale 0-100), $t(86) = -0.04$, $p = .97$, nor on participants' need to hand-wash ($M_{Disease\ context} = 34.93$, $SD = 31.70$ and $M_{Non\text{-}disease\ context} = 35.16$, $SD = 33.79$), $t(86) = -0.03$, $p = .97$

Accuracy. Overall accuracy in detecting the target letter ranged from 76 to 99%, with an average of 92.5% (*SD* = 5.2) correct target identifications. There were no significant main effects nor interactions (highest $F(1, 86) = 2.11$, $p = .150$, for the main effect of SOA), suggesting that participants did not differ in their ability to identify the correct target letter depending on the type of stimuli, the SOA and the context. Thus, participants were very good in discriminating the targets irrespectively of our manipulated variables (see Figure 20).

Figure 20.

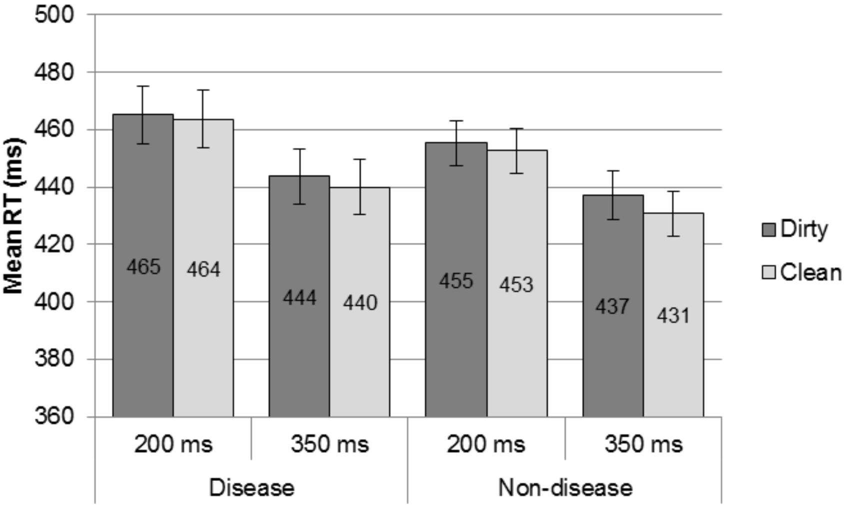
Proportion of accuracy in detecting the target after the presentation of each stimulus type (dirty, clean) as a function of SOA (200, 350 ms) and context (disease, non-disease). Error bars represent SEM.



Response times. RTs for correct responses to targets that followed pictures of objects on dirty hands were generally longer compared to those that followed pictures of objects on clean hands, as revealed by a significant main effect of type of hands, *F*(1, 86) = 4.46, *MSE* = 1139.060, $p = .038$, $\eta_p^2 = .049$ (see Figure 21). A significant main effect was also found for SOA, *F*(1, 86) = 166.17, *MSE* = 39567.022, $p < .001$, $\eta_p^2 = .659$, indicating that people were faster at detecting the target-letter when it was presented 350 ms after the cue-stimulus onset (i.e., at longest SOAs). Despite the fact that, descriptively, RTs were higher in the disease context (vs. non-disease context), no significant main effect of context nor interactions were found (highest *F*(1, 86) = 1.16, $p = .285$, for type of hands x SOA interaction).

Figure 21.

Mean RTs for each stimulus type (dirty, clean) as a function of SOA (200, 350 ms) and context (disease, non-disease). Error bars represent SEM.

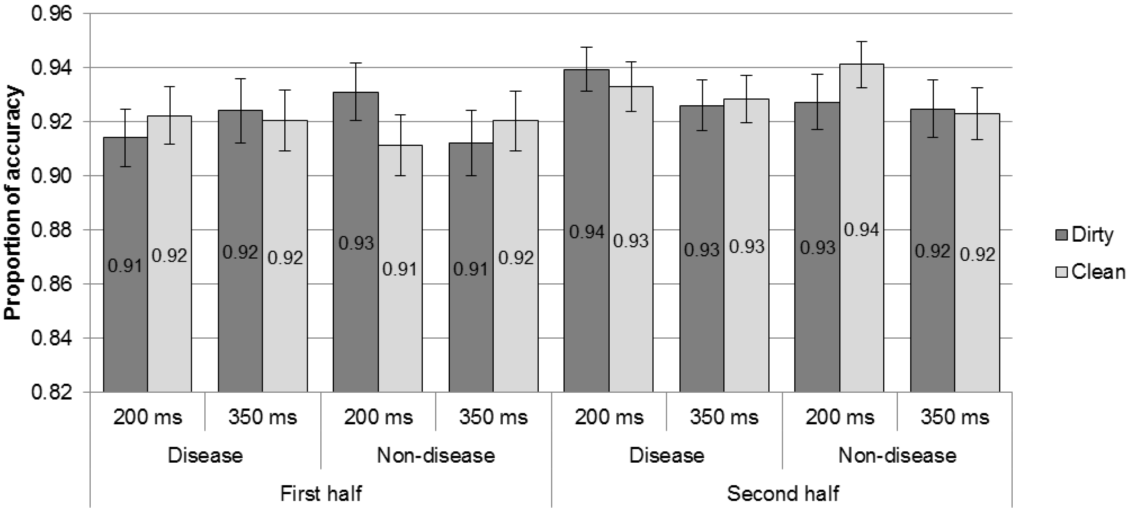


Habituation effect. Regarding accuracy, the mixed ANOVA revealed a significant main effect of half, *F*(1, 86) = 4.78, *MSE* = 0.021, $p = .031$, $\eta_p^2 = .053$, with participants being more accurate during the second half of the task. A significant four-way interaction among all variables was also obtained, *F*(1, 86) = 6.84, *MSE* = 0.011, $p = .011$, $\eta_p^2 = .074$. No other significant effects were found (highest *F*(1, 86) = 2.71, $p = .103$ for the SOA x half interaction). Follow-up analysis conducted separately for each half of the experiment revealed a significant three-way interaction among type of hands, SOA and context in the first half of the experiment, *F*(1, 86) = 4.62, *MSE* = 0.008, $p = .034$, $\eta_p^2 = .051$, and a significant main effect of SOA in the second half, *F*(1, 86) = 4.14, *MSE* = 0.009, $p = .045$,

η_p^2 = .046, with participants being more accurate in detecting target-letters presented 200 ms after the cue-stimulus. Note that RTs were also longer, suggesting a potential speed-accuracy trade-off. To clarify the three-way interaction observed in the first half, separate repeated measures ANOVAs were carried out for each context: no significant effects were found in the disease context but a significant type of hands x SOA interaction was found in the non-disease context, $F(1, 43) = 4.28$, $MSE = 0.008$, $p = .045$, $\eta_p^2 = .091$; this was due to a larger accuracy in detecting targets after the dirty hands presentation (as compared to the clean hands) under the 200 ms SOA, $t(43) = 2.36$, $p = .023$, $d_z = 0.355$, with the opposite obtained for the 350 ms SOA; however, this last did not reached traditional significance levels, $t(43) = -.93$, $p = .360$ (see Figure 22). Thus, overall, these analyses revealed that participants were more accurate in the second than in the first half with no clear differences among conditions on the attentional bias to contamination.

Figure 22.

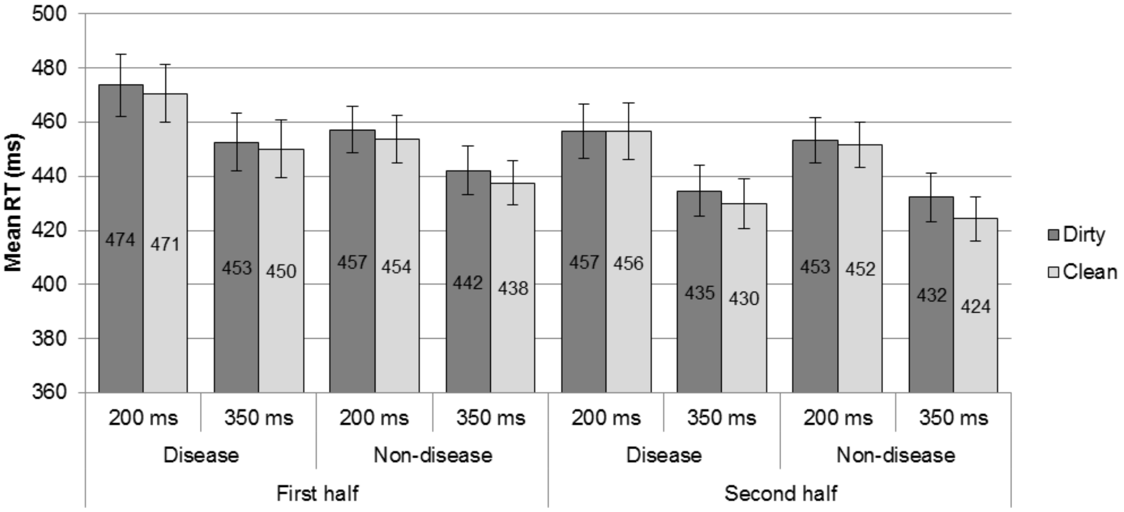
Proportion of accuracy in detecting the target letter after the presentation of each stimulus type (dirty, clean) as a function of SOA (200, 350 ms) and context (disease, non-disease), for each half of the task. Error bars represent SEM.



For the RTs, the main effects of type of hands and of SOA remained significant, $F(1, 86) = 4.34$, $MSE = 2221.862$, $p = .040$, $\eta_p^2 = .048$, and $F(1, 86) = 168.10$, $MSE = 79537.531$, $p < .001$, $\eta_p^2 = .662$, respectively. A significant main effect of half, $F(1, 86) = 12.25$, $MSE = 26740.786$, $p = .001$, $\eta_p^2 = .125$, and an interaction between half and SOA, $F(1, 86) = 4.91$, $MSE = 1630.461$, $p = .029$, $\eta_p^2 = .054$, were also found, suggesting that participants were quicker to identify the letter during the second half of the experiment, but particularly so for the longer SOA. The remaining effects did not reach significance levels (highest *F*(1, 86) = 2.02, p = .159, for half x context interaction; see Figure 23). In sum, these results indicate that, although participants got faster at responding to the target letter from the first to the second half of the experiment (particularly for the longer SOA), the effect of hands remained significant.

Figure 23.

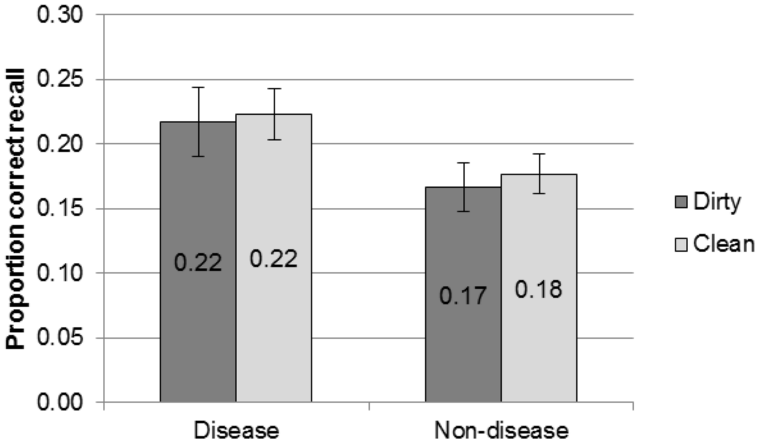
Mean RTs for each stimulus type (dirty, clean) as a function of SOA (200, 350 ms) and context (disease, non-disease), for each half of the task. Error bars represent SEM.



Free recall. Results revealed a marginally significant main effect of context, *F*(1, 86) = 3.749, *MSE* = 0.104, *p* = .056, η_p^2 = .042, with participants assigned to the disease context recalling more items than those in the non-disease context (see Figure 24). Nor the main effect of type of hands nor the interaction were significant, both *Fs*(1, 86) < 1.

Figure 24.

Mean proportion of correct free recall for each type of hand and in each context. Error bars represent SEM.



5.2.2 General discussion of a study exploring attention and contamination

As briefly alluded to earlier, because human attentional resources are limited, our attention systems have evolved to monitor, detect and process stimuli that are of survival value (Vuilleumier, 2005). A bias for preferentially attending to threat-related information confers a highly adaptive advantage and improves chances of survival by prompting people's awareness of the danger posed by a given situation and preparing them to cope with it if necessary (Carretié, 2014). Accordingly, fear-inducing stimuli, such as snakes, spiders and angry faces are particularly effective at recruiting our attention (e.g., Eastwood et al., 2001; LoBue & DeLoache, 2008; Öhman, Flykt, et al., 2001; Öhman, Lundqvist, et al., 2001; Pinkham et al., 2010). Of interest in our case was if, and to what extent, disease-related stimuli are attention-grabbing. Several studies have provided evidence that disgusting stimuli capture one’s visual attention (e.g., Ackerman et al., 2009; van Hooff et al., 2013). In the present study, we expected an attentional bias for contamination, observable in poorer accuracy to discriminate peripheral targets (i.e., letters) and longer response times in correct responses on trials in which pictures of dirty hands holding items were presented (vs. pictures of clean hands). Accordingly, our data suggested that pictures of objects held by dirty hands captured attention at an automatic level, disrupting target identification – as reflected by the longer response times taken to correctly discriminate the target letters presented after such cues. Remarkably, the potential for contamination seems to interfere with the processing of other information even when a single source of contamination (i.e., dirty hands) was repeatedly presented. Prior studies have used a wide panoply of disgust-inducing stimuli, which probably required a constant and continuous analysis of each new stimulus. Exploration of the external environment may constitute an adaptive response; by exploring each stimulus participants could estimate, for example, the infection load/disease risk afforded by each one. In addition, some authors have proposed that some disgust-eliciting stimuli could actually bring benefits after exploration (e.g., bitter-tasting medicines may have healthful benefits; Carretié et al., 2011). Our stimuli, however, depicted a single vehicle of contamination, for which participants were already informed about. Thus, even though some examination was expected, it is likely not comparable to what might have happened in previous studies. Nevertheless, the disgusting substance was in direct contact with a neutral item and the allocation of attentional resources to examine the potential of contamination would be adaptive to minimize possible future contact with the contaminated items. Further research exploring if disgusting stimuli (e.g., differing in ambiguousness), tend, indeed, to undergo more thorough perceptual exploration may shed additional light on the matter.

Our results also suggested that dirty-distractors seem to divert attentional resources from target-items, irrespectively of the provided context (disease vs. non-disease); that is, whether the objects were described as being in direct physical contact with a sick person (i.e., being held by hands covered with diarrhea – a potential infection vector) or as being held by people whose hands were covered in chocolate spread (a non-contamination vector). In light of the ‘smoke detector principle’, the BIS might be over-reacting to potentially health-threating stimuli, potentially causing a false-positive interpretation of innocuous chocolate spread as a vehicle of diseases in order to minimize the likelihood of failing to avoid a truly contaminated item. Such interpretation might seem implausible in light of the lack of a significant difference on the disgust activation from the pre- to the post- task in the non-disease context. Nevertheless, our contextual activation might have worked (at least to some extent) as the subjective disgust ratings increased significantly from the pre- to the post-task in the disease context but not in the non-disease context. This combination of results is at odds with our prediction that the experience of disgust would facilitate attention toward potentially contaminated objects. We should note, however that the level of disgust disclosed by the participants was relatively low and possibly not strong enough to have an effect on the observed variables. Alternatively, as was proposed by Schaller in 2014, “the arousal of disgust may simply be coincident with, rather than an actual cause of, behavioral avoidance” (p. 253) and/or other processes related to the BIS. In addition, we should acknowledge the possibility that the attentional biases towards the dirty items, as compared to the clean hands, might be due to the low-level visual properties of the stimuli (e.g., luminance, contrast and visual complexity). Results are also possibly accounted for by several factors, such as the distinctiveness or novelty of the dirty stimuli. Take the example of studies showing increased visual attention and gaze allocation to physically disabled people compared to people with no disability (Ackerman et al., 2009; Miller & Maner, 2011). It was hypothesized that these people are perceived as a threat to health and, therefore, require vigilance (Park et al., 2003). However, other researchers suggest, as an alternative explanation, that the attention paid to disfigured people may be driven by the novelty of the disability (Langer, Fiske, Taylor, & Chanowitz, 1976). To what extent are our results driven by these features (e.g., distinctiveness, novelty)? This is a question that needs to be considered in future studies.

Similarly to what was found in van Hooff et al. (2013), participants were faster at identifying the target-letters presented at longer SOA. However, in such work, the authors found an attentional bias only at 200 ms (and not at 500, 800 and 1100 ms), arguing that the emotional effect on attention works at earlier stages of visual processing. In our study, the pattern of results was similar for the SOAs of 200 and of 350 ms. It is possible that the latter SOA still falls within the time frame of the emotional influence on perception but more studies are needed to explore these questions.

Regarding the target-identification accuracy, participants were equally good at identifying the target letters presented shortly after the cue-images of either dirty or clean hands and in both the disease and non-disease contexts. These results contradict our initial hypothesis, which predicted that participants would be less able to discriminate the target after the presentation of potentially contaminated items (vs. non-contaminated items) and, particularly, in the disease context (vs. non-disease context). Our results also disagree with the data of van Hooff and co-authors (2013, 2014), which found lower accuracy to identify targets followed by disgusting stimuli, particularly after a SOA of 100 and of 200 ms. This lower accuracy occurred in spite of the fact that participants took longer to correctly identify the target letters in these conditions. In our case, in order to maintain the same level of target identification accuracy for targets following the presentation of dirty hands as those followed by clean hands, participants did so at the expense of taking longer to identify the targets in the former case.

Target-letter detection was faster during the second half of the experiment, closely resembling what has been described in previous studies (van Hooff et al., 2013). However, not only were participants faster, but also more accurate in their judgments, a result that was different from that obtained by van Hooff et al. (2013), for whom none of the effects involving this variable were significant when exploring habituation effects. These differential results could be related to the fact that the disgusting component (dirty hands) was the same throughout the task whereas in their study they varied from stimuli to stimuli. In our study, the preferentially attentional capture by disgusting stimuli remained significant, even though participants got faster at detecting the target letter from the first to the second half of the experiment, suggesting that there was no habituation effect.

Finally, and regarding the final surprise free recall task, participants assigned to the disease context recalled more items than participants in the non-disease context. This marginally-significant effect is consistent with that reported in the discussion of studies 3a and 3b where a similar result was obtained. On the other hand, the lack of a mnemonic effect of type of stimuli (dirty vs. clean) is at odds with the pattern of results reported in the memory experiments that used dirty vs. clean stimuli. Such result could relate to differences in the encoding procedure used between experiments: whereas in the memory experiments participants were fully attending to the to-be-remembered objects and explicitly relating them to a disease (dirty hands) and non-disease (clean hands) condition, here they were trying to prevent these stimuli from exerting an effect in the discrimination performance. Still, they were able to recall a fair amount of objects, possibly due to the fact that they were presented eight times each during the experiment.

Interestingly, our results dissent from those studies that more directly explored attention to health-threatening information, building on the assumption that humans should have developed disease-avoidance strategies to solve the adaptive problem of preventing diseases. For example, by also administering a letter-identification task, Magalhães, Pandeirada, Fernandes, and Soares (2018) explored the attentional bias for neutral faces following contextual activation of the BIS. In their experiment, half of the participants were situationally primed with disease threat (i.e., watched a video about the flu virus) prior to performing the attentional task; the other half watched a video about cardiovascular disease instead (non-disease threat; control condition). Participants for whom disease threat had been experimentally primed showed significantly higher accuracy in detecting the target letter compared to those in the control condition. No significant difference between groups was found in the time taken to provide correct responses. The authors proposed that these results could be due to a general hypervigilance associated with the activation of the BIS. This study, however, differs from ours in their use of a priming procedure and neutral faces as cues, which are a special class of stimulus (Farah, Wilson, Drain, & Tanaka, 1998).

The current experiment used a novel procedure to explore the commitment of attention to potential contamination. Even though not all of our predictions were confirmed, the results showed that response times can be compromised when facing such stimuli. As noted throughout the discussion, the results are open to alternative explanations that require further investigation. Furthermore, the memory results are (partially) aligned with a mnemonic tuning for contamination. Further discussion of this exploratory study is provided in the General Discussion (Part IV).

III

EMPIRICAL
STUDIES

CHAPTER 6.

“It is not as bad for me as it is for you!”: Individual differences

- . Introduction
- . The impact of individual variables on memory for contamination
    - - Disgust propensity and sensitivity
    - - Perceived vulnerability to disease
    - - Participants’ health status
- . General discussion

6.1 Introduction

The BIS is supposed to be universal but flexible, varying in strength across individuals and situations (see Chapter 2 to a brief *Theoretical Introduction*). Chapter 6 attempted to explore, in a preliminary and very rough way, the impact of individual differences[16] on the magnitude of the memory advantage for contamination. As denoted in the procedural description of some of the studies, information on individual characteristics (i.e., propensity and sensitivity to disgust, perceived vulnerability to disease, and health status) were collected. In this chapter, we used that information to conduct exploratory analysis on this issue. To that end, we combined the samples from the different studies and split them into high and low subgroups on the variables of interest (e.g., high/low disgust propensity; high/low vulnerability to disease). We then explored if the size of the mnemonic effect for contamination would be influenced by those variables.

Firstly, an attempt was made to elucidate if people more prone to experience disgust and people who interpret such feelings as more negative or harmful, remember substantially better contaminated objects (vs. non-contaminated objects) than people less prone to feel disgust and people who were less concerned by being disgusted. Previous studies have consistently found that people who experience more disgust when perceiving potential contaminants, also displayed relatively less approach and more avoidance behaviors towards the disgust-eliciting stimulus (Deacon & Olatunji, 2007). As the emotion of disgust ought to function as a disease-avoidance mechanism (Oaten et al., 2009), it seems reasonable to expect disgust to influence memory retention as well. Remembering a contaminant means avoiding it successfully in future encounters. Thus, we tested whether individual differences in disgust propensity (the dispositional proneness to experience disgust; DP) and in disgust sensitivity (the extent to which people perceived their experiences of disgust as negative or harmful; DS) impact the mnemonic effect for contamination. Towards this end, the *Disgust Propensity and Sensitivity Scale-Revised* (DPSS-R; Olatunji et al., 2007) was applied in some of the studies conducted in Portugal and the *Pathogen Disgust Subscale* (PDS; Tybur et al., 2009) was administered in the studies conducted in the USA. This latter questionnaire only allows the assessment of the DP and, therefore, the DS of our American sample could not be investigated in the present research. We predicted that individuals with higher values in DP and DS would

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[16] Please consult Supplementary Material 2 for descriptive statistics of each scale in each study, as well as the correlation coefficients among the different variables.

demonstrate a stronger memory advantage for potentially contaminated items than those with lower scores in these dimensions.

Additionally, we wanted to explore if people who are – or perceive themselves to be – particularly vulnerable to diseases remember substantially more potentially contaminated objects (vs. non-contaminated objects) than people who are – or perceive themselves to be – less vulnerable to disease; that is, if the mnemonic advantage for contaminants would be larger in the former than in the latter group.

The BIS is believed to respond in a flexible manner to best manage the trade-offs between its benefits in terms of disease-avoidance and the costs accrued in other fitness dimensions (the 'functional flexibility principle': e.g., Murray & Schaller, 2016; Schaller & Park, 2011; Schaller et al., 2007). It would therefore seem to be especially beneficial to activate such a system under conditions in which people are – or subjectively perceive themselves to be – more vulnerable to infection. In such a situation, an increased activation of the BIS would confer a significant fitness advantage as it would provide an alternative solution to the organism when the BIO responsiveness to pathogens is compromised (Nairne & Pandeirada, 2008). Accordingly, people who consider themselves more vulnerable to infection or who are particularly susceptible to infections due to some degree of immune impairment (e.g., recent illness, pregnancy), showed more aversive responses (e.g., more disgust, more avoidance behaviors, and so forth) to things or people that may pose an infection risk (Miller & Maner, 2011).

To provide a preliminary investigation of whether individuals' subjective perception of vulnerability to infection is likely to influence the mnemonic tuning for contamination, the *Perceived Vulnerability to Disease Scale* (PVDS; Duncan et al., 2009) was administered in some of the memory experiments (see Chapter 4). The PVDS is theorized as having two distinct constructs: people's subjective beliefs about their likelihood of contracting a disease [i.e., Perceived Infectability (PI)] and their subjective discomfort in contexts in which pathogens can be transmitted [i.e., Germ Aversion (GA)]. Previous researchers found these two constructs to predict different outcomes (Duncan et al., 2009). For example, GA (but not PI) has been associated with negative evaluations of obese people (Park et al., 2007), whereas PI (but not GA) is related to negative reactions toward the elderly (Duncan & Schaller, 2009). Thus, besides exploring the influence of the overall PVD score on memory performance we also explored the impact of each of the subscales. The influence of PVD on memory was only explored in Portuguese participants because the application of the respective questionnaire was not part of the IRB protocol, and therefore, could not be administered to students from Purdue University. We predicted that objects characterized as potential sources of contamination would be more likely remembered than objects that carried a lower risk of contamination in both groups with low or high PVD, but particularly so for those people who feel particularly vulnerable to diseases.

In some of the experiments, the participants' health status (illness recency) was also measured using the questions proposed by Miller and Maner (2011). Following these authors, we hypothesized a more prominent activation of the BIS in individuals who had recently been ill or who were still sick at the time of the study; this follows from the idea that these participants would experience a decline in their immune function and consequently an increased susceptibility to new diseases. Hypothetically, this would translate into a higher mnemonic advantage for contamination in such participants compared to those who are or have been healthy at the time of the study (and, thus, would be less vulnerable to diseases).

6.2 The impact of disgust propensity and sensitivity on memory for contamination

To test whether, and to what extent, individual differences in disgust propensity and sensitivity influence the mnemonic tuning for contamination, memory performance of participants scoring high was compared to that of participants scoring low on these dimensions ("combined": global DPSS-R score, and "separated": scores obtained in each DPSS-R subscale).

6.2.1 Method

Participants. Portuguese participants from Studies 3a and 4b were pooled together to create a sample of 96 participants, which were split in two groups based on their total scores and subscale scores on the DPSS-R (see description in the Materials). The combined American samples of Studies 5a, 5b and participants in the disease-context of Study 6 (total *N* = 136) were similarly divided into two groups, according to the participants scores on the PDS (see also the Materials for a detailed description of the instrument). Table 14 shows the number of participants in each group and the average score obtained for each dimension after splitting the sample in low/high groups.

Table 14.

Number of participants assigned to each subgroup (low and high DPS, DP and DS) along with the corresponding mean score and standard deviation.

		Portuguese sample			American sample		
		N	*M*	*SD*	*N*	*M*	*SD*
Combined disgust propensity and sensitivity	**Low**	57	27.09	4.24			
	High	39	37.28	4.70			
Disgust Propensity	**Low**	53	16.85	2.26	71	3.48	0.58
	High	43	22.26	2.54	65	4.77	0.35
Disgust Sensitivity	**Low**	50	8.86	2.16			
	High	46	15.33	2.47			

Materials.

The Disgust Propensity and Sensitivity Scale-Revised (DPSS-R; Olatunji et al., 2007). The DPSS-R measures DP, the individuals' dispositional tendency to experience disgust (that is, the ease with which people become disgusted; e.g., item 8: "I experience disgust"), and DS, the emotional impact of disgust experiences (that is, how negatively people appraise such experiences or how concerned they are by being disgusted; e.g., item 3: ''It scares me when I nauseous"). Participants rated the 11 items that compose the Portuguese version of the DPSS-R, on a 5-point Likert-type scale ranging from 1 (never) to 5 (always). Total scores, which range from 11 to 55, were calculated by summing all responses. The DP and DS scores were computed by summing the items from each subscale (i.e., DP: items 1, 4, 5, 6, 8, 10; DS: items 2, 3, 7, 9, 11). The questionnaire was validated for the Portuguese population by Ferreira et al. (2016), demonstrating good internal consistency, as shown by a Cronbach's coefficient alpha higher than .7 (α = .833 for the DPSS-R, α = .776 for DP, and α = .790 for DS). In the present study, internal consistency was also good (α = .854 for the DPSS-R, α = .812 for DP, and α = .775 for DS). Following previous studies (e.g., Bell & Buchner, 2010), participants were split in two groups based on their median scores on the entire scale and on each subscale ($Mdn_{DPSS\text{-}R}$ = 32, Mdn_{DP} = 19, Mdn_{DS} = 12). Participants with scores below or equal to the median value were considered "low", whereas participants with scores higher than the median were described as "high" in each dimension (i.e., DPS, DP and DS).

Pathogen Disgust Subscale of the Three Domain Disgust Scale (PDS; Tybur et al., 2009). The Three Domain Disgust Scale assesses disgust propensity for pathogen, sexual, and moral domains. Only the 7-item Pathogen Disgust Subscale of the Three

Domain Disgust Scale was used in our studies. This subscale measures the degree to which stimuli highly related with disease elicit disgust (e.g., item 2: “Shaking hands with a stranger who has sweaty palms”). Participants are requested to rate the degree to which they fell each situation disgusting, using a 7-point Likert-type scale ranging from 0 (not disgusting at all) to 6 (extremely disgusting). The PDS score was calculated as the mean of ratings assigned to each item, with higher scores reflecting higher DP (total score ranges between 0 and 6). Participants were similarly grouped into two groups based on their scores; the median value of 4.14 was used as the dividing point.

Previous studies have established good internal consistency ($\alpha = 0.83$), concurrent validity, and discriminant validity of this subscale (Tybur et al., 2009). The Cronbach's alpha coefficient on our sample was .669.

Procedure. The DPSS-R and the PDS were administered to the Portuguese and American participants, respectively, after completing the PVDS and the health status questionnaire (in the case of Portuguese participants) or after rating the stimuli on particular dimensions (e.g., arousal; in the case of American participants), as also denoted in the description of the procedure in the corresponding studies in Chapter 4.

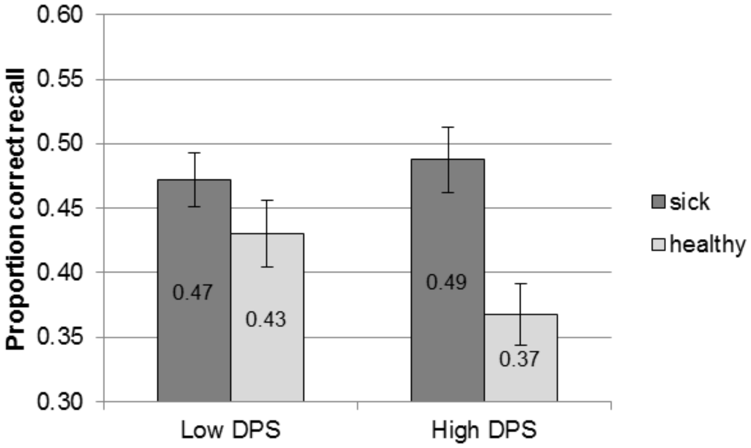
Statistical analysis. To investigate the degree to which self-reported DPS, DP and DS differentially affect the mnemonic effect for contaminants, a two-way mixed ANOVA was conducted, with group (i.e., low and high) as a between-subjects factor and image condition (i.e., sick and healthy) as the within-subject factor. Paired-samples *t*-tests were also conducted separately for each group, whenever the interaction was significant.

6.2.2 Results

Combined disgust propensity and sensitivity. There was a significant main effect of condition, $F(1, 94) = 15.37$, $MSE = 0.302$, $p < .001$, $\eta_p^2 = .141$, but not of group, $F(1, 94) < 1$, and a marginally significant interaction between the variables, $F(1, 94) = 3.57$, $MSE = 0.070$, $p = .062$, $\eta_p^2 = .037$. Separate follow-up analyses for each group indicated that participants scoring high in DPS recalled significantly more of the objects touched by sick than healthy people, $t(38) = 3.84$, $p < .001$, $d = .615$; whereas participants with low DPS did not differ significantly on the proportion of objects recalled in each of the conditions, $t(56) = 1.57$, $p = .121$ (see Figure 25).

Figure 25.

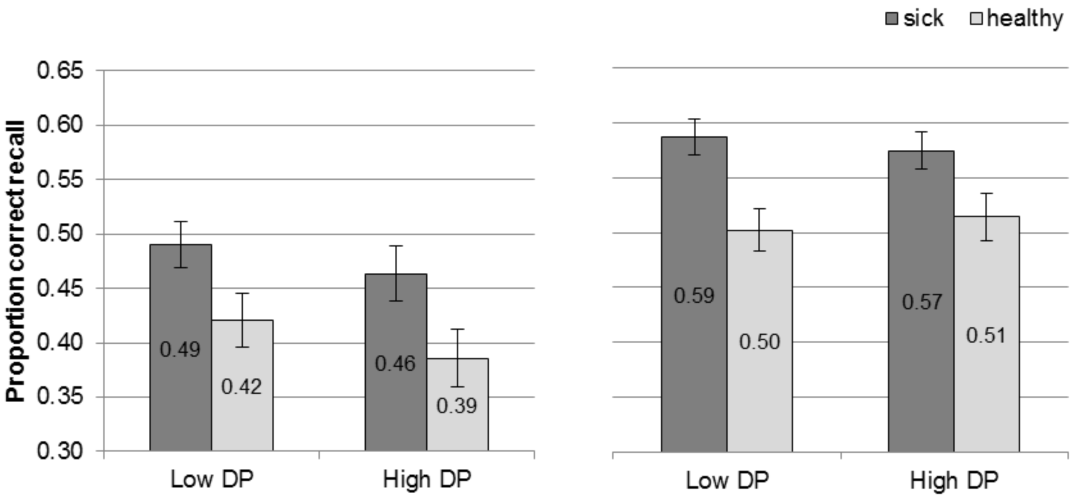
Mean proportion of recall for each condition by Portuguese participants with low and high DPS. Error bars represent SEM.



Disgust propensity. Results from the mixed ANOVA failed to indicate a significant main effect of group or interaction between group and condition, both in the Portuguese, *F*(1, 94) = 1.23, *MSE* = 0.045, *p* = .270 and *F*(1, 94) < 1, respectively, and in the American sample, both *Fs*(1, 134) < 1. Nevertheless, the main effect of condition remained significant in the two samples [Portuguese: *F*(1, 94) = 12.71, *MSE* = 0.259, *p* = .001, η_p^2 = .119; American: *F*(1, 134) = 19.89, *MSE* = 0.356, *p* < .001, η_p^2 = .129], suggesting that people remembered more contaminated than non-contaminated objects, irrespectively of their DP (see Figure 26).

Figure 26.

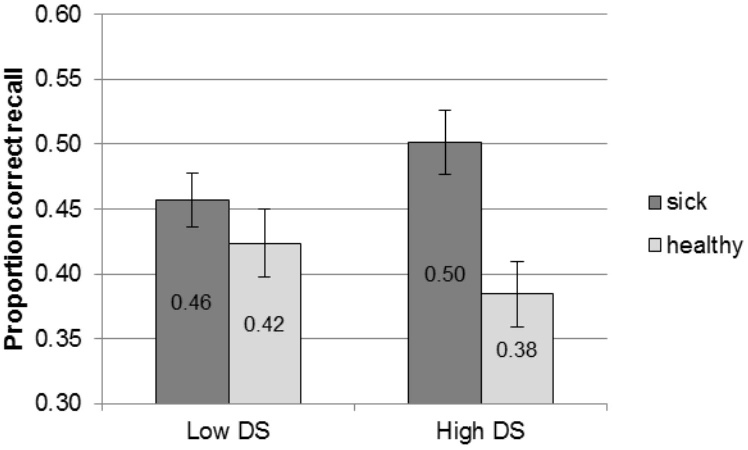
Mean proportion of recall for each condition by Portuguese participants (on the left) and by American participants (on the right) with low and high DP. Error bars represent SEM.



Disgust sensitivity. Results revealed a significant main effect of condition, $F(1, 94) = 13.89$, $MSE = 0.271$, $p < .001$, $\eta_p^2 = .129$, denoting the mnemonic advantage for contamination. The interaction between variables was also significant, $F(1, 94) = 4.30$, $MSE = 0.084$, $p = .041$, $\eta_p^2 = .044$. The main effect of group was not significant, $F(1, 94) < 1$. Further analyses conducted separately for each group revealed that people with high DS showed an enhanced memory advantage for contaminated than non-contaminated items, $t(45) = 4.17$, $p < .001$, $d_z = 0.615$, whereas this effect was not statistically significant for the participants low in DS, $t(49) = 1.16$, $p = .253$, even though, descriptively, the results are in the same direction (see Figure 27).

Figure 27.

Mean proportion of recall for each condition by Portuguese participants with low and high DS. Error bars represent SEM.



6.2.3 Interim discussion

The hypothesis that individuals high in DP are particularly good at remembering contaminated items, more so than low-DP people, was not verified. Both high- and low-DP groups recalled significantly more items touched by sick than healthy people. This pattern of results was consistent in the two different cultural samples (Portuguese and American) and using different measures to assess DP (with a specification of a set of disgust elicitors or without such specification). Nevertheless, our findings provide support for the hypothesis that memory for contamination depends upon the extent to which people evaluate negatively their experiences of disgust as the high-DS participants demonstrated a stronger memory advantage for potentially contaminated items (vs. non-contaminated items) than the low-DS group. In fact, in the low-DS group of participants, the mean proportion of items recalled from each condition did not differ significantly, even though their memory was still descriptively better for contaminated objects (as compared to the non-contaminated objects). These findings highlight the potential importance of incorporating the assessment of both constructs (DP and DS), since they seem to influence memory differently.

6.3 The impact of perceived vulnerability to disease on memory for contamination

Next we analyzed if individual differences on memory performance for disease-related stimuli might be tied to individual differences on perceived vulnerability to disease.

6.3.1 Method

Participants. Data collected from 96 undergraduate Portuguese students who participated in Studies 3a and 4b were combined. To thoroughly examine the potential influence of the PVD, participants were stratified into two groups based on their global scores and scores on each subscale of the PVD (see description in the Materials; Table 15).

Table 15.

Number of participants assigned to each subgroup (low and high PVD, PI and GA) along with the corresponding mean score and standard deviation.

		N	*M*	*SD*
Perceived vulnerability to disease	**Low**	48	2.63	0.43
	High	48	3.98	0.53
Perceived Infectability	**Low**	52	2.25	0.59
	High	44	3.89	0.72
Germ Aversion	**Low**	50	2.87	0.53
	High	46	4.40	0.74

Materials.

Perceived Vulnerability to Disease Scale (PVDS; Duncan et al., 2009). The PVDS was used to assess the participants' beliefs about their susceptibility to infectious diseases (PI; e.g., item 7: "In general, I am very susceptible to colds, flu and other infectious diseases."), and the participants' discomfort regarding situations of an increased likelihood for the transmission of pathogens (GA; item 1: “It really bothers me when people sneeze without covering their mouths.”). The Portuguese version of the questionnaire (Ferreira et al.) was administered. This version is composed of 12 items. Participants were asked to indicate the extent of agreement or disagreement with each item, using a 7-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). Participants' scores on each subscale were computed by averaging their responses for the items on each subscale (i.e., PI: items 2, 5, 7, 8, 10, 11; GA: items 1, 3, 4, 6, 9, 12) after reverse-scoring the negatively worded items. The total score was calculated by averaging all responses. Higher scores indicate greater PVD. Participants were divided in two groups according to their perceived vulnerability to disease (median split from PDVS total score) and according to scores on each subscale (Mdn_{PDVS} = 3.29, Mdn_{PI} = 3.00, Mdn_{GA} = 3.50).

The scale has shown good internal consistency (α = .804 for PI, and α = .746 for GA). In the current study, the Cronbach's Alpha coefficients were .771 for the PVDS, .819 for PI, and .647 for GA.

Procedure. Participants completed the PVDS scale at the end of the experiments, immediately after the surprise memory task.

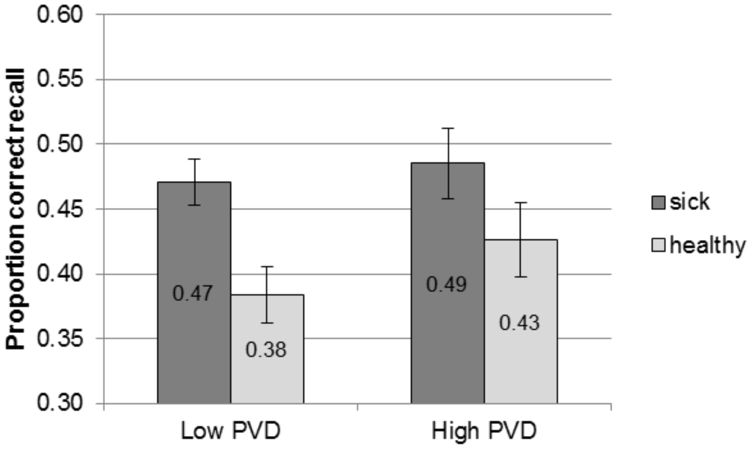
Statistical analysis. A two-way mixed ANOVA was conducted, with group (i.e., low and high) as a between-subjects factor and image condition (i.e., sick and healthy) as the within-subject factor.

6.3.2 Results

Perceived vulnerability to disease. The mixed ANOVA indicated that the main effect of condition was significant, $F(1, 94) = 12.76$, $MSE = 0.259$, $p = .001$, $\eta_p^2 = .120$, but neither the main effect of group, $F(1, 94) = 1.08$, $MSE = 0.039$, $p = .302$, nor the interaction between the two variables approached significance, $F(1, 94) < 1$. Potentially contaminated items were better retained than non-contaminated items, irrespectively of participants’ PVD (see Figure 28).

Figure 28.

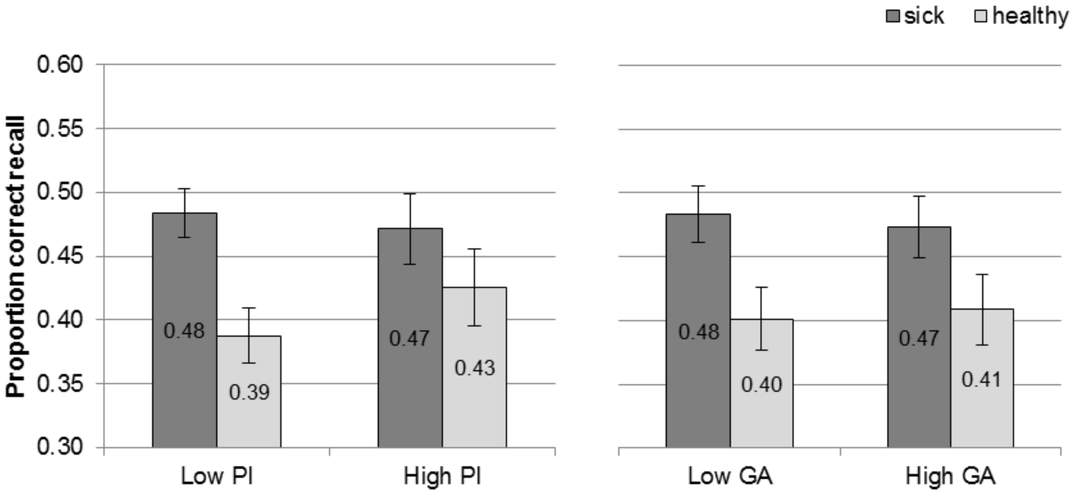
Mean proportion of recall for each condition by participants with low and high PVD. Error bars represent SEM.



***Perceived Infectability*.** Results revealed a significant effect of condition, *F*(1, 94) = 12.09, *MSE* = 0.243, *p* = .001, η_p^2 = .114, but neither the main effect of group nor the interaction between the two variables were significant, *F*(1, 94) < 1 and *F*(1, 94) = 1.50, *MSE* = 0.030, *p* = .224, respectively (see Figure 29).

Figure 29.

Mean proportion of recall for each condition by participants with low and high PI (on the left) and with low and high GA (on the right). Error bars represent SEM.



Germ Aversion. Data regarding GA closely followed the result pattern found in the two PVD and the two PI groups. That is, a significant main effect of condition was found, $F(1, 94) = 12.57$, $MSE = 0.256$, $p = .001$, $\eta_p^2 = .118$, but neither the main effect of group nor the interaction between the two variables reach significance, both $Fs(1,94) < 1$ (see Figure 29).

6.3.3 Interim discussion

We predicted that, under circumstances in which participants felt especially vulnerable to infectious diseases, the mnemonic advantage for contamination would be especially strong. However, this hypothesis was not supported as both groups (low- and high-PVD) remembered more items touched by sick than those touched by healthy people. The pattern of results was constant, even when considering the individuals' explicit beliefs regarding their susceptibility to contracting infectious diseases (PVDS-PI subscale), and the individuals' emotional discomfort in situations that imply high likelihood of pathogen transmission (PVDS-GA subscale) separately.

6.4 The impact of participants’ health status on memory for contamination

Finally, we examined if the participants’ health status at the time of the experiment played a role in strengthening memory for contaminated items. Particularly, we tested if the mnemonic tuning for contamination was especially strong in those participants that were ill or had been recently ill.

6.4.1 Method

Participants. Participants who took part in Studies 3a, 4a, 4b, 5a, 5b, and the disease context of Study 6 responded to questions regarding their health status and thus their data were combined into a single dataset ($N = 337$). Participants were classified into two groups (recently ill and not recently ill) based on their self-reported health status using both a continuous and a categorical measure (see description in the Materials). According to the first measure, 65 (19.3%) participants were considered as ill and 76 (22.6%) as not ill (see Table 16); the remaining participants were not included. According to the latter measure, the majority of the participants were not ill when they responded to the task ($n = 214$; 63.5%) whereas 112 (33.2%) participants reported being ill when they participated or during the preceding week (see Table 16). Eleven participants could not be categorized with respect to this variable due to a technical error that prevented collection of these data.

Table 16.

Number of participants assigned to each subgroup (recently ill and not recently ill) along with the corresponding mean score and standard deviation.

		N	*M*	*SD*
Continuous measure	**Recently ill**	65	5.46	0.74
	Not recently ill	76	1.06	0.11
Categorical measure	**Recently ill**	214		
	Not recently ill	112		

Materials.

Health status questionnaire. Participants' illness recency was measured by administrating the questions developed by Miller and Maner (2011). Participants reported their level of agreement with four statements (continuous measure): (1) "Over the past couple of days, I have not been feeling well"; (2) "Lately, I have been feeling a little under the weather"; (3) "I felt sick within the past week"; and, (4) "I had a cold or flu recently." All items were rated on a 7-point Likert-type scale that ranged from 1 (strongly disagree) to 7 (strongly agree). An average score of all of these responses was computed for each participant and used as a continuous measure of his/her health status. Following the same grouping strategy adopted by the authors, participants with an average score of 4.50 or higher (i.e., > 1 SD above the mean for the entire sample) were considered 'recently ill' and those with an average score of 1.28 or lower (i.e., < 1 SD below the mean) were considered 'not recently ill'. Scores of the remaining participants (*n* = 196) fell in the middle and, therefore, were not included in the analyzes.

Additionally, participants were asked to specify which of the following response options best described the last time they were sick (e.g., had a cold; categorical measure): "today," "a couple days ago," "a week ago," "a couple weeks ago," "a month ago," "a few months ago," and "a year or more ago." Participants were categorized into two groups: recently ill (if the participant selected one of the first three response options) and not recently ill (if participants provided one of the other options). This categorization was chosen because it "reflects the typical window of the BIO system's heightened susceptibility to new diseases after infection" (Miller & Maner, 2011, p. 1468).

Procedure. The health status questionnaire was applied at the end of the experiments, after participants responded to the PVDS (in the case of Portuguese participants) or the PDS (in the case of American participants).

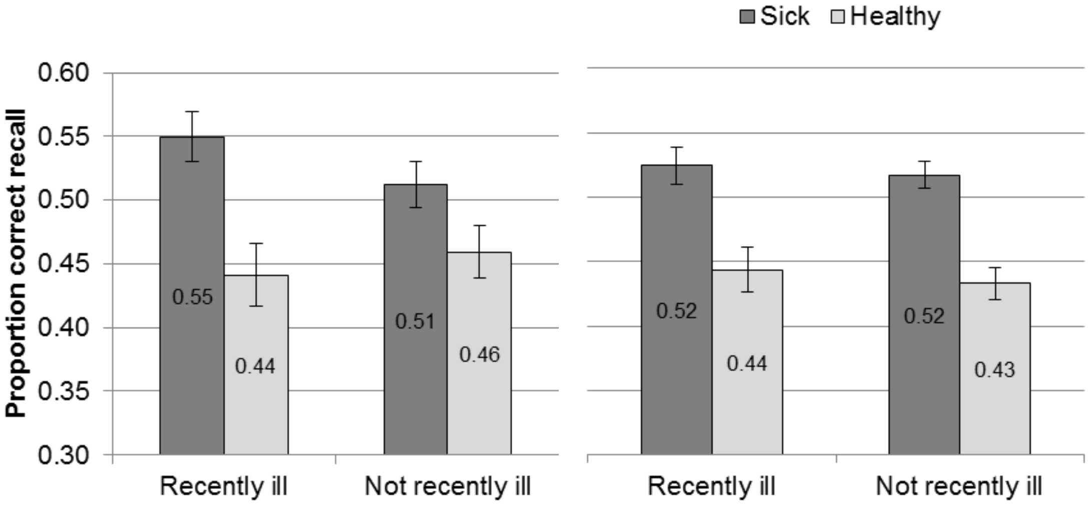
Statistical analysis. The influence of the participants' health status in the strength of the mnemonic effect for contamination was assessed through a two-way mixed ANOVA, with group (i.e., recently ill and not recently ill, according to both the categorical and the continuous measure) as a between-subjects factor and image condition (i.e., sick and healthy) as the within-subject factor.

6.4.2 Results

Using the continuous measure of illness recency, the main effect of condition remained significant, $F(1, 139) = 23.09$, $MSE = 0.453$, $p < .001$, $\eta_p^2 = .142$, and no main effect of group was found, $F(1, 139) < 1$. However, the interaction between condition and group was marginally significant, $F(1, 139) = 2.80$, $MSE = 0.055$, $p = .096$, $\eta_p^2 = .020$. An enhanced memory effect for contaminated than non-contaminated items was found in both groups; however, this effect was particularly strong in the group of participants who had been recently ill, $t(64) = 4.57$, $p < .001$, $d_z = .577$, as compared to those not recently ill, $t(75) = 2.24$, $p = .028$, $d_z = .258$ (see Figure 30).

Figure 30.

Mean proportion of recall for each condition by participants who had and who had not been recently ill using the continuous (on the left) and the categorical (on the right) measure of illness recency. Error bars represent SEM.



A mixed ANOVA on the categorical measure indicated that the main effect of condition was significant, $F(1, 324) = 56.69$, $MSE = 1.00$, $p < .001$, $\eta_p^2 = .149$, but neither the main effect of group nor the interaction between the two variables reached significance levels, $Fs(1, 324) < 1$. These results suggest that, considering this categorical measure, potentially contaminated items were better retained than non-contaminated items, irrespectively of the participants' health status at the time of the experiment (see Figure 30)[17].

6.4.3 Interim discussion

Overall, the memory advantage for contaminated items was replicated in both groups of individuals who had and had not suffered from a recent illness. However, when considering the continuous measure, the size of the effect regarding the difference in memory for objects touched by sick and healthy people was larger in individuals who had recently been ill, as compared to that of the groups of participants who scored lower on this measure, a result that is consistent with our initial hypothesis.

6.5 General discussion of exploratory analyses on individual differences

This chapter presents exploratory analyses conducted with the goal of obtaining a more comprehensive understanding of whether and how individual differences influence the mnemonic tuning for contamination. Our data suggest that the way people appraise and cope with disgusting experiences (i.e., DS) impacts memory performance for disease-related stimuli, as the mnemonic tuning for contamination was particularly pronounced for participants scoring high in this dimension; of note, memory performance in the low-DS people still matched the predicted pattern – more contaminated than non-contaminated objects being recalled, although the difference was not statistically significant. However, the same does not hold true for the degree to which people feel disgusted by disgust elicitors (i.e., DP), as the memory advantage for potentially contaminated (vs. non-contaminated) items was found, irrespectively of the participant's disgust propensity.

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[17] Additional analyzes were conducted with the sample divided into three groups as follows: currently ill (if the participant selected "today"; $n = 38$), recent illness but not currently ill (if the participant selected either "a couple days ago" or "a week ago""; $n = 74$) and not recently ill (if participants provided one of the other options; $n = 214$). A significant main effect of condition, but no significant main effect of group nor interaction, was similarly found. It is interesting to note, however, that the memory advantage for contamination (as compared to the non-contamination items) was descriptively stronger in the currently ill group (a difference of 12% vs. 6% vs. 8%, respectively for each group).

The few studies that have addressed the impact of disgust propensity on cognitive processes have yielded contradictory results. For example, Charash and McKay (2002) found that people more prone to feel disgust are also more likely to direct their attention towards to and to remember disgust-related stimuli, particularly those primed with disgusting stories. In addition, Bell and Buchner (2010) observed a source-memory advantage for faces associated with disgusting descriptions, which was further modulated by participants' disgust propensity; although both high- and low-DP individuals were better at identifying the source of faces previously paired with disgusting behaviors (vs. pleasant and neutral behaviors), the magnitude of the effect was larger in the high-DP group. Vogt et al. (2011), on the other hand, found no evidence of an effect of DP on attention to disgusting pictures. As far as we know, no other studies have tested the influence of DS on memory for disease-related stimuli. It is possible that these apparently disparate conclusions are related to the variety of instruments that have been used to evaluate participants' disgust propensity and also to the different cognitive processes that have been explored (source memory, free recall, attention).

Schaller (2014) argued that disgust is likely to be “concomitant rather than an antecedent cause” (p. 252) of disease-avoidance behaviors. Consequently, one’s aptitude to avoid contact with infectious carriers is plausibly causally independent of one's capacity to experience disgust (Schaller, 2014). Accordingly, Nicholson and Barnes-Holmes (2012) claimed that it is the DS, rather than the DP, that drives behaviors to mitigate disease-threats; that is, the more negatively people interpret disgust, the more likely they are to engage in disease-avoidance behaviors (see, however, Goetz, Lee, Cougle, & Turkel, 2013 for contraditory results). Such findings neatly parallel those obtained in our exploratory analyses.

Grounded in the ‘functional flexibility principle’ we also predicted that, under circumstances in which participants felt especially vulnerable to infectious diseases (PVD) or were actually more vulnerable to diseases (recent illness), the mnemonic advantage for contamination would also be especially strong. With regards to the PVD, our results contrast with prior studies that have found a positive association between self-perceived vulnerability to infectious diseases and disease-avoidance strategies. For example, individuals who believe themselves to have significantly higher vulnerability to disease also groom themselves more than individuals who believe to be less vulnerable (Prokop et al., 2014; Thompson, 2010). Instead, we found that the mnemonic advantage for contamination was held, independently of the individuals' self-perceived vulnerability to infections. It should be noted that these studies tested different components of the BIS other than the cognitive, which could explain the discrepancy of results. In fact, our findings are in line with those obtained by Prokop et al. (2014), who reported that people who considered themselves more vulnerable to infectious diseases did not retain more information on parasites than those less vulnerable.

Our results, when based on a continuous measure of illness recency, seem to point to a stronger mnemonic tuning for contamination in participants who had recently been ill or were still sick at the time of the study. However, the same did not hold true when groups were formed based on a categorical measure; analyses using this last classification showed that participants recalled significantly more items that harbor pathogenic microorganisms, independently of their health status. These findings differ from those of previous studies, which have shown that having had a recent illness seem to yield a compensatory activation of the BIS. For example, Miller and Maner (2011) found participants to be particularly wary of conspecifics exhibiting heuristic cues signaling infectious disease (that is, were more attentive to) and had stronger avoidant motor responses to disfigured faces. However, a contrary result was noticed by Prokop, Fančovičová, and Fedor (2010) who found that better health was positively associated with more disease-avoidance behaviors (including contact with pathogen-carrying conspecifics, contact with animals, and hygiene practices). Again, such studies explored disease-avoidance behaviors instead of memory.

It is interesting to note that, regardless of the effect of the individual variables we explored, our data yielded consistent findings in the predicted direction – that is, better memory performance for potentially contaminated items in all groups. One should keep in mind that these results are still very preliminary and several caveats need to be considered before drawing meaningful and strong conclusions (see Chapter 7 for insight into the limitations of these analyses and suggestions for future studies). Nonetheless, and although only exploratory in nature, our results highlight the importance of considering individual differences when studying disease-avoidance strategies.

PART IV

GENERAL DISCUSSION AND CONCLUSIONS

IV

GENERAL DISCUSSION AND CONCLUSIONS

CHAPTER 7.

What did we find out and where to go next?

. Summary, integration, and limitations of the experimental findings

. Open questions and possible future directions

. Concluding remarks

7.1 Summary, integration, and limitations of the experimental findings

Over our evolutionary history, humans have recurrently faced a broad array of adaptive problems, including selecting and retaining a desirable mate, deterring sexual rivals, hunting for food, caring for children, navigating terrains, gathering and securing resources, engaging in social exchange, detecting and avoiding predation, and – most central to the core of this project – detecting and avoiding disease-causing microorganisms (Buss & Penke, 2015; Kenrick et al., 2010; Nairne & Pandeirada, 2008). Our ancestors evolved and thrived in environments fraught with pathogens, long before medicine was available and the etiology and pathogenesis of infectious diseases were known (Tybur & Lieberman, 2016). To cope with life-threatening pathogens, natural selection crafted the BIO and the BIS, "as well as the functional integration and synergy of these two systems in defending against parasites" (Thornhill & Fincher, 2015, p. 419). Whereas the BIO has been long-recognized as playing an important role in detecting and destroying pathogens within the human body, the BIS has only recently come under study (although see Murray, Prokosch, & Airington, 2019). This latter system offers unique adaptive benefits by minimizing one's exposure to harmful pathogens, thereby preventing acquisition and transmission of infection in the first place (Schaller & Park, 2011). To that end, the BIS prompts a cluster of functionally-coordinated psychological processes (i.e., affective, cognitive, and behavioral processes) in response to environmental cues connoting infection risk.

The main objective of this thesis was to explore the cognitive mechanisms underlying the operation of the BIS. To achieve this goal, substantial time and effort was dedicated to the development and validation of a database of images, which we named the "Objects-on-Hands Picture Database". Needless to say, the design of optimal experimental procedures, including the selection of appropriate stimuli, has been a long-standing goal shared by researchers. Pictures are commonly used in different research fields although, often times, they have lacked ecological validity (e.g., line-drawings). We developed a set of high-quality standardized photographs of objects from six different categories (women's accessories, fruits, kitchen utensils, office supplies, toys, and vegetables), recorded under two camera viewpoints (frontal and top viewpoints), and five presentation conditions (on its own, held by clean hands, and by hands covered with different substances: sauce, chocolate and mud). As illustrated in Chapter 3, we expect this database to be of great value for researchers from different knowledge domains and with different research goals. Care was also taken to normalize the photo stimuli for name agreement and familiarity (Study 1). Such information was collected both in Portuguese and American samples to increase the utility of the dataset to researchers from different countries. Information on arousal, disgust and emotional valence (Study 2) was also gathered on a Portuguese sample. All of these variables are well known to impact performance in a variety of tasks.

Furthermore, data on arousal, disgust and emotional valence were collected when stimuli were framed in different contexts (e.g., disease vs. non-disease vs. no-context). Overall, the obtained results support the idea that one's emotional state, when using exactly the same stimuli, can be influenced by the provided context. Researchers strive to maximize the ecological validity of their studies by using photographs but, frequently, such studies contain item-selection problems. For example, a task comparing mnemonic performance for disgusting with non-disgusting items typically uses different stimuli, which invites alternative accounts based on the items themselves, rather than simply based on the emotional manipulation (we return to this point below). Our database allows researchers to avoid item-selection problems commonly present when comparing responses to neutral and emotional items since various staging conditions can be used to induce different emotional states while keeping the object of interest constant.

Having secured adequate stimulus materials for solving item selection artifacts, we proceeded to the main contribution of this work, which was to explore the existence of a mnemonic tuning for contamination. Previous studies have found that disgust-eliciting stimuli – commonly associated with transmission paths of pathogens – were recalled and recognized better than frightening, positive or neutral stimuli (e.g., Chapman et al., 2013). Nonetheless, as already pointed out, these studies typically suffered from a methodological problem as they compared memory performance across different stimuli. In fact, even when considerable effort is devoted to equating the stimuli, they may still vary along a number of uncontrolled (and potentially relevant to memory) dimensions (Nairne, 2010). To ensure that a mnemonic advantage does not depend upon intrinsic features of the to-be-remembered stimuli, in our experiments everyone was asked to remember exactly the same "neutral" stimuli but their fitness-relevance was manipulated by framing them as potentially contaminated or as non-contaminated.

Our studies were inspired by the "law of contagion", which states that, when two things come into contact, there is a transference of properties between them (Rozin & Fallon, 1987; Rozin et al., 1986). Thus, when a disease-source contacts another object, the object becomes "contaminated", eliciting a disgust reaction. This has been demonstrated, for example, by participants' reluctance and refuse to drink a juice that had been in contact with a dead sterile cockroach (Rozin et al., 1986). Avoiding objects that may be contaminated by contact with a primary route of infection is clearly adaptive, as pathogens can survive or persist in these objects for long periods (e.g., *Escherichia coli* has been reported to live on inanimate objects for 1.5 hours to 16 months), causing objects to be as contagious as the original source of disease (Kramer, Schwebke, & Kampf, 2006). As Chapman and Anderson (2012) put it: “the clothing or bedding of a person who has a skin infection may be almost as infectious as the diseased person themself" (p. 63). In order to avoid them in future encounters, we need to remember which objects are potentially contaminated.

Researchers already know that memory is specially tuned to disgusting items, but does this memory boost extend to things that have come in contact with something disgusting or signaling disease? To address this issue we tested whether people would remember items that have been touched by a sick person better than when the same items were touched by a healthy person. Adopting an immediate memory paradigm, participants were presented with sub-sets of three items along with cues denoting the health status of the person who contacted with each item (i.e., cues of sickness or cues of health). Then, after every third item, these same items were again presented and participants had to indicate whether each had been touched by a sick or a healthy person (encoding phase). After a series of these presentations and a short distractor task, participants were asked to remember all the items they had seen during encoding (surprise free recall task). We anticipated a recall advantage for the objects that had come in contact with a source of contamination – a sick person (Studies 3-7).

As Ryan et al. (2012) pointed out, the vast majority of diseases that afflict mankind – those that bear the highest mortality and morbidity rates – produce symptoms particularly noticeable on the face. Therefore, in Study 3a the potential for contamination was informed via the association of faces with diagnostic signs of contagious diseases. Objects touched by people with sick faces were found to be remembered significantly better than when they were touched by people with a healthy face. The effect was extended to source memory as well; that is, when asked to indicate who touched the object, a sick or a healthy person, participants were significantly better at identifying that the object had contacted a sick person.

People may rely on different information sources when deciding whether an object is contaminated or not; not only perceptual cues (e.g., those extracted from faces), which are not always available, but also verbal information shared socially. Thus, in Studies 4a and 4b, short descriptors served as cues of contamination status. Even though, “linguistic labels are an historically recent means of identifying diseased individuals” (Park et al., 2003, p. 68), the mnemonic advantage for contamination was again observed, with participants remembering items associated with sick descriptors better than those associated with healthy descriptors.

Following the above-mentioned studies, Studies 5 and 6 explored the direct transmission of contamination by presenting objects in direct physical contact with a contamination (dirty hands covered with vomit: Studies 5a and 5b; dirty hands covered with diarrhea: disease context of Study 6) or a non-contamination source (clean hands). In these experiments, only a single cue of contamination was presented during the entire task (i.e., dirty hands), as opposed to our previous studies which used multiple different cues (e.g., the faces could contain signs of conjunctivitis, herpes, or Sweet syndrome). A single cue was enough to boost memory for the contaminated objects (as compared to the clean ones) as a contamination advantage was replicated.

In all of the above described memory studies in which a mnemonic advantage was obtained for the objects presented along with a cue of potential contamination, the sick condition (sick faces, sickness descriptors or dirty hands) was compared against a healthy condition (health faces, physical descriptors or clean hands), always using a within-subject design. Note, for example, that the “healthy” descriptors represent benign descriptors of a person’s physical appearance (e.g., “person with brown hair”, “person with green eyes”). It is possible that the disease-connoting sentences might be more distinct than the latter which could somehow “transfer” to the accompanying object. In the future, other descriptors could be used (e.g., “person with a birthmark”, “person sneezing because of cat allergy”, “person with a tattoo”, “person with eye twitch”). Such descriptors do not indicate sickness but might be closer to the “sick” descriptors used in our studies in terms of distinctiveness. Similarly, instead of using neutral faces without any manipulation to represent healthy faces we could add distinctive features (e.g., tattoos, piercings, hair color, makeup) to equate the stimuli for distinctiveness. In fact, distinctiveness has been consistently shown to enhance memory in within-subject designs (for reviews, see Huff, Bodner, & Fawcett, 2015; Hunt & Worthen, 2006). However, we are not aware of previous empirical work that has tested such putative form of “distinctiveness contagion” to associated objects. Furthermore, if an item (face, descriptor or hand) is more distinctive, and thus potentially more likely to grab the participants’ attention (Hunt & Worthen, 2006), it is feasible that it would reduce the attention paid to the associated items (the to-be-remembered items) as compared to less distinctive accompanying items. Consequently, this more limited attention could actually produce poorer memory performance for the objects (as less attention was devoted to them) in the more (allegedly) distinctive condition; our results confirmed the opposite of this prediction. Thus, we think it is unlikely that distinctiveness of the contamination cue (sick faces, sickness descriptors or dirty hands) is the mechanism driving the reported mnemonic effect for contamination. Still, this is a hypothesis worth exploring. As mentioned above, such an investigation could be done by using stimuli equated on distinctiveness. Alternatively, it could be tested using other procedures known to be less sensitive to manipulations of this dimension, such as between-subjects designs (Dewhurst & Parry, 2000; Schmidt & Saari, 2007).

Our work has inspired follow-up studies, seeking to build on and extend our understanding of this topic. The mnemonic tuning for contamination has been replicated by different research teams using different research designs and different stimuli. For example, Bonin, Thiebaut, Witt, and Méot (2019), in a replication and extension of our Study 3a (see Chapter 4), found that contaminated (vs. non-contaminated) items produced better retention and source identification. During their encoding phase, participants were presented with objects paired with sick- or healthy-looking faces (the exact same sickness conditions as in our Study 3a were reproduced by the authors using Adobe Photoshop), and were asked to report their perceived discomfort in a hypothetical situation of contact with each object (i.e., incidental learning task: Experiment 5a), or to memorize the pair of stimuli consisting of a sick/healthy face and an object (i.e., intentional learning task: Experiment 5b). After a brief distractor task, participants performed a free recall task for the objects and a source memory task (i.e., was the object associated with a sick or healthy face). Memory for contaminated objects was also tested in Bonin and collaborators' work using colored drawings of a healthy and a sick face (their Experiment 4). In this study, participants were asked to imagine a specific episode in which they helped two brothers (one of whom had a serious cold and the other was healthy) prepare a birthday party. Objects belonging to each brother were paired with the corresponding face. During encoding, participants had to pay attention to each pair of stimuli (i.e., healthy/sick face – object). After a distractor task, participants were surprised with a recall memory task for the objects. Again, objects paired with the drawing of a sick face were remembered better compared to those paired with the healthy face. Whereas in our experiments we used an immediate memory procedure that called the participants' attention to the sick and healthy conditions, in Bonin et al. (2019) participants were not asked about the health status of the person who had touched each item. Nevertheless, the contamination effect still persisted (even when participants had simply to look freely at the pictures).

Also drawing on our original work, Gretz and Huff (2019) very recently tested the idea that the mnemonic tuning should be more pronounced when a higher potential for contamination is involved. To this end, they presented videos in which a person was interacting with objects placed in different contexts (kitchen, bedroom, bathroom, and garage). Importantly, to different groups of participants, the person was described as having a contagious disease (i.e., influenza), as having a non-contagious disease (i.e., cancer), or as having no disease (i.e., healthy). Following the video presentation, participants performed a distractor task and were then required to remember as many objects as possible. After the recall task, a source-recognition task was given, in which participants were required to indicate whether each item was touched, non-touched or neither. In general, participants recalled more touched- than non-touched objects, irrespectively of the person who touched them. However, the recall difference between touched- and non-touched objects and the proportion of correct source attributions for touched objects was higher in the influenza group as compared to the cancer and healthy groups (performance between the latter did not differ).

Overall, the results from these studies suggest that the contamination effect holds when using different encoding tasks (some that call the participants' attention to the contamination status of the stimuli and others do not) and in both intentional and incidental learning conditions (although see Studies 2 and 3 in Bonin et al., 2019). Such evidence coupled with past work (e.g., survival processing; Nairne & Pandeirada, 2016), indicates that human memory might be optimized to process and retain fitness-related information. As already highlighted, an individual who is able to successfully detect and remember potential sources of contamination is more likely to avoid them in future encounters than an individual lacking this capacity, consequently maximizing his/her chances for survival and reproduction (Fernandes et al., 2017). Interestingly, our memory system may play a role not only in helping us avoid coming into contact with potential sources of infection (i.e., prior-infection) but also in finding a cure when infection is already established (i.e., post-infection). In this sense, Nairne and Pandeirada (2010a) conducted an experiment in which participants were asked to imagine they "had been hurt and a dangerous infection might be developing" (p. 8). In order to survive, participants would have to consider searching for and finding medicinal plants (in the grasslands of a foreign land: ancestral scenario) or antibiotics (in the city of a foreign land: modern scenario). Participants were then shown a set of words; half of the presented words were rated for their relevance in an attempt to cure the infection and the other half were rated for pleasantness. People recalled more words rated for survival-relevance (in both the ancestral and the modern scenario) than words rated for their pleasantness. Similar results were reported in Experiment 1 by Bonin et al. (2019). In their experiment, participants were asked to imagine one of three scenarios: an ancestral and a modern context of contamination (as in Nairne and Pandeirada but with an emphasis on the risk of contamination) and a control condition (a tour guide context, in which participants had to organize a trip for a group of people, for whom they need to provide, for example, accommodation and meals). Participants had likewise to rate the relevance of a set of words for the provided scenario. Memory was significantly better in the first two conditions compared to the latter. Results from these studies are also consistent with the conceptualization of the BIS considering that it might contribute not only to avoid life-threatening ailments but also to control or rid the body of an already-existing infection (Hart, 2011). For example, so-called “sickness-related behaviors” seem to be an important means to facilitate recovery from an infection (Ackerman et al., 2018; Dantzer & Kelley, 2007). Such behaviors have been proposed to belong to the behavioral repertoire of the BIS (Ackerman et al., 2018). The just mentioned results suggest that memory could be related (at least to some extent) to this component of the BIS; alternatively, they could simply be reflecting the more general survival-related tuning as all of the scenarios directly mentioned this selective pressure.

At this time the reader may probably wonder: With such astounding systems (i.e., the BIO and the BIS) – a marvel of evolution – working in concert to promote our health, why do we still get sick (see, for example, Nesse & Williams, 1994)? Nowadays infectious diseases are still among the leading causes of morbidity and mortality worldwide, being responsible for the death of about 15 million people per year according to the World Health Organization (2012). As previously noticed in the *Theoretical Introduction*, detecting disease-causing agents “is no small feat” because most pathogenic microorganisms are imperceptible to the unassisted human eye (Tybur & Lieberman, 2016, p. 6). To make it even more challenging, they have a strong ability to spread easily and rapidly, can be transmitted through numerous routes, and can manifest themselves in different ways or not manifest at all, resulting in no detectable disease signs (Curtis et al., 2011). Consequently, our sensory systems are sensitive to stimuli that had reliably harbored pathogens in ancestral environments (Curtis et al., 2004). In addition, and given the difficulty in accurately detecting pathogens’ presence, the BIS is believed to be calibrated to detect stimuli that are heuristically (and often rather crudely) related with infection but that are not necessarily an *actual* threat (Kurzban & Leary, 2001; Schaller &

Duncan, 2007; Schaller & Park, 2011). That is, it has been designed to lessen false-negative errors at the expense of higher false-positive errors. Because the costs of failing to detect a truly disease carrier can be devastatingly expensive (i.e., may result in severe illness and possibly death; Haselton & Nettle, 2006), the BIS tends to be hypervigilant (Schaller & Duncan, 2007; Schaller & Park, 2011) and to operate according to the smoke detector principle (Haselton & Nettle, 2006; Nesse, 2005). “Like an overly sensitive fire alarm, it “goes off” and triggers avoidance behaviors for stimuli that merely bear a resemblance to infectious agents” (Brenner & Inbar, 2015, p. 28). Needless to say, a general tendency of avoidance would decrease the likelihood of exposure to disease-bearing pathogens.

With this in mind, we explored the BIS’s tendency for hypervigilance by testing whether the mnemonic tuning holds when the stimuli only resemble real pathogen-threats (but are presented as not posing an *actual* threat) as compared to when they are described as indeed representing such threat. To that end, we employed once again the immediate memory paradigm, and presented pictures of objects being held by hands covered with two substances (Studies 7a and 7b). The stimuli were exactly the same but were framed either in a fitness relevant manner or not. That is, for some participants one substance covering the hands was described as diarrhea, which represents a contamination threat, but for other participants that same substance was described as being chocolate spread, which is less likely to pose life-threatening risks. Participants from the former group were also shown objects on hands covered with another substance, described as pasta sauce, whereas for those of the latter group the substance was described as being vomit. We found that participants remembered about the same proportion of objects, regardless of the type of hands holding them. Data from these studies are consistent with the operation of the abovementioned smoke detector principle. Nevertheless, the distinctiveness alternative explanation considered above could also be applied to these results. Since in both the “sick” and “healthy” conditions the hands were covered with a substance, participants might have had a harder time clearly discriminating between conditions (which translated into a lower performance in the immediate memory task) limiting the possibility of an effect occurring. Additionally, both types of hands might have been similar in emotionally activating participants; such a case would resemble those studies on emotionality in which the use of “pure” lists designs tends to eliminate the mnemonic advantage for emotional items as compared to neutral items (Dewhurst & Parry, 2000; Schmidt & Saari, 2007). These are questions that need to be scrutinized in the future.

Maintaining the BIS in a permanently activated state would be, however, an unwieldy and impractical endeavor. In fact, avoiding every single source of disease can be difficult (if not impossible) to accomplish. To do so we would need, for example, to forgo eating, drinking, breathing, mating, or establishing potentially profitable relationships by avoiding all contact, which, in evolutionary terms, would jeopardize our survival as it would come at the expense of other fitness-relevant goals (e.g., mate, feed). Engaging in other adaptive responses naturally "imply non-zero infection risks" (Tybur & Lieberman, 2016, p. 7). Therefore, people must trade-off the costs and benefits of pathogen avoidance against alternative activities. These costs and benefits likely differ across both contexts and individuals. Thus, instead of a solid blueprint, the BIS likely evolved to be functionally flexible, calibrating its functioning depending on the threats present in the environment and the individual's capacity to cope with such threats (Ackerman et al., 2018; Fessler et al., 2005; Murray & Schaller, 2016). We will first concentrate on the context (individual differences will be explored later in this discussion).

Considering the basic proposition that the BIS might be influenced by the context within which an individual is embedded (different situations afford different levels of health-threat), the type of available cues and the way they are framed should up- or down-regulate the activation of the BIS. In fact, in some situations, the contamination mnemonic effect seems to depend on fitness attribution. For example, when "sick" faces were presented along with objects, but participants were led to believe that the facial cues were actually from the application of make-up rather than from disease, no memory advantage for the associated objects was found in comparison to those presented with the healthy faces (Study 3b). These findings differ somehow from those obtained in Studies 7 that we just described. Should not the actresses' faces be heuristically associated with disease and boost memory for objects as well? It is possible that thoughts of disease and contamination were least often endorsed in the actresses' condition, as makeup may pose little or no health threat contrary to the dirty-hands stimuli (even when covered with innocuous substances). In reality, instead of avoiding them, people tend to approach actresses. If makeup does not represent a potential disease threat in one's environment then there is no need to trigger the BIS. Be aware that people have several pressing adaptive problems to solve (e.g., find nourishment). "As a means of maximizing the benefits, while minimizing the costs, it appears that these [disease-avoidance] mechanisms are engaged somewhat flexibly, contingent upon the presence of additional information indicating the extent to which infectious diseases should be considered a cause for concern" (Duncan & Schaller, 2009, p. 100). Therefore, people are likely to first glean and sift through the available environmental information before mounting a behavioral immune response. Accordingly, the BIS was found to be more strongly activated under circumstances in which the threat posed by disease-causing pathogens was made temporarily salient. For example, disease concerns seem to influence how people perceive and remember individuals heuristically associated with pathogen threat. Note that, in both Study 3b and in the non-disease context of Study 6, no reference was made to disease-threats, that is, both cues referred to potentially healthy people (Study 3b: an actress or a TV-show viewer; non-disease context of Study 6: someone with chocolate spread in her hands and someone with clean hands) contrary to the remaining studies (where there was at least one contamination cue). Do participants need to be alerted to the threat of disease? Would we have a contamination advantage if no context was provided? Is it possible that, in certain circumstances (e.g., when disease threat is not salient), participants do not feel the need to engage in a "better safe than sorry" strategy (reducing the false-positive error rate)? Even though we recognize that constantly activating a behavioral immune response would be a costly enterprise, we believed that, as with most evolved mechanisms, disease-avoidance responses occur spontaneously, requiring little conscious or effortful thinking (Park et al., 2003). Understanding why the smoke detector principle "reins" in some situations and not in the others is a question that continues to intrigue us and that needs further exploration. Note that, in these studies (Study 3b and non-disease context of Study 6), even though the actresses and the hands with chocolate were more distinctive than the TV-show viewers and the clean hands, respectively, no memory advantage was found, suggesting that distinctiveness does not seem to account for the effect.

To provide additional confirmation that the mnemonic tuning for contamination is a robust phenomenon, one that cannot be accounted for by methodological artifacts, it is important to explore new experimental procedures. We went in this direction in the last experiments presented in the Chapter 4 (Studies 8 and 9). Using a blocked within-subject design, we compared a *contamination generation*, which required participants to formulate contamination situations in which the object could either contribute to or prevent them from getting sick, to a *pleasantness rating* task, in which participants rated the pleasantness of objects (Study 8) or to an *autobiographical generation,* in which participants specified specific events from their lives in which the object was relevant (Study 9). This paradigm allowed us to explore memory for contamination in the absence of any fixed scenario and with a completely new encoding procedure. Whereas in the previous studies the health-threat was always posed by conspecifics carrying an infectious disease, Studies 8 and 9 set no limits to the things that could serve as vectors or reservoirs of pathogens. Additionally, besides considering potential events of direct contamination (likely derived from the participants' past experience), participants could also conjecture about ways to prevent contamination (which could help to anticipate future events). Contamination generation produced significantly better retention than both control conditions (although only at the item-level in the latter), confirming the idea that our cognitive systems seem to be tuned to remember potential sources of contamination. Additionally, the mnemonic effect did not seem to relate to factors such as the complexity, variability, arousal and valence of the generated responses (as suggested by the supplementary analysis). Prior work has focused on the human capacity to envisage, simulate and predict future scenarios and how that influences the capability to cope with threats (Mobbs, Hagan, Dalgleish, Silston, & Prévost, 2015; Nairne & Pandeirada, 2016). Such capacities, in turn, rely on humans' access, through memory, to relevant past experiences (Nairne & Pandeirada, 2016). In this sense, these authors strongly believe that our memory systems "are likely engineered to use the past in the service of the present, or perhaps to predict the likelihood of events occurring in the future" (Nairne & Pandeirada, 2010b, p. 978). Remembering from past experiences which things are likely to harbor pathogens, or which plants have medicinal properties (to name just a few examples), might be of use in the present to identify and implement effective strategies to reduce the probability of contact with and infection by pathogens.

Our studies and those that followed focused mainly on the ultimate cause of the contamination effect leaving the proximate mechanisms underlying such an advantage unexplored (see Nairne & Pandeirada, 2016, for an overview of these approaches). Still, some explanatory hypotheses have been proposed. For example, perhaps people have a stronger emotional reaction or allocate more attentional resources to the contaminated items than to the non-contaminated items, which ultimately facilitates memory (see Chapter 4 for a more detailed discussion). Are contaminated items more emotionally arousing than non-contaminated items, resulting in better memory for the former? Do we focus our attention on contaminated items and therefore recall them better? Distinctiveness is another candidate to explain the observed effect (as mentioned at the beginning of this discussion). In fact, some researchers have found arousal, distinctiveness and attention effects on memory tasks (Hunt & Worthen, 2006; L. J. Levine & Pizarro, 2004; Sharot & Phelps, 2004). Chapter 5, in a sense, briefly explored the last question. In that Chapter we tested the existence of an attentional bias for contamination by means of a letter-identification task and, then, conducted a memory task for all objects.

Participants were asked to identify target letters presented shortly after a picture of an object being held by dirty hands or by clean hands. The dirty hands were framed either in a fitness relevant manner (i.e., diarrhea: disease context) or not (i.e., chocolate spread: non-disease context). As stimuli inducing disgust have been shown to preferentially “capture” one’s attention compared to neutral or fearful stimuli (e.g., Ackerman et al., 2009; van Hooff et al., 2013), we expected poorer accuracy to discriminate peripheral targets and longer response times for correct responses on trials in which pictures of dirty hands were presented. Accordingly, participants were slower in detecting target-letters on trials in which distracting pictures of dirty hands (vs. pictures of clean hands) holding items were presented, suggesting that disease-related stimuli are attention-grabbing. Additionally, the dirty-distractors seemed to divert attentional resources from the target-items, irrespectively of whether the substance covering the hands was described as a potential infection vector or not. We hypothesized that these results might reflect the functioning of the smoke detector principle previously described. However, our prediction regarding accuracy was not confirmed as no differences were obtained on this variable as a function of type of distractor or context. On the final surprise free recall task, participants assigned to the disease context tended to recall more items than participants in the non-disease context, a result that parallels that reported in the discussion of studies 3a and 3b. On the other hand, no difference was found as a function of type of stimuli (dirty vs. clean) which is inconsistent with the results obtained in the memory experiments. As discussed in Chapter 5, there are several aspects of this experiment that are likely responsible for the differences in the results from the memory component. In all, we also found other caveats in our procedure that merit further consideration. For example, even though the subjective evaluation of disgust between the pre- and post-task moments only differed in the disease context (as expected), the level of disgust activation was relatively low (rating of about 19 at the post-task moment on a 0-100 scale); such a result suggests that our manipulation might not have been particularly effective. Relatedly, in the future, we should evaluate the plausibility of the presented scenario (i.e., do people consider that it is possible for someone to be holding objects with their hands covered with diarrhea or chocolate?), along with participant’s ability to imagine such a situation. In fact, the perceived likelihood of contracting a specific disease has been argued to depend on the accessibility of the mental representations of the disease. As found by S. J. Sherman, Cialdini, Schwartzman, and Reynolds (1985), participants “who rated the disease as easy-to-imagine judged the disease as more likely to occur, whereas those who experienced difficulty in imagining the disease rated it as less likely to occur” (p. 118). Also, the obtained response time differences in the correct identification of the targets followed by dirty compared to clean hands (irrespectively of context) could result from perceptual differences between these two groups of stimuli (e.g., image complexity, novelty). Therefore, these findings should be considered as only preliminary and further work is necessary. Additionally, in parallel to behavioral studies, oculometric data would provide a more accurate and precise estimate of the potential attentional biases for contamination-related stimuli. Thus, in future studies, eye movements (considered as dependent variables; e.g., number of fixations, fixation duration, or blinking rate) and pupillary responses (e.g., pupil size) should be recorded applying eye-tracking technology. In fact, few studies have monitored participants’ eye movements during the presentation of disgust-eliciting stimuli (for an exception see Bradley, Houbova, Miccoli, Costa, & Lang, 2011). We have already collected some of these data which we aim to report in the near future.

The last issue explored in this thesis relates to the idea that differences in the activation of the BIS may also be rooted in individual differences related to the ability to deal with life-threatening pathogens (mentioned above when we introduced the benefits-costs trade-off). Chapter 6 reports the results of exploratory analyses that aimed to investigate the impact of individual differences on the magnitude of the contamination effect. Our data suggest that the mnemonic tuning for contamination was stronger for participants scoring high in disgust sensitivity compared to those scoring low on this dimension. Similarly, we obtained a tendency for the illness status to influence the mnemonic tuning, particularly when comparing groups formed on the basis of the health continuous measure. On the other hand, participants' disgust propensity and perceived vulnerability to disease did not seem to influence memory performance. However, our findings should be taken in light of certain limitations. In our statistical analysis, the same memory data were used for the various comparisons of groups which increases the likelihood of obtaining false positive significant results. Still, even when applying a correction on *p* value considering the number of performed comparison, the difference regarding DS remains significant.

Because self-report instruments are prone to reporting biases, governed by concerns about social desirability and the desire to comply with social norms (van de Mortel, 2008), individual differences might be further explored using more accurate measures. For example, to evaluate whether people are more or less prone to experience disgust, we could measure facial (frequency and amplitude of facial muscle contraction), gastric (frequency and amplitude of gastric muscle contractions), and cardiovascular (heart rate variability) reactivity, using physiological measures such as facial electromyography activity at the levator labii, corrugator, and zygomatic regions, electrogastrography, and electrocardiographic, respectively (Shenhav & Mendes, 2014). Participants' health status and vulnerability to diseases could be measured using immune markers, such as interleukin-6, salivary secretory immunoglobulin A and tumor necrotizing factor alpha. The subjective measures we used to assess the health status may also not be the best way to measure what we actually intended; for example, the continuous measure of the health status questionnaire includes items that are not necessarily physical by nature (e.g., "Over the past couple of days, I have not been feeling well"). This potential problem might underly the different classification of some of the participants on this variable (i.e., healthy or sick). Such problems could be solved by using the suggested objective measures, which could improve the validity of our results by ensuring that our sample is correctly classified as "truly" belonging to each group.

Additionally, one should note that splitting the sample based on median values to create the high and low groups on each variable resulted in groups that did not differ to a great extent on the variable. For example, scores of the Disgust Propensity subscale could range from 6 to 30. Utilizing median splits, participants classified as low on this dimension scored around 17, whereas those classified as high scored around 22. Even though this difference is statistically significant, one can wonder if this 5-point difference is enough to distinguish the two groups and to impact the functioning of memory as a potential component of the BIS. Our analytic strategy of comparing high and low groups followed the strategy employed in other studies (e.g., Miller & Maner, 2011). However, alternative and more sophisticated statistical techniques (e.g., ANCOVA or multilevel analyses) could offer other insights into the data. One last and important limitation of the presented analyses lies in the uneven number of participants from each counterbalancing version of the experiment represented in each group (high and low in each dimension). Future work should select participants prior to the experiment to ensure that each group would have an equal representation across the experiment versions. In spite of all of the just mentioned limitations of our data regarding this issue, we should note that the disparate results obtained in our study reflect those found in related literature (as discussed in Chapter 6), which have looked for associations between individual variables and other components of the BIS (e.g., attention and avoidance behaviors). Thus, we can wonder if differences on these measures do effectively reflect an activation of the BIS (see also Supplementary Material 2 with related information).

In general, our studies suggest that memory might be tuned to better remember potential sources of contamination (vs. non-contaminated items) and that attention can be preferentially captured by contaminated-looking stimuli. People also seem to adopt a 'better safe, than sorry' strategy, responding in a hypersensitive way when they are somehow primed to a potential for contamination and stimuli resemble real pathogen-threats are used (even when told that they do not pose an *actual* threat; e.g., diarrhea vs. pasta sauce), following what has been dubbed as the smoke detector principle. Our data also suggest that the mnemonic advantage for contamination is likely to be functionally flexible and plausibly affected by environmental cues, as in cases of no reference to a potential for contamination, it ceased to exist (e.g., chocolate vs. clean hands). In addition, it may be influenced by individual differences, particularly those related to disgust sensitivity – that is, the extent to which people evaluate negatively their experiences of disgust (findings that are only exploratory at this point). However, as noted in this discussion so far and also pointed out in the chapters' discussions, these patterns of results are open to alternative explanations that merit consideration.

Throughout the discussion of the different studies conducted within this PhD project, some limitations and shortcomings have been considered and specific needs and suggestions for future studies have already been proposed. Yet, other interesting and tantalizing questions are left on the table, leaving plenty of room for future research and continued incremental improvements in this field of research. Next, some future research work is considered.

7.2 Open questions and possible future directions

The mnemonic tuning for contamination has been shown to be replicable and robust as it generalizes to different stimulus materials, experimental designs, and populations. Nevertheless, future studies should confirm the replicability and robustness of these earlier findings by using other stimuli, by developing new research designs and methodologies, and by testing the effect in different cultural groups. These should also provide a test for alternative explanations of our results.

Regarding the first, in our studies we have mainly used visual cues to signal the pathogens' presence. Studies that followed also focused on visual stimuli. Nevertheless, humans rely on multiple sensory channels to probe their immediate environment for pathogens' cues. Body odors, for example, are thought to convey people's health status. For example, Olsson et al. (2014) reported that sick individuals' body odors were perceived as unhealthier, more unpleasant and intense by participants. In addition, faces (whether sick or healthy) paired with a sick body odor (i.e., from people injected with lipopolysaccharide to induce an inflammatory response) were seen as significantly less likeable than faces paired with a control odor (i.e., an unused sampling pad; Regenbogen et al., 2017). Would the mnemonic advantage for contamination still prevail if the objects were paired with olfactory (e.g., the smell of diarrhea), auditory (e.g., the sound of someone vomiting), or tactile (e.g., the feel of sticky substances) cues? Or even with cues of different modalities combined? Given the imperfect nature of disease-detection (i.e., pathogens presence cannot be directly observed and must be inferred through perceptual cues), it would be fruitful to integrate a more holistic, multisensory approach to explore the functioning of the BIS (Murray et al., 2019). We predict that the contamination effect will replicate using different perceptual cues.

Our studies, as well as the work that followed from other authors, have already introduced a variety of procedures to explore the mnemonic tuning for contamination. Even so, other experimental designs could be implemented to yield a better understanding of the effect under scrutiny. As noted above, most studies have adopted within-subject designs opening the possibility for distinctiveness to play a role in the obtained results (although see Gretz & Huff, 2019). To expand our knowledge in this area and help rule out alternative explanations, future studies should implement between-subjects designs.

One could also explore how different manipulations might affect memory for contamination. As noted before, enhancing disease concerns via situational priming influences memory in particular ways (see Ackerman et al., 2009; Miller & Maner, 2012). The mnemonic tuning for contamination should be further explored under conditions in which the threat of pathogenic infection is made especially salient. This could be made, for example, by showing a set of images and information about infectious diseases to prime participants to think about diseases, or by having participants perform the experiment sitting next to someone explicitly exhibiting signals of infectious diseases (e.g., coughing and sneezing). This leads us to the next point: the need to test memory for contaminated items when the disease-threat is not just temporary (as above) but, instead, permanent.

Throughout history, humans have conquered a surprisingly wide range of ecological niches, some of which are more favorable to the propagation and transmission of disease-causing microorganisms than others (Wang, Michalak, & Ackerman, 2018). It follows that, even though pathogens, and the diseases caused by them, posed a threat to people worldwide, “there is considerable geographical and ecological variability in the distribution of human infectious diseases and in the burden they place on human welfare” (Schaller & Murray, 2011, p. 108). This distribution may be determined by various climatic factors, such as temperature, humidity, rainfall, and sunlight. People inhabiting warmer and wetter environments, such as those found in the tropics and regions near the Earth’s equator, may face a strong selective pressure posed by pathogens (Guernier, Hochberg, & Guégan, 2004). This unequal distribution of pathogens may have translated into differences in the activation pattern of the BIS. For example, disgust propensity was found to be especially pronounced in regions with a higher prevalence of infectious diseases (Skolnick & Dzokoto, 2013, but see Oaten et al., 2009). Our experiments were conducted in two different countries, the USA and Portugal, helping to establish the generalizability of the mnemonic tuning for contamination. However, the two regions are located at similar latitude and the estimated magnitude of disease burden is likely close (as pathogen prevalence is highly correlated with latitude). Therefore, future studies should be conducted with people from pathogen-rich and pathogen-free ecologies. Would the mnemonic advantage for contamination be especially strong in the first rather than in the latter environment? Or would the opposite result pattern occur? As suggested by Tybur et al. (2018), the benefits from mounting a behavioral immune response are relatively low in a pathogen-rich ecology and people should invest primarily in other fitness-enhancing activities.

To further understand how people resolve the inevitable trade-off between costs and benefits of engaging in disease-avoidance behaviors, we could also explore the activation pattern of the BIS when facing pressing adaptive problems additional to the contamination one, such as food acquisition. “Because hunger signals nutritional stress, and nutritionally stressed individuals have more to gain from eating” (Lewis, Al-Shawaf, Conroy-Beam, Asao, & Buss, 2017, p. 361), the activation of the BIS should be less pronounced under conditions of starvation. Data reported by Al-Shawaf and Lewis (2013) neatly parallel this idea by showing that the disgust levels of hungry individuals were lower than those of satiated individuals. Would this variable impact memory for potential sources of contamination as well? What about other fitness goals, such as avoiding other threatening entities (e.g., spiders, angry faces)?

In the *Theoretical Introduction*, we assumed that different threat-management systems likely evolved over our 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 et al., 2011). Our studies focused on the mnemonic tuning for disease threats but one could wonder if a similar tuning exists for other threat-related items. Also, do these systems involve separate mechanisms or could they simple be derivative of a general evolutionary mechanism that helps us survive? The research showing that stimuli engendering 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), suggests that different mechanisms could be at work. These are, ultimately, empirical questions that need to be investigated.

Finally, this project presented some exploratory analysis of the relevance of some individual differences considered in previous research on the mnemonic effect for contamination (e.g., propensity and sensitivity to disgust, perceived vulnerability to disease). However, there are other individual variables that could be considered. For example, researchers strongly believe that stress suppresses immune responses and increases susceptibility to disease (Hussain, 2010; for a meta-analysis, see Segerstrom & Miller, 2004). Consequently, an increased activation of the BIS should be expected in stressed individuals compared to unstressed ones. Accordingly, Al-Shawaf and Lewis (2013) found that high levels of stress increase disgust propensity (measured using the Disgust Scale-Revised). Would stressed individuals remember substantially more contaminated objects (vs. non-contaminated objects) compared to non-stressed controls?

Sex is another variable worth exploring. Females have been consistently found to be more disgust-prone than males (Sparks, Fessler, Chan, Ashokkumar, & Holbrook, 2018). Several theoretical explanations for these sex differences have been offered, such as the discrepant amounts of minimum obligatory parental investment (see Al-Shawaf, Lewis, & Buss, 2018 for a systematic analysis). Our samples were mainly composed of females, which might have influenced our findings. Does the mnemonic tuning for potential sources of contamination remain the same (or not) as a function of the participants' sex? A mixed ANOVA[18] with stimulus condition (i.e., contaminated vs. non-contaminated) as a within-subject variable and sex (female vs. male) as a between-subjects variable, revealed a significant main effect of condition, $F(1, 336) = 60.12$, $MSE = 1.055$, $p < .001$, $\eta_p^2 = .152$, but neither a main effect of sex or an interaction between the variables, both $Fs(1, 336) < 1$. These results suggest that both male and female participants remember contaminated items better that non-contaminated items. However, the interpretation of this finding is constrained by the same limitations pointed out in the exploration of the individual variables (e.g., different sample size of groups and unequal distribution across versions).

University course is also a variable to consider in future studies. Even though our samples were mostly from psychology courses, there were times they were drawn from

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[18] The samples from Studies 3a, 4a, 4b, 5a, 5b, and the disease context of Study 6 were combined to conduct this analysis.

the vast university population. Some studies have suggested that the disgust propensity of students training to become health professionals is less pronounced compared to other students (Rozin, 2008; N. C. Sherman & Sherman, 1998). Therefore, the impact of participants' course should be measured. Note that the samples used in our studies are limited to university students, thereby limiting the generalizability of the findings. In fact, Doctoroff and McCauley (1996) found that education and socioeconomic status negatively correlated with disgust propensity. Future researchers might focus on population groups other than university students.

Another fascinating topic relates to the dynamic relationship between the BIO and the BIS. Specifically, we could explore if, and how, the BIS activation pattern is modulated by the differential activation of the BIO. In our exploratory analyzes we tested if the mnemonic tuning for contamination was especially strong in those participants that were ill or had recently been ill (e.g., had the flu) compared to those that were healthy. Such an idea could be extended to a comparison across different conditions of the BIO: for example, individuals with acute immunosuppression (e.g., pregnant women in the first trimester), with chronic immunosuppression (e.g., patients undergoing kidney transplantation), and without immunosuppression could be tested. As already proposed by some researchers (e.g., Miller & Maner, 2011), people more vulnerable could lessen the risk of contracting diseases and safeguard their health through a compensatory activation of the BIS. Thus, a particularly strong mnemonic tuning should be expected in participants with immunosuppression, as compared to those with no immunosuppression. More interestingly, these three groups could be tested in two separated phases in order to verify if, once passed the period of acute immunosuppression (e.g., pregnant women could be tested once again in the third trimester), the manifestation of the BIS returned to levels similar to those observed in healthy participants. We believe that such study would provide helpful insights into the proposal recently put forward by Ackerman et al. (2018) to examine and better understand the extent to which these two systems are "complementary (working in tandem, providing overlapping functions) or compensatory (activation of one predicting decreased activation of the other)" (p. 5).

Besides the cognitive 'toolkit' that evolved as part of the BIS (the focus of the present thesis), future studies should investigate other mechanisms comprising this system (e.g., behavioral avoidance). For example, would participants display faster avoidance movements than approach movements in response to stimuli of contamination? Would they increase the frequency of cleaning behaviors? Are behavioral responses also governed by the smoke detector principle? More interestingly, are these different mechanisms interconnected? That is, are enhanced disgust reactions associated with increased allocation of attention, better mnemonic performance, and quicker avoidance-movements in response to potential contaminants? Or do the different components of the BIS (e.g., attention and behavior) respond differently to the same type of stimuli? For example, the Gretz and Huff (2019) study reported at the beginning of the discussion suggests that the mnemonic tuning for contamination is particularly strong for objects touched by someone described as having a contagious disease (compared to someone described as having a non-contagious disease or as being healthy). However, Ryan et al. (2012) found that people were less willing to make contact with objects previously touched either by someone with influenza or by someone with a birthmark (i.e., regardless of whether facial signs were contagious or not) compared to someone healthy, particularly when asked to touch the object with the mouth (vs. with hands, head, and face). Taken together these results suggest an affirmative response to the latter question. As the reader can see, there is still a long way to go to completely understand the phenomenon under study.

7.3 Concluding remarks

We mentioned earlier, in an attempt to formulate an answer to the question “why do we still get sick?”, that the BIS faces the challenge of detecting microscopic pathogens, whose presence is not directly perceptible and go easily unnoticed. Likewise, the BIO’s efforts to counter disease threats are not without challenges. Pathogenic microorganisms and their hosts are known to undergo dynamic and co-evolutionary interactions, where adaptations in one are followed by counter-adaptations in the other, and so on (Thornhill & Fincher, 2015).[19] That is, the BIO developed the capability to sense invading pathogens and to quickly mobilize immune responses to eliminate them. Pathogens, in turn, developed strategies to optimally circumvent the detection and neutralization by the BIO. This results in the evolution of a new armory of defenses against pathogens, which gave rise to new evasion strategies to overcome the new defenses (Bliven & Maurelli, 2016). This everlasting antagonistic co-evolution explains why it is not possible to eradicate all infectious diseases.

Efforts to reduce disease burden have mainly been directed to the development

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[19] The dynamics of the coevolution process are often explained by two models: the *Red Queen* hypotheses and the *Arms Race* model (Woolhouse, Webster, Domingo, Charlesworth, & Levin, 2002).

and improvement of vaccines, antibiotics and other cures[20] (Curtis, 2011). Although many diseases have been successfully conquered by advances in medicine and technology, new ones are constantly emerging whilst others re-emerge or change (Prokop & Fedor, 2013; Thornhill & Fincher, 2014). The development of antibiotic resistance represents a remarkable example of how bacteria have the ability to rapidly evolve and adapt to environmental and host changes (Bliven & Maurelli, 2016). Anecdotally, far less attention has been given to behavioral strategies that can prevent the acquisition and transmission of infection in the first place (Curtis, 2011). Emerging, re-emerging and changing pathogens are likely to remain a threat to public health for the foreseeable future. Promoting disease-avoidance behaviors may be one of the most powerful and cost-effective means of preventing disease. Hand washing practices, for example, was estimated to decrease the risk of diarrhoeal diseases by 42 to 47% (Curtis & Cairncross, 2003). Consequently, they have been encouraged in a number of health promotion campaigns and other preventative health programs, and are widely recommended by both the World Health Organization and the Centers for Disease Control and Prevention. Additionally, the design of settings that carry a high pathogen load (e.g., public bathrooms, hospitals or other health-care environments) has been rethought so as to reduce disease transmission. For example, hand-free automatic devices (e.g., flush valves, soap dispensers, faucets, hand dryers) and foot-operated mechanisms (e.g., flush valves, door opener) enable people to use a public bathroom without hand contact with potentially contaminated surfaces. Another strategy that has been recognized as an important means of preventing the spread of infection is the provision of alcohol-based hand sanitizer dispensers, which are praised for their versatility and ease of use.

The functional importance of the BIS in minimizing people's risk of infection and contributing to their fitness is well recognized. As pointed out by Curtis (2011), without disgust and the mechanisms underpinning the BIS, “infectious diseases would cause far more morbidity and mortality in our own – and in all free-living animal – species” (p. 3479). “Evolutionarily informed work that can explain the causes of disease avoidant behavior may offer vital clues as to how best to change environments and cultures so as to favor changes in group and individual behavior, and hence to prevent this annual toll of infectious disease” (Curtis et al., 2011, p. 398). Thus, understanding how this system

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[20] Is this growing use of pharmaceutical products likely to have effects in the activation of the BIS? That is a question to think about. In fact, less disease-avoidance behaviors (e.g., less prejudice toward immigrants) were found in people who believed themselves to be protected from diseases (e.g., by vaccination; Huang, Sedlovskaya, Ackerman, & Bargh, 2011).

works would be helpful for the development of future public health strategies and/or improvement of existing programs[21]. For example, by understanding the circumstances in which our memory is most effective we can develop more feasible and effective modes of prevention.[22] In fact, the BIS may prove useful not only at combating the threats from infectious diseases, but also other health hazards such as cigarette smoking, illicit drug use, excessive alcohol consumption, and over-eating. See the example of anti-tobacco campaign messages portraying disgust-inducing images: Researchers have found that disgust increased both attention to, and memory of, anti-tobacco message content, evoked negative emotional responses, lowered smoking urges, and strengthened smokers' intentions to quit smoking (Clayton, Leshner, Bolls, & Thorson, 2017; Leshner, Bolls, & Thomas, 2009).

Undoubtedly, the study of the BIS is an exciting, timely and promising field of research, as emphasized by the recent increasing interest in this area. Nevertheless, there is still a challenging agenda for future research. We believe our work adds to the understanding of this system but continued efforts to understanding it are crucial both for theoretical (e.g., to understand why our memory systems might have evolved) and practical reasons (e.g., to inform strategies for addressing some of the public health challenges of our time). It was beyond the scope of this thesis to delve deeply into a proximate analysis of the contamination effect as we were mainly interested on the ultimate (or evolutionary) function of our memory system. Nevertheless, we acknowledge the importance of further studies exploring the proximate mechanisms behind the contamination effect, in order to help fully characterize this phenomenon. Importantly, as noted in various works inspired by a functional analysis, prioritizing ultimate questions in our research agendas often leads to the discovery of new phenomena that would otherwise be left undiscovered (Nairne, 2015). We should keep in mind that the key to understanding both “how” and “why” a system operates as it does, “lies at least partly in understanding its evolutionary lineage” (Nairne, Pandeirada, & Fernandes, 2017, p. 290). We look forward to providing and inspiring new contributions in this field.

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[21] Researchers have highlighted the importance of developing and implementing “theoretically informed programs”, as they are proven to be “more effective in changing health behavior than those that are not theoretically informed” (Painter, Borba, Hynes, Mays, & Glanz, 2008, p. 359).

[22] Nevertheless, we must keep in mind that adherence to health promoting behaviors may be influenced by other factors, such as powerful social and economic pressures. For example, expected social behaviors, such as shaking hands, may undermine the avoidance of contact with sick people; the need to earn money may encourages people to turn up at work, despite being ill, instead of staying at home (Kozlowski, Kiviniemi, & Ram, 2010).

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SUPPLEMENTARY MATERIAL 1.

Analysis of the Generated Responses

1. Qualitative analysis by two independent researchers

To expand the scope of understanding with respect to the situations generated in Study 9, and to verify whether these variables correlate with the contamination effect, an informal qualitative analysis was conducted. Responses were categorized and evaluated by two independent researchers, regarding the variables of complexity and of variability.

Complexity was defined as a measure of the richness or elaboration of the participants' responses. More elaborated/complex responses were particularly vivid and included a detailed description of the situations (e.g., allow us to situate the episode in time and space), whereas less elaborated/complex responses were poor in detail. Each response was scored on a scale of 1 (low elaboration) to 8 (high elaboration), resulting from the sum of points assigned whenever each of the dimensions described in Table 1 was present. A mean of the response scores was then calculated for each participant.

Table 1.

Dimensions that served as the basis to determine the complexity score.

Autobiographical	The participant… . described how s/he established contact with the object . located the episode in time (temporal location) . located the episode in space (spatial location) . characterized/described the object (e.g., using adjectives) . specified what object was used for; what purpose did the object serve . referred other subjects and their role in the episode . reported thoughts or emotions associated to the episode . contextualized the episode; indicated a sequence of events that constituted the episode (several linked actions)
Contamination	The participant… . specified the type of action that may lead him/her to get sick or prevent him/her from getting sick . specified one source of contamination . specified a second source of contamination . specified three or more sources of contamination . recognized the possibility of becoming contaminated/sick after interacting with the object . specified the type of disease involved in the situation that s/he can get . reported thoughts or emotions associated to the episode (e.g., disgust) . contextualized the situation; indicated a sequence of events that constituted the episode (several linked actions)

Variability, on the other hand, was defined as a measure of the distinctiveness of the participants' responses. It is directly related with the number of different episodes/ situations elaborated by the participant during the experiment. Regarding the autobiographical condition, participants may refer a unique life episode that involved several objects (e.g., for the words sofa and whistle: “Last Saturday, I saw the SL Benfica football game sitting on the **sofa** at my house.” and “At the football game I saw on Saturday, the referee used a **whistle**.”) or indicate different episodes for each object (e.g., for the same words sofa and whistle: “Yesterday after arriving from the university, I sat down on the **sofa** to snack.”, and “When I played football, I always wore a red **whistle**.”). In the case of the contamination condition, participants may repeatedly refer the same type of contamination situation with a single disease transmission vehicle for various objects (e.g., for the words table and scissors: “The **tables** in the canteen and classroom should be disinfected several times a day.” and “The **scissors** that hairdressers use to cut hair should also be disinfected.”), or indicate distinctive contamination situations for each object (e.g., for the words table and scissors: “The **table** was full of spoiled food.” and “When cutting the hair in a barbershop, the same **scissors** is used in several people without being disinfected.”). The number of different episodes/situations generated in each condition was summed up for each participant.

Inter-rater agreement. The inter-rater agreement was assessed by measuring the Weighted Kappa-coefficient (kw; Cohen, 1968). The kw was moderate for the dimension of complexity (k = 0.581: 95% CI [0.55, 0.61]) and almost perfect for variability (k = 0.815: 95% CI [0.76, 0.87])[23].

***Complexity*.** The autobiographical episodes were more complex and elaborated than the contamination generated responses (M = 3.27, SD = .60 and M = 2.95, SD = .71, respectively), $t(49) = 3.49$, $p = .001$, $d_z = 0.494$.

Variability. Participants provided more differentiated situations in the autobiographical than in the contamination condition (M = 10.34, SD = 1.48 and M = 6.98, SD = 2.06, respectively), $t(49) = 9.64$, $p < .001$, $d_z = 1.364$. Examples of the type of contamination situations generated by participants are described in Table 2.

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[23] Interpretation of Kw was as follows: 0-0.20 slight agreement; 0.21-0.40 fair agreement; 0.41-0.60 moderate agreement; 0.61-0.80 substantial agreement; 0.81-1.0 almost perfect agreement (Landis & Koch, 1977).

Table 2.

Examples of contamination situations generated in Study 9 organized within main themes. The percentage of participants that generated at least one situation related to the main theme (%P) and percentage of responses that fall into each main theme (%R) are also provided.

MAIN THEMES GENERATED	EXAMPLES	%P	%R
Contamination Transmission:			
▪ by contact with people carrying germs (e.g., sick people)	"Someone accidentally drank from my ***glass*** and has herpes; if I had not noticed the likelihood of contracting herpes is very high." "I may be reading a ***book*** from the library that someone with a contagious disease has touched and I can get sick"	96%	33.1%
▪ by contact with contaminated bodily products (e.g., blood, saliva, diarrhea, vomit, snot)	"If someone infected with the AIDS virus cut themself with a ***scissors***, by getting the blood it can contaminate me if I use it and also make a wound." "If someone who is ill has sneezed or vomited onto the ***couch***, it becomes a source of contamination."	82%	14.8%
▪ by contact with items or surfaces potentially contaminated	"A ***carpet*** that has been trampled on with dirty shoes from walking in the street (stepping, for example, on spit and dog poo), becames contaminated and can cause illness and allergies." "People put their suitcases and shopping bags on the ***table***. If any food falls on the table during a meal, it may become contaminated."	58%	6.3%
▪ by contact with potentially contaminated animals (e.g., lice, tick, flies, rats, worms)	"In the shop window, there was a fly around the ***cake***." "There was a rat in the ***boots*** and the girl became contaminated."	44%	4.2%
▪ by poor hygiene	"The ***sofa*** may not have been cleaned for some time; if we eat after we've been sitting there without washing our hands we can catch a gastrointestinal disease" "A ***watch*** that is not cleaned assiduously can accumulate litter, microbes or bacteria that can cause us skin problems."	66%	8.8%

▪ by improper food production, storage, preparation and handling practices	“The ***cake*** may have been made with spoiled food and we may get gastroenteritis.” “Due to the use of harmful chemicals in the cultivation of the ***onion***, we can get a food poisoning.”	56%	6.4%
▪ by airborne allergens (e.g., dust, pollen, mold, mites)	“The ***sofa*** can contain dust and mites, contributing to respiratory problems and allergies.” “There may be mold in the ***book*** because it has been stored for a long time.”	30%	3.5%
▪ Without specifying the source of contamination	“A ***carpet*** is a reservoir of pathogenic organisms.”	32%	7.6%
▪ Others	“If I cut myself with a ***knife*** with rust, I can catch the tetanus disease.”	48%	3.6%
Contamination prevention:			
▪ by avoiding contact with people carrying germs (e.g., sick people)	“I do not use a ***glass*** that has been used by other people because I do not want to catch herpes.” “I avoid using another person's ***boots*** because I can get diseases like athlete's foot.”	20%	2.4%
▪ by avoiding contact with items or surfaces potentially contaminated	“The ***carpet*** in the bathroom serves not to walk with wet feet on the floor after bathing and contracting diseases.”	12%	1.5%
▪ through good hygiene practices / avoidance of objects that have been subject to poor hygiene	“When I go to the esthetician I want to see if she disinfects the ***scissors*** before cut my nail because I do not want to get a fungus on my nails.” “Whenever I touch ***money*** I try to wash my hands as fast as I can.”	20%	3.8%
▪ through proper food preparation	“When we ask for a ***steak*** at some restaurant we should be careful about how it is prepared”	14%	1.2%
▪ through medication or consumption of certain foods	“When I'm with flu I use ***money*** to buy drugs to get better.” “I eat a lot of ***onion*** because it is rich in substances that prevent flu and other health problems related to the immune system.”	16%	1.4%
▪ Without specifying how	“A ***boot*** can serve as a means of protection against some contamination.”	4%	0.5%
▪ Others	“A ***lamp*** can be used to better visualize some contaminated area and avoid contact with it.”	10%	0.9%

When participants can freely imagine contamination situations, they mainly generated circumstances related to the transmission of diseases (about 88% of all of the generated situations) rather than to prevention (about 12% of the generated sentences). The majority of responses refereed to the health-threat posed by conspecifics carrying an infectious disease, followed by contaminated bodily products (e.g., blood, saliva, diarrhea, vomit, snot), and poor hygiene. Prevention was mainly focused on good hygiene practices, followed by avoidance of sick people (see Table 2).

Correlation among variables. Pearson correlations were conducted in order to examine the relationship between each of the above-described dimensions and recall (at the subject-level). To examine this relation, difference scores were calculated for each participant on each measure by subtracting the scores for the contamination condition from those for the autobiographical condition. No significant correlations were found (lower *p* = .429; see Table 3). The major finding that emerges from these analyses is that the mnemonic tuning for contamination observed in Study 9 is not related with complexity and variability.

Table 3.

Pearson correlation coefficients among the differences scores of recall, complexity, and variability.

	∆recall	**∆complexity**
∆recall		
∆complexity	.10	
∆variability	-.06	-.11

Note: ∆recall = $\text{recall}_{\text{contamination}}$ - $\text{recall}_{\text{autobiographical}}$; ∆complexity = $\text{complexity}_{\text{contamination}}$ - $\text{complexity}_{\text{autobiographical}}$; ∆variability = $\text{variability}_{\text{contamination}}$ - $\text{variability}_{\text{autobiographical}}$.

2. Norming study in an online sample

Additional data regarding these two variables were collected through a web-based survey powered by Qualtrics (Qualtrics Labs Inc., Provo, UT) and disseminated to Portuguese universities by email. Using a 9-point rating scale, 113 participants (females = 92; M_{age} = 41.02, *SD* = 13.20; age range: 18-70 years old) were asked to rate on several dimensions a sample of generated sentences. Specifically, they were asked to evaluate the complexity (1-poorly elaborated/complex, 9-very elaborated/complex), emotional arousal (1-very calm, 9-very excited) and valence (1-very negative, 9-very positive) of each generation. Additionally, participants were required to press “YES” if they thought the sentence described a situation of potential contamination or “NO” if it was unrelated to contamination. Each participant rated a set of 24 sentences, half generated for the contamination task and half generated for the autobiographical task; these were randomly selected from a larger sample of 336 generated sentences. This pool was, in turn, randomly drawn from the total of 1145 responses generated in Study 9. Sentences were also presented on a random order for each participant and no information was provided about the sentence condition. Responses were self-paced. Informed consent was obtained from all participants prior to data collection.

Complexity. The sentences generated in the contamination condition were classified as more complex than the autobiographical condition (see Table 4).

Arousal. The contamination-generated sentences were perceived as significantly more arousing than the autobiographical-generated sentences (see Table 4).

Valence. Participants rated the contamination generations as significantly more negative than the autobiographical episodes (see Table 4).

Table 4.

Mean (and standard deviation) obtained for each dimension along with the paired t-test comparison results.

	Contamination	**Autobiographical**	***t*-tests comparisons**
Complexity	3.91 (0.47)	3.56 (0.42)	$t(23) = 2.53$*
Arousal	3.94 (0.44)	2.66 (0.40)	$t(23) = 10.33$***
Valence	3.61 (0.43)	5.36 (0.77)	$t(23) = -10.37$***

* $p < .05$; *** $p < .001$

Correlation among variables. To determine whether recall was related to the just-mentioned variables, Pearson correlations were again performed (at the item-level). Once again, difference scores were calculated for each item on each measure by subtracting the scores for the contamination condition from those for the autobiographical condition. Recall was not significantly correlated with none of the variables (see Table 5). These analyses also seem to suggest that the mnemonic advantage for contamination (defined as the difference between recall of a given word for which participants generated a contamination situation vs. for which participants generated an autobiographical episode) does not seem to relate with the complexity, arousal, or valence of the generated situation.

Table 5.

Pearson correlation coefficients among the differences scores of recall, complexity, arousal, and valence.

	∆recall	**∆complexity**	**∆arousal**
∆recall			
∆complexity	.28		
∆arousal	.21	.65**	
∆valence	.01	-.22	-.60**

Note: ∆recall = recall$_{\text{contamination}}$ - recall$_{\text{autobiographical}}$; ∆complexity = complexity$_{\text{contamination}}$ - complexity$_{\text{autobiographical}}$; ∆arousal = arousal$_{\text{contamination}}$ - arousal$_{\text{autobiographical}}$; ∆valence = valence$_{\text{contamination}}$ - valencel$_{\text{autobiographical}}$.

Contamination situation. Participants provided a higher proportion of “yes” responses to the sentences formulated in the contamination condition compared to the autobiographical condition (M = .78, SD = .10 and M = .09, SD = .09, respectively), $t(23) = 32.88$, $p < .001$, $d_z = 6.711$. In addition, they also gave a higher proportion of “no” responses to sentences generated in the autobiographical condition compared to the contamination condition (M = .91, SD = .09 and M = .22, SD = .10, respectively), $t(23) = -32.88$, $p < .001$, $d_z = 6.711$. These results suggest that participants of Study 9, for the large majority, were following instructions and formulating the required situations.

3. Final Conclusion

The results of the just described qualitative analyses suggest that the responses generated in the autobiographical condition were more complex than those generated on the contamination condition. However, the opposite was observed when considering the subjective ratings provided by an independent sample; that is, responses generated to the contamination condition were considered more complex than those provided in the autobiographical condition. These conflicting results may in part be due to the differing methods used to obtain these evaluations; whereas in the first, two independent raters followed a strict guideline, assigning points whenever a certain specification was present in the response (see Table 1), in the latter, independent participants subjectively rated how complex they thought the sentence was, with no guidelines being provided. This left room for a wide range of subjective assessments; for example, the generated sentence

“Someone sneezed on the cake.” obtained subjective ratings that ranged from 1 to 7 (*M* = 3.50, *SD* = 2.59), compared to a rating of 1 given by the researchers. Additionally, each participant rated only a set of 24 responses, whereas the two researchers rated 1145 responses. It could be that the randomly selected sentences were, by themselves, more complex in one case than in the other. In spite of this variability, when we consider the same 336 sentences that were submitted to the two forms of evaluation, we obtained a positive and significant correlation of .36, p < .001. Nevertheless, and most importantly to the purpose of these analysis, the recall advantage for contamination was not associated with complexity nor with the remaining variables.

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SUPPLEMENTARY MATERIAL 2.

Descriptive statistics and correlation among individual variables

Self-reported data on individual characteristics were collected at the end of the experiments (as indicated in the procedural description of some of the studies). These included information on each person's propensity and sensitivity to disgust (Portuguese sample: DPSS-R, DP, and DS; American sample: PDS), perceived vulnerability to disease (PVD, PI, and GA; Portuguese sample only), and health status. This Supplementary Material aims to characterize our samples in terms of these dimensions. Additionally, considering that, to date, little is known about whether, and how, these variables are related, we were also interested in examining correlations between these individual variables. Table 1 and Table 2 summarize the descriptive statistics of all individual scales and respective subscales administrated in the Portuguese and American samples. Table 3 presents the *Pearson* correlations among the individual variables.

Portuguese participants scored around 30 on the DPSS-R scale (i.e., at the mid-scale: total score range = 11–55; see Table 1), whereas the American participants scored, on average, around 4 (total score range = 0–6; see Table 2). The scores of the DP and DS subscales were correlated with each other, and with the total scores of the DPSS-R. The scored of both the PI and the GA subscales correlated strongly with the PVDS total score, but only moderately with each other (see Table 3); these findings resonate with those of Duncan, Schaller, and Park (2009), who proposed that these two subscales represent different constructs with different implications and, consequently, are only modestly correlated. Significant correlations were also found between the subscales of the different scales. Our results are also in line with those reported by Duncan et al. (2009), who found that DP and GA were moderately correlated but DP and PI were only weakly correlated.

More importantly to our purposes, was to examine if objective and subjective vulnerability to disease relates positively with elevated propensity and sensitivity to disgust. Our results indicated that vulnerability to disease (actual or perceived) is positively correlated with DP and DS (see Table 3). In other words, the more participants perceived themselves as susceptible to infection transmission, the more likely they were to feel disgust and to experience such emotion as negative and harmful. Additionally, the less able to cope with illness they reported to be (due to recent illness; based on the continuous measure), the higher they estimate the negative consequences of experiencing disgust. These findings make evolutionary sense, because a higher experience of disgust propensity and sensitivity will likely prompt individuals to minimize contact with costly pathogens in a period in which their immune system is not able to effectively contain microorganisms that could result in opportunistic diseases. Recent illness and DP were, however, only marginally correlated in Portuguese participants (see Table 3). A similar result was obtained in the American sample, *r* = .12, *p* = .125. Other studies testing DP in immunocompromised individuals have found mixed results. For example, studies with pregnant women revealed that women in the first trimester are more prone to experience disgust compared to women in later stages of pregnancy (Fessler, Eng, & Navarrete, 2005). Contrariwise, DP scores in patients with a diagnosis of rheumatoid arthritis (an immunosuppressed group) did not differ from those obtained in age-matched controls, and the use of immunosuppressive drugs was even associated with lower DP (Oaten, Stevenson, & Case, 2017). Likewise, cocaine-dependent men (with elevated inflammatory markers, receiving more antibiotics and with enhanced difficulty fighting off infections) had similar DP levels to age-matched controls (Ersche et al., 2014). De Barra et al. (2014) also did not find a significant correlation between DP and self-reported illness recency. Interestingly, in the study by Stevenson, Case and Oaten (2009), DP was positively associated with illness frequency (i.e., the number of times that each individual was sick in the last year), but not with illness recency (i.e., the time when an infection was last present). This is an interesting finding worth additional investigation. In our studies, however, illness frequency was not assessed and thus this relation could not be tested. In fact, these authors found that people who were more disgust prone had significantly fewer recent infections, suggesting that a higher DP decreases the likelihood of being infected by pathogens.

Finally, no relation was found between the GA subscale and health status (see Table 3). This subscale measures the participants’ agreement with statements describing behavioral avoidance of situations in which pathogens can be transmitted (e.g., item 4: “I do not like to write with a pencil someone else has obviously chewed on”) and preferences for hygienic behaviors (e.g., item 6: “I prefer to wash my hands pretty soon after shaking someone's hand”). Because such strategies would mostly benefit immunologically compromised individuals, we expected the GA to be positively related with participants’ illness recency, which was not the case. Our findings are more aligned with those of Prokop, Fančovičová, and Fedor (2010). Anecdotally, and contrary to expectations, these authors found more disease-avoidance behaviors in healthy participants compared to those with poorer health. As advocated by the authors, “better health can therefore be viewed at least partly as a result of more effective strategy protecting our bodies against parasites" (Prokop et al., 2010, p. 231).

In sum, the correlation analyses here conducted provide another look at how these variables are interconnected. Of particular interest was how participants' illness recency (as measured by the continuous variable of health status) relates to the sensitivity to the emotional reaction of disgust and to perceived infectability. As noted elsewhere, some of the items included in this continuous measure of health status could lead participants to respond according to non-physical wellbeing. On the other hand, the categorical measure of health status referred specifically to the last time that the participant was sick. When we compare the results obtained in the various individual measures between those participants classified as recently ill or not, no significant differences were found (Portuguese participants: highest *t*(131) = 1.34, *p* = .184 for PI; American participants: *t*(174) = 1.53, *p* = .127; see Table 4).

Note, however, that all of these results should be interpreted with caution because we used self-reports of health status rather than immune markers of inflammation. Because self-report instruments are prone to reporting biases (Van de Mortel, 2008), further studies should incorporate more objective accurate measures of health status (e.g., access to medical records). Additionally, these results raise doubts on the idea that high values on these self-reported individual differences do indeed reflect an activation of the BIS.

Table 1.

Mean, Standard Deviation, and range (minimum-maximum) obtained in the questionnaires administered to Portuguese participants.

	Study 3a			**Study 3b**			**Study 4a**			**Study 4b**		
	N = 48			*N* = 48			*N* = 106			*N* = 48		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
DPSS-R	31.52	5.59	17-43	28.81	5.60	15-40				30.94	7.69	17-53
DP	19.60	3.15	12-26	17.15	3.34	10-23				18.94	4.00	10-30
DS	11.92	3.60	5-21	11.67	3.37	5-22				12.00	4.36	5-23
PVDS	3.26	0.80	1.58-5.42	3.53	0.56	1.83-5.27				3.35	0.86	1.75-5.50
PI	2.92	0.99	1.33-5.83	2.88	1.05	1.00-5.50				3.08	1.11	1.00-5.67
GA	3.60	0.97	1.83-6.67	3.35	1.11	1.33-6.17				3.61	1.03	1.50-6.50
Health status	2.79	1.56	1.00-7.00	2.60	1.72	1.00-6.00	2.95	1.64	1.00-6.50	2.54	1.38	1.00-5.25

Table 2.

Mean, Standard Deviation, and range (minimum-maximum) obtained in the questionnaires administered to American participants.

	Study 5a			**Study 5b**			**Study 6 – DC**			**Study 6 – NDC**		
	N = 48			*N* = 48			*N* = 40			*N* = 40		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
PDS	4.15	0.92	1.86-5.71	4.12	0.70	1.86-5.43	4.01	0.81	2.29-5.14	4.23	0.69	3.14-5.86
Health status	3.01	1.67	1.00-7.00	3.00	1.60	1.00-6.25	3.00	1.81	1.00-7.00	2.46	1.59	1.00-6.25

Note: DC = Disease condition; NDC = Non-disease condition

Table 3.

Pairwise Pearson correlation coefficients among the individual variables administered in Portuguese participants (Studies 3a, 3b and 4b; N = 144).

	DPSS-R	**DP**	**DS**	**PVDS**	**PI**	**GA**
DPSS-R						
DP	.86***					
DS	.87***	.50***				
PVDS	.27**	.21*	.25**			
PI	.25**	.18*	.25**	.71***		
GA	.30***	.36***	$.16^{+}$	.64***	.34***	
Health status	.26**	$.16^{+}$	.29***	.28**	.34***	.10

$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 4.

Means (and standard deviations) obtained in each dimension by sick and healthy Portuguese participants (on the left; Studies 3a, 3b and 4b) and American participants (on the right; Studies 5a, 5b and 6), according to the categorical measure.

	Sick	**Healthy**	**Sick**	**Healthy**
	N = 31	*N* = 102	*N* = 67	*N* = 109
DPSS-R	31.10 (7.49)	30.45 (6.14)		
DP	19.13 (3.91)	18.40 (3.65)	4.24 (0.76)	4.06 (0.79)
DS	11.97 (4.44)	12.05 (3.52)		
PVDS	3.43 (0.85)	3.37 (0.72)		
PI	3.15 (1.17)	2.87 (0.97)		
GA	3.52 (1.06)	3.53 (1.05)		

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