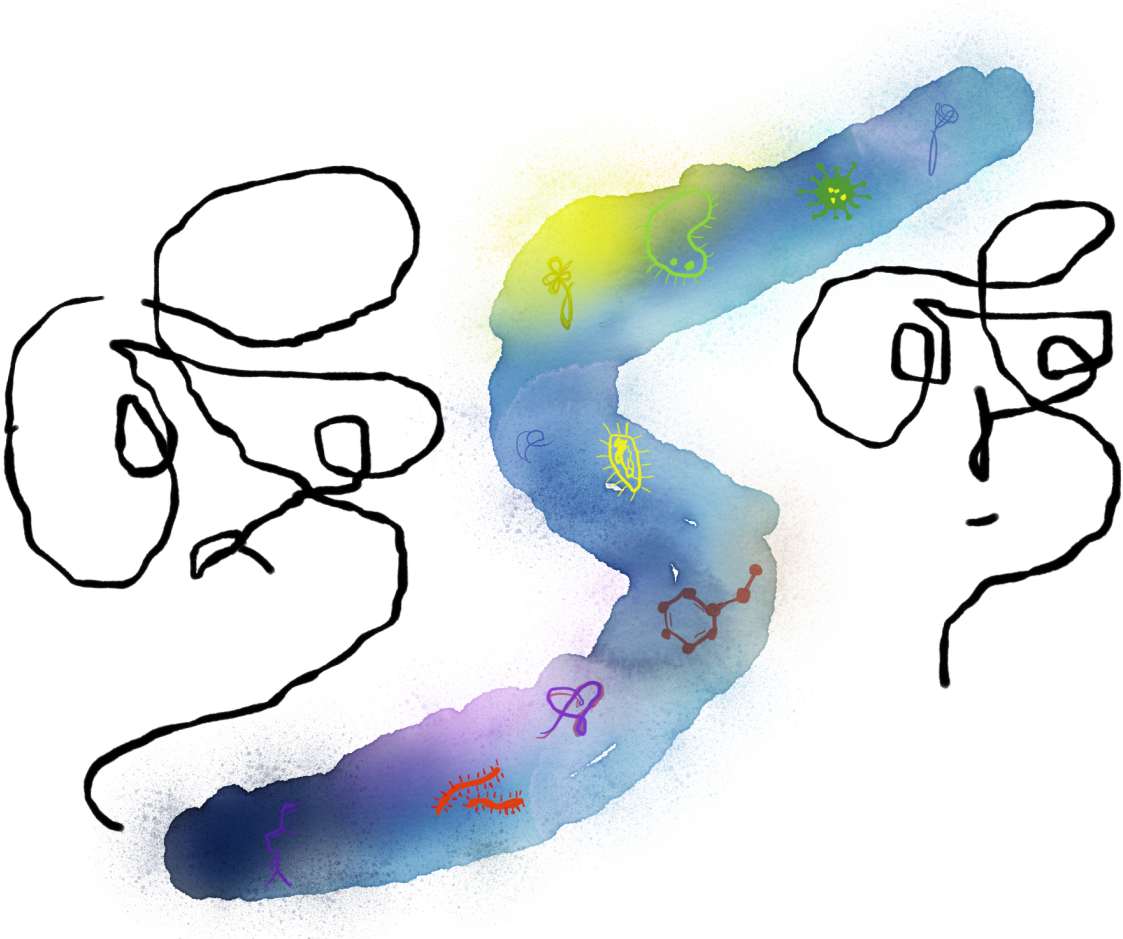
Stockholm University

Olfaction and prejudice

The role of body odor disgust sensitivity and disease avoidance in understanding social attitudes

Marta Zakrzewska



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Academic dissertation for the Degree of Doctor of Philosophy in Psychology at Stockholm University to be publicly defended on Thursday 25 August 2022 at 10.00 in Hörsal 4, Hus 2, Albano, Albanovägen 18 and online via Zoom, public link is available at the department website.

Abstract

Disease avoidance is one of the main roles of olfaction. In particular, body odors are universal elicitors of disgust, a core emotion that plays a key role in disease avoidance. The disease avoidance theoretical framework emphasizes psychological mechanisms – attitudes and behaviors – aiming to recognize and evade pathogen threats. Thus, it focuses on behavioral immune defenses and disgust, which often evokes such attitudes and behaviors. Importantly, the quality of body odors changes with sickness, and thus olfactory disease detection is possible. Body odor disgust sensitivity (BODS) might reflect a behavioral disposition to avoid pathogens, and it may also involve social attitudes that prefer limited contact with strangers. The general aim of this thesis was to investigate the connection between olfaction, (body) odor disgust, and social attitudes from the perspective of disease avoidance.

In **Study I**, I investigated the relationship between disgust sensitivity to body odors and prejudice. Using an online survey, I found that high levels of BODS were associated with stronger prejudice towards a fictitious refugee group and that this relationship was partially explained by perceiving the group as different in terms of food, hygiene, and sanitary practices. In **Study II**, I looked at the association between olfactory stimulation, BODS, and implicit bias toward an outgroup. BODS levels were positively related to implicit bias towards an outgroup; however, this bias was not affected by olfactory cues. In **Study III**, I aimed to see if the relationship between BODS and prejudice generalizes across different cultures and locations. I found that higher BODS levels were associated with more prejudiced attitudes towards a fictitious refugee group across nine countries on all continents. As in Study I, this relationship was partially explained by perceived dissimilarities of the refugees' norms regarding hygiene and food preparation, and general attitudes toward immigration. In **Study IV**, I investigated the relationship between the self-reported body odor disgust and perception of real odors, showing that individuals with higher BODS levels perceived smells as more highly valenced overall: unpleasant smells were rated as more unpleasant, and pleasant smells were rated as more pleasant.

Overall, the research presented in this thesis supports the idea that there is a link between olfactory disgust and prejudice, which can be explained by disease avoidance behaviors.

Keywords: *olfaction, disease avoidance, prejudice, body odors, disgust sensitivity.*

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To my grandparents,
who passed away all too
soon

Abstract

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In **Study I**, I investigated the relationship between disgust sensitivity to body odors and prejudice. Using an online survey, I found that high levels of BODS were associated with stronger prejudice towards a fictitious refugee group and that this relationship was partially explained by perceiving the group as different in terms of food, hygiene, and sanitary practices. In **Study II**, I looked at the association between olfactory stimulation, BODS, and implicit bias toward an outgroup. BODS levels were positively related to implicit bias towards an outgroup; however, this bias was not affected by olfactory cues. In **Study III**, I aimed to see if the relationship between BODS and prejudice generalizes across different cultures and locations. I found that higher BODS levels were associated with more prejudiced attitudes towards a fictitious refugee group across nine countries on all continents. As in Study I, this relationship was partially explained by perceived dissimilarities of the refugees' norms regarding hygiene and food preparation, and general attitudes toward immigration. In **Study IV**, I investigated the relationship between the self-reported body odor disgust and perception of real odors, showing that individuals with higher BODS levels perceived smells as more highly valenced overall: unpleasant smells were rated as more unpleasant, and pleasant smells were rated as more pleasant.

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Samanfattning på Svenska

Att undvika sjukdomar är en av luktsinnets huvuduppgifter. Kroppslukter framkallar äckel, en grundläggande känsla som spelar en nyckelroll för att undvika sjukdomar och för det beteendemässiga immunförsvar. Beteendemässiga immunförsvaret omfattar (bland annat) psykologiska mekanismer – attityder och beteenden – som syftar till att känna igen och undvika patogenhot, ofta genom att framkalla äckel. Kroppslukter förändras vid sjukdom, vilket gör att sjukdomar kan upptäckas av luktsinnet. Äckelskänslighet för kroppslukter (*body odor disgust sensitivity*, BODS) speglar möjligen en beteendemässig disposition att undvika patogener, och det kan också involvera sociala attityder. Det generella syftet med denna avhandling var att undersöka sambandet mellan luktperception, äckelskänslighet för kroppslukter och sociala attityder utifrån perspektivet att undvika sjukdomar och det beteendemässiga immunsystemet.

Studie I undersökte sambandet mellan äckelkänslighet för kroppslukter och fördomar. Med hjälp av en online-undersökning fann jag att höga nivåer av BODS var förknippade med starkare fördomar mot en fiktiv flyktinggrupp, och att detta förhållande delvis förklarades av att gruppen uppfattades som olika vad gäller mat, hygien och sanitära metoder. **Studie II** undersökte sambandet mellan luktstimulering, BODS, och implicita fördomar mot en utgrupp. BODS-nivåer var positivt relaterade till fördomar mot utgruppen, men detta samband påverkades inte av luktstimulering. **Studie III** syftade till att se om förhållandet mellan BODS och fördomar generaliserar över olika kulturer och platser. Resultaten visade att högre BODS-nivåer var förknippade med starkare fördomar mot en fiktiv flyktinggrupp i nio länder på alla kontinenter. Liksom i Studie I förklarades detta förhållande delvis av upplevda olikheter i flyktingarnas normer för hygien och matlagning, samt av allmänna attityder till migration. **Studie IV** undersökte sambandet mellan den självrapporterade äckelkänsligheten för kroppslukter och uppfattningen av verkliga lukter, och visade att individer med högre BODS-nivåer uppfattade behagliga dofter som mer behagliga, och obehagliga dofter som mer obehagliga.

Sammantaget stöder forskningen som presenteras i denna avhandling tesen att det finns ett samband mellan äckelskänslighet för kroppslukter och fördomar, vilket kan förklaras av beteenden relaterade till att undvika sjukdomar.

Acknowledgments

I have been looking forward to writing this part for many years. At times, I even thought I should start drafting it to make sure I will not forget those who helped me at the beginning of my journey. Surprisingly, many of you are still here.

First and foremost, I want to thank my supervisors, Jonas Olofsson and Marco Tullio Liuzza. I have been truly happy to have you both on this journey. Jonas, you always gave me a lot of independence while at the same time giving me absolutely invaluable guidance in how to proceed with my research. I learned a lot from you, not the least of which is how to nourish an *inner fan* next to my well-established inner critic. Marco, thank you for numerous discussions about what is it that we want to study, what it all means and how to make sure we use the best available statistical tools to approach the topic.

I need to thank the two people who although not officially in any way connected to my PhD, gave me abundant support and advice through the journey. Maria Larsson, you are an inspiration and a ray of sunshine on darker days. Mats Nilsson, I learned something new every time we taught together and I am eternally grateful for putting causality into my mind.

My GEL colleagues, current and past, and fellow PhD students. I would need an entire chapter to thank each and one of you properly. Joanna for being always there both as a friend and a colleague, it has been such a pleasure to share this academic adventure with you! Ingrid for sharing more than an office in our different, yet similar paths. Stina, tack för att du alltid förbättrar min svenska och mitt liv i labbet. Philip and Kim – it's been a pleasure to be together on all the event planning committees, even if I complained about it at times. Hellen, thank you for motivating each other to climb higher (literally).

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My boardgaming team: Anders Sand, Andreas Jemstedt, Henrik Nordström, Jim Åkerström and Tina Sundelin, who regularly stimulated not only my competitiveness in camel racing, gathering birds, or escaping rooms but also my curiosity about science and the desire to question what is taken as proven or known. Anders kept being the voice out loud of my own biggest doubts about this research and gave me opportunities to think and discuss freely, for which I will always be thankful (and not at all *grumpy*).

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To 방탄소년단 who unaware of my existence taught me so much about my own unaware prejudice. They made me discover that many of the very wise and lovable people in my life are also holders of biased attitudes toward the unknown, and that each one of us can do something to diminish the overall sum of bias in the world.

Mamo, Tato – dziękuję za wsparcie w moich zapewne często nie zrozumiałych wyborach życiowych.

Last but not least: to the two dearest people in my life, whose birthdays are inconveniently very close to each other and make for impossible choices every now and then. Kasik, it's a thrill to share most of my crazinesses with you. I'd be a different person if not for you, and not a better one. I purple you <3! Kalle, you're the best support I could have wished for, and the only one I am not afraid to ask for. I love you. Thank you for existing.

List of Studies

This doctoral thesis is based on the following studies:

I **Zakrzewska, M. Z.**, Olofsson, J. K., Lindholm, T., Blomkvist, A., & Liuzza, M. T. (2019). Body odor disgust sensitivity is associated with prejudice towards a fictive group of immigrants. *Physiology & Behavior*, *201*, 221–227. https://doi.org/10.1016/j.physbeh.2019.01.006. *

II **Zakrzewska, M. Z**., Liuzza, M. T., Lindholm, T., Blomkvist, A., Larsson, M., & Olofsson, J. K. (2020). An Overprotective Nose? Implicit Bias Is Positively Related to Individual Differences in Body Odor Disgust Sensitivity. *Frontiers in Psychology*, *11*, 301. https://doi.org/10.3389/fpsyg.2020.00301. **

III **Zakrzewska, M. Z.**, Challma, S., Lindholm, T., Olofsson, J. K. & Liuzza, M. T., (*Submitted*). Body odor disgust sensitivity is associated with xenophobia: Evidence from 9 countries across 5 continents.

IV **Zakrzewska, M. Z.**, Liuzza, M. T., & Olofsson, J. K. (*Submitted*). Body odor disgust sensitivity (BODS) is related to extreme odor valence.

Contents

Abbreviations

BF_{01}	Bayes Factor, evidence for null over alternative hypothesis
BF_{10}	Bayes Factor, evidence for alternative over null hypothesis
BIS	Behavioral immune system
BODS	Body odor disgust sensitivity
DAG	Directed acyclical graph
DS (-R)	Disgust scale (- Revised)
HDPI	Highest density posterior interval
IAT	Implicit association test
LPS	Lipopolysaccharide
MHC	Major histocompatibility complex
OB	Olfactory bulb
OFC	Orbitofrontal cortex
OSF	Open science framework
PCI	Posterior credible interval
PVD	Perceived vulnerability to disease
RWA	Right-wing authoritarianism
SDO	Social dominance orientation
SDS	Social distance scale
SDT	Signal detection theory
SE	Standard error; ΔSE – standard error of the difference
SEM	Structural equation modeling
TDDS	Three domain disgust scale
VA	Valeric acid
VOC	Volatile organic compound
WAIC	Widely applicable information criterion (also known as the Watanabe Akaike information criterion); ΔWAIC – WAIC difference

Introduction

> "Odors have a power of persuasion stronger than that of words, appearances, emotions, or will. The persuasive power of an odor cannot be fended off, it enters into us like breath into our lungs, it fills us up, imbues us totally. There is no remedy for it"
>
> (Süskind, *Perfume:The story of a murderer*)

The work presented in this thesis is devoted to the study of the sense of smell (olfaction) and its perhaps unexpected relevance to understanding attitudes towards other people. My research revolves around olfaction and body odors, pathogens and avoiding diseases, and prejudice. Understanding the relationship between these three topics is important for creating a comprehensive view of contemporary attitudes and prejudice. I will start by introducing a theoretical overview of concepts related to prejudice and its bases. Second, I will present what we know about avoiding diseases, the role of disgust in eluding pathogens, and how it is relevant to prejudice. Next, I will discuss the importance of olfaction, body odors, and olfactory disgust for both disease avoidance and social interactions. Finally, I will bring all three topics (prejudice, disease avoidance, and olfaction) together, outlining the theory and hypotheses behind the aims of this thesis, thus ending the introductory part of this text. The aims of the thesis will be then presented, following an overview of the methods I used, and individual descriptions of the four Studies I conducted. In the last part of the thesis, I will reflect on my aims and discuss my findings in a more general way, providing ideas for future work in this topic.

Social bias, intergroup bias and prejudice

People often rely on generalizations regarding others, based on their group memberships or superficial attributes. Social bias towards a group (or: intergroup bias) can be defined as a 'systematic tendency to evaluate one's own membership group (the ingroup) or its members more favorably than a non-membership group (the outgroup) or its members' (Hewstone et al., 2002). It is thought to take different forms such as prejudice, discrimination, and stereotyping (Dovidio et al., 2010; Hewstone et al., 2002). Although the exact definitions of these three forms of intergroup bias can vary depending on the author or discipline, there is usually a common notion that prejudice refers to *attitudes*, discrimination to *behavior*, and stereotyping to *cognition* (Hewstone et al., 2002). Of particular interest here is prejudice, so the attitudes towards other people and groups that are not based on experience. From a social psychology perspective, all attitudes are thought to have three components: affective component (emotions towards the outgroup, e.g., dislike or disgust), cognitive component (thoughts and beliefs about the outgroup), and a conative component (a general, behavioral predisposition to behave in a certain way towards the outgroup). Note that other definitions of prejudice encompass it as an umbrella for stereotypes (the cognitive component), discrimination (the behavioral component), and an affective component. Through this thesis, whenever I talk about social or intergroup bias, I mean the related attitudes (prejudice), unless otherwise stated.

Theoretical overview

Intergroup bias research came in three waves according to Dovidio and colleagues (2010). In the first and earliest wave of research, prejudice was thought to be a pathology. Social bias was thus nothing more than psychopathology, an unnatural process. The second wave suggested a contrary approach: bias was now perceived as normal or at least coming from normal, healthy cognitive processes. It was a product of the general tendency of humans to categorize and simplify various aspects of the otherwise overwhelming world (and the people in it). In this wave, concepts of social identities and group processes were first introduced as having an effect on social bias. The third wave of research followed naturally, focusing on both interpersonal and

intergroup relations, combining interests in intrapersonal factors (emotions, conscious and unconscious processes, neural processes, motivation, etc.) with more macro-level factors, pointing out the roles of societal structures and institutions in social bias. Overall, we see a historical shift from how prejudice was conceptualized and approached: starting from seeing prejudice as "a natural response to the deficiencies of "backward" peoples", going through stages of focusing on psychoanalysis and frustration theories, sociocultural explanations or cognitive processes until finally arriving at the current stage, where prejudice is viewed as complex phenomena with multiple bases: cultural, affective and motivational, among others (Duckitt, 2010, p. 31). Researchers nowadays are more fully embracing the need to approach the topic from many disciplines: psychology, sociology, biology, anthropology, and political sciences (Dovidio et al., 2010). This thesis is situated in the current multidisciplinary approach to studying prejudice and adds another discipline's perspective: sensory science. Before this new perspective makes a proper appearance, I would like to present some key concepts from prejudice literature that are crucial for this thesis.

Ingroups and outgroups

The terms *ingroup* and *outgroup* are in my opinion very specific for social psychology and thus need some clarification. As mentioned in the definition of intergroup bias, an ingroup is the group that an individual considers himself or herself to be a part of. Members of an ingroup are thus members of one's own group. In contrast, an outgroup is an existing group, to which an individual does not consider himself or herself to belong to. The outgroup also is perceived as a group, just not one's own group. In very similar words: members of an outgroup, are *not* members of one's own group, but members of some other group. The perception of ingroup and outgroup is a result of the general human tendency to categorize and put oneself (us, ingroup) and others (them, outgroup) into groups. One result of such categorization is a generalization about both ingroups and outgroups: minimizing differences within each group and overemphasizing differences between each group (Allport, 1985). These two terms are relevant for two main aspects of social biases, both in terms of attitudes and behaviors: ingroup favoritism and outgroup derogation.

Ingroup favoritism vs. outgroup derogation

Prejudice does not always need to include dislike for outgroups or be derogatory in nature. In fact, research shows that the most common form of prejudice and discrimination (so both in terms of attitudes and behaviors, for example, allocation of resources) towards an outgroup is not an overtly negative response to the outgroup itself, but a vast preference for, and positive attitude

towards the ingroup (see e.g. M. B. Brewer, 1999). In other words, prejudice can lack actual negative feelings towards the outgroup (M. B. Brewer, 2007). Even more, ingroup favoritism may occur when there is no outgroup present at all (Gaertner et al., 2006). Ingroup favoritism is considered to be a beneficial adaptation evolved to help humans get the most out of living in groups. Researchers suggest that emotions play a big role in shifting from ingroup favoritism to outgroup derogation (Mackie & Smith, 1998), especially strong emotions such as fear, hatred, or disgust (Smith, 1993).

Bases for prejudice: evolution, emotions, and cognition

What has research suggested so far in terms of bases for prejudice? Each subfield of psychology, sociology, anthropology, and probably other sciences could add something to answer this question. Here, I will briefly describe the most relevant ideas for the scope of my thesis. They mostly steam from evolutionary and cognitive perspectives but include also ideas that focus on motivation and emotions, structural hierarchies in society, and cultural aspects.

When talking about evolutionary bases for prejudice, we should mention two distinct processes: genetic evolution and (socio-) cultural evolution. The first one is related mostly to changes in genes, which take a long time, and focus on entire populations of our ancestors; the second usually happens across shorter time scales and can focus also on individuals, even if it has consequences for entire populations. Usually, when thinking about evolutionary adaptations we have in mind the effects evolution has on genes: certain genes get promoted, and certain discarded. However, it is important to realize that evolutionary adaptations can also take the form of promoting (or discarding) certain behavioral dispositions or psychological features that can increase survival and reproductive fitness (Mesoudi et al., 2006; Schaller, Gideon Conway III, et al., 2010).

The disposition to form groups

A good example of behavioral evolutionary adaptations is the fact that we have evolved to live in groups. Living in groups was (and is) beneficial and thus our predecessors formed groups in which individuals were dependent on each other and had to cooperate; humans are particularly apt to live this way (e.g. Brewer & Caporael, 2006). This is also reflected in a notion coming from cognitive psychology that we have an inclination toward categorizing objects and people into groups (Allport, 1985). In fact, this tendency of humans to form groups, and to categorize people into groups is very relevant for forming biases. A natural consequence of forming a group is that we a) have group members, and individuals that do not belong to our group, and b) have other, not our own, groups – the outgroups. In the evolutionary literature, such

groups are often called coalitional groups (e.g., Kurzban et al., 2001). For coalitional groups to function best, it is important that we try to benefit our own coalition group members as much as possible, while not showing similar altruism to members outside of our group (e.g. Brewer & Caporael, 2006). In other words, group life is facilitated by ingroup favoritism, a preference for the ingroup. Contemporary social categorizations (Cosmides & Tooby, 2015) emerged as a function of coalition groups (Kurzban et al., 2001; Schaller, Gideon Conway III, et al., 2010). Similarly, norms evolved as a part of a similar psychological mechanism. Namely, the benefits gained from coalitional groups should be highest if the group function like a well-oiled machine, and for this to happen, rules are needed. If rules are broken, the cooperation within the group is not fully efficient and can limit the benefits. Thus, individuals who disregard norms are a threat to the cost-benefit balance of the group (e.g., Neuberg et al., 2000). In this context, outgroup members (members of other coalitional groups) can be perceived as a threat because they are thought to follow partly different norms, which might differ substantially from the ingroup norms. This perspective highlights possible evolutionary adaptations relevant both for prejudice against outgroups, and against deviant ingroup members. Interestingly, this translates into emotions related to encounters with outgroups: negative emotions accompanied interactions with minority ethnic groups when they were perceived as culturally dissimilar, while positive emotions were felt when the minority group was more similar in terms of culture (Dijker, 1987).

Simplifying and speeding up the processing of information

Evolutionary adaptations can be manifested in other ways, also of particular relevance for prejudice. For example, there are adaptations related to cognitive aspects of the processing of information, such as attentional biases, shortcuts done when processing information, and categorization processes (Maner et al., 2007; Miller & Maner, 2012; Todd & Gigerenzer, 2000). From a cognitive perspective, these processes are often referred to as automatic; they are applied without deliberation and may be largely outside of the individual's control. For example, research shows that categorizing others by race, sex, age or even attractiveness happens at a sub-second level (see Fiske, 1998 for review; Macrae & Bodenhausen, 2000, 2001). This rapid classification often relies on activations of related stereotypes about the category (group) that can be then used for individuals. Such automatic categorization can be thought of as resulting from relevant categorizations that are over-generalized (Fiske & Russell, 2010). These processes illustrate one cluster of evolutionary and cognitive bases for prejudice.

Response to threats

The human mind has evolved to respond to stimuli in adaptive ways, which include emotional and cognitive processes, as well as overt behaviors (Schaller, Gideon Conway III, et al., 2010). These responses are often reactions to events that are relevant to the fitness of the group or individual, for example events that constitute threats. Some of the most common threats are the threat of violence/aggression, the threat of limited resources, and the threat of disease (Neuberg & Cottrell, 2006). The threat of disease is of great relevance for this thesis and will be discussed in detail shortly. For now, I would like to look at the more general consequences of threat-related adaptations. First, different threats evoke different emotions. Research shows that when outgroups are classified as creating a threat of a certain type (e.g., violence, or showing a disregard for ingroup norms) they evoke feelings corresponding to this particular type of threat. The possibility of violence would evoke fear, while disregard for norms might evoke anger or disgust (Cottrell & Neuberg, 2005). Second, prejudice is boosted by a perceived threat, even if it's symbolic (not tangible). In fact, bias profits from ambiguity and ambivalence, just as it does from automaticity (Schaller, Gideon Conway III, et al., 2010).

The dual-process framework (Duckitt, 2001) provides a cognitive perspective that is especially relevant for contemporary social attitudes. It focuses on how distinct threats contribute to shaping different world views: either perceiving the world as "a competitive jungle" or as "a dangerous place". The first worldview is connected with the threat of competition for the limited resources (therefore the jungle metaphor). The second worldview can be related to the dangers of disease transmission. Both viewpoints can lead to perceiving outgroups as an overall threat and lead to intergroup bias.

Implications of evolutionary, cognitive, and emotional bases of prejudice

What are the normative implications of these adaptations and cognitive processes? Does it mean we are *justified/destined* to be prejudiced? It turns out that adaptations can be maladaptive, and cognitive shortcuts - misleading. Indeed, several of the adaptations mentioned above are maladaptive nowadays as present-time environments hardly resemble those of our ancestors. Importantly, psychological mechanisms are rather flexible. From an evolutionary perspective of balancing costs with benefits, psychological mechanisms need to be flexible, they should adapt based on cues from the context (Schaller et al., 2007).

Just because we can find evolutionary roots of intergroup bias doesn't mean that there is something "evolutionally fundamental about either race or ethnicity (…), race and ethnicity happen to be superficial markers for the evolutionarily fundamental distinction between coalitional groups." (Schaller, Gideon

Conway III, et al., 2010 p.84). What is fundamental, are the universal mechanisms of categorization process, attributes related to race/ethnicity are the superficial features that happened to be involved in these processes. To highlight this point, research shows that in presence of other meaningful grouping features (for example team uniforms), the tendency to classify people based on race decreases (Kurzban et al., 2001).

Most importantly, even though some cognitive processes are fairly automatic, it does not mean that they are not changeable. In fact, people can influence their automatic biases when confronted with information and/or when motivated to do so (Fiske & Neuberg, 1990)

Measuring prejudice

Prejudice is a complex phenomenon - I hope that by now I have conveyed this message to the reader. How can we tap into this complex construct and learn about individuals' attitudes? There is no golden tool, one questionnaire or task that gives us an accurate and reliable answer. Through this thesis, I used various tools to estimate people's attitudes towards outgroups. The most prominent distinction between prejudice measures concerns *implicit* vs. *explicit* measures. Again, the exact definition of what constitutes an implicit/explicit measure is not homogenous in the field, there is no consensus on the meaning of these terms. In this thesis, I follow the description presented in Correll et al., (2010). For a measure to be explicit, the individual has to be aware that prejudice is being assessed, and/or the answers given can be easily manipulated (controlled) by the individual. In contrast, for a measure to be implicit, it has to lack either one or both of these features: either awareness or controllability (or both). Note that in this definition, the implicitness or explicitness is a feature of the measure, not the attitudes measured. Thus, it does not say anything about whether the measure in question assesses automatic or controlled attitudes or processes. Explicit measures can focus on general or more content-specific attitudes and even include concepts that are related, but not fully equivalent to prejudice, such as authoritarianism or social dominance orientation. Implicit measures focus mostly on a) reaction times using (evaluative) priming paradigms or the Implicit association test (IAT, Greenwald et al., 1998), and b) physiological reaction, such as brain or facial muscles activity.

Both types of measures have their benefits and challenges. Explicit measures can suffer from self-presentation bias, where individuals are tempted to hide their attitudes related to socially sensitive issues (Dovidio et al., 2003), especially as negative attitudes towards outgroups are becoming unacceptable (Bobo, 2001). Another challenge is that individuals are often not fully aware of their own biases and attitudes.

Implicit measures have their own set of challenges, the most important of which is the lack of certainty about what type of bias they actually tap into. The general idea is that implicit measures reflect automatic biases. They do so by assessing the overlap between a group of interest and both positive and negative categories. The discussion is whether these automatic biases reflect associations and attitudes that the participant is unaware of, aware of but unwilling to disclose, or even if they are indeed based on individual attitudes rather than reflect learned cultural associations (Dovidio et al., 2002; Fiske & Russell, 2010). The last perspective is based on results from these implicit tasks, showing that pairing positive stimuli with the culturally dominant group produces quicker responses, and that biases are often in favor of the cultural majority group, while the opposite can be true for cultural outgroups (negative stimuli pairings produce quicker responses, Karpinski & Hilton, 2001). Taking into account research showing that results on implicit tasks are sensitive to instructions (Correll et al., 2010) and that it is not fully impossible to cheat on them if taught how to do so (Fiedler & Bluemke, 2005), the cultural-association argument gains strength. Leaving these discussions aside, it is still safe to say that implicit measures reflect positive and/or negative associations between the concepts of ingroup and outgroup. It is important not to draw too strong conclusions regarding the implicit nature of these processes.

As a consequence of these challenges and discussions connected to both explicit and implicit measures, there is also a disagreement about whether the two of them tap into the same thing (prejudice). When looking at the facts, the two types of measures are rather weakly related (Hofmann et al., 2005), load on independent factors in factor analyses (Cunningham et al., 2004) and are differently related to behavior (Lambert et al., 2005). A radical take on these differences is that we have only one type of prejudice and that it can only be evaluated by implicit measures, as explicit measures suffer too much from their limitations (Dunton & Fazio, 1997). On the other hand, some of the newer research suggests that the most reliable estimate of prejudice might be a simple question about group preference (Axt, 2018). Among the more inclusive explanation of the discrepancies between implicit and explicit measures, is that although they do tap into a single attitude (of prejudice), they do so at different stages of expressing this opinion, which also accounts for social desirability affecting the explicit expressions (later stage) more than implicit (earlier stage; Fazio et al., 1995). Alternatively, implicit and explicit could correspond to older vs. more newly funded attitudes (Wilson et al., 2000), or different aspects/components of the attitudes e.g. cognitive or affective (Rudman, 2004). A standpoint most close to my own is somewhere in the middle: an assumption that we have both implicit and explicit attitudes and prejudices, and that we should study them both, as distinct but valuable constructs that may teach us about intergroup bias (Hing & Zanna, 2010).

Individual differences in prejudice

"The individual differences that predict generalized prejudice can appear to be a laundry list" (Hing & Zanna, 2010, p. 166). Indeed, when going through research using the various explicit and implicit measures of prejudice, it can be hard to find order and method, which is important for making deductions (at least according to Hercule Poirot). Nevertheless, some patterns emerge and should be mentioned. Most importantly, individuals who show explicit prejudice towards a particular group are also likely to be prejudiced towards other groups. For example, prejudice towards ethnical minorities tends to go hand in hand with prejudice against sexual minorities or poor people (Aosved & Long, 2006; Bäckström & Björklund, 2007). There are examples of theories that try to integrate what we know about the bases of prejudice and the theories we have at hand into a more comprehensive framework. The dual processing framework (Duckitt, 2001) mentioned before is one example that tries to combine the evolutionary and cognitive perspectives of bases for intergroup bias with concepts related to prejudice that can be looked into using explicit measures.

The dual-process framework

According to this framework, there are two personal characteristics that are associated with prejudice, each in a different way: social dominance orientation and right-wing authoritarianism. Importantly, the two are distinguishable in terms of how they related to disease avoidance.

Social dominance theory (Sidanius & Pratto, 1999) focuses on the importance of hierarchical group structure for group benefits. The world is competitive and other groups might be thus perceived as threats. Some groups are more privileged and have more fitness benefits than others. Naturally, individuals (and groups, and even societies) can approve of the existing hierarchies to a different degree (e.g., Sidanius & Pratto, 1999). Social dominance orientation (SDO) reflects these preferences: people with high levels of SDO accept that groups differ in terms of status, support the hierarchy, and are not in favor of equality (Pratto et al., 1994), as a result of believing that the word is a competitive jungle. High levels of SDO are related to ingroup favoritism among high-status groups (Levin et al., 2002) and explicit outgroup bias (e.g. Amiot & Bourhis, 2005; Pratto et al., 1994).

On the other hand, we have authoritarianism, and its more updated concept: right-wing authoritarianism (RWA, Altemeyer, 1998). RWA encompasses a) conventionalism (or traditionalism), the adherence to norms and traditional values, b) aggression (or punitiveness), the negative attitudes towards and will to punish those who deviate from established norms, and c) submission, following authority figures. This mindset also places outgroups as potential threats. Again, individuals differ in terms of how they agree with the concepts

of RWA. High levels of RWA are related to explicit prejudice towards many groups (Duckitt, 2006).

In the dual-process framework, SDO and social dominance are related to perceiving the world as a competitive jungle, while RWA is related to perceiving the world as a dangerous place. These are the two cognitive and motivational paths that contribute to prejudice (Duckitt, 2001). Taken together, RWA and SDO give us substantial information about individuals' attitudes towards outgroups (e.g. McFarland, 2010) They both rely on the perceived threat to the ingroup, yet they uniquely account for prejudice, and reflect two of the most important dimensions of socio-political (or socio-cultural) attitudes and promote different strategies of how to deal with the threat (Duckitt et al., 2002). SDO focuses on boosting the economic and political advantage of the ingroup, while RWA focuses on following group norms and values as means of limiting the potential disadvantage of the ingroup. A further distinction between these two paths is reflected in research indicating that SDO is related to economic conservatism more than to social conservatism, the opposite being true for RWA, which is more related to social, rather than economic, conservatism (Duckitt, 2006; Duriez et al., 2005; Jost et al., 2009). Not surprisingly, people with high levels of both SDO and RWA are among the most prejudiced towards ethnic groups (Altemeyer, 2004).

Disease avoidance

> "Any pathogen avoidance system must be capable of first detecting pathogens. This is no small feat, given the microscopic nature of microbes"
>
> (Tybur & Lieberman, 2016)

Pathogens are a persistent threat, responsible for more deaths in the history of humans than any other threat, including war (Inhorn & Brown, 1990; Oldstone, 2010). They are invisible to the naked eye, which makes them a unique threat. In fact, it was not until the discovery of electron microscopy in the late 1890s that humans were able to actually see viruses; bacteria were discovered and observed some 40 years earlier, thanks to the work done by Louis Pasteur and Robert Koch (Oldstone, 2010). The mere idea of viruses as distinct agents was not around until the 1890s, when viruses were discovered independently by several scientists, including Dmitri Losifovich Ivanovski and Martinus Beijernik. Until then, the most popular theory about how diseases spread was the *miasma* theory. Miasma (meaning 'to soil' or 'to corrupt' in ancient Greek) theory held that diseases spread through bad air (miasma) which was contaminated by polluted objects such as rotten corpses or by air exhaled by sick individuals (Menuret de Chambaud, n.d.). This theory influenced responses to disease outbreaks: bad air was blamed for the cholera outbreak in 19th century London (Halliday, 2001). It is also the explanation behind the famous 'beak doctors' during the 17th-century plague – doctors covering their faces with beak-shaped masks filled with herbs and flowers in order to prevent coming in contact with the contagious air (Blakemore, 2020).

Despite the lack of knowledge, and misconceptions such as miasma theory, our ancestors were to some extent able to detect and avoid pathogens and life-threatening diseases (Tybur & Lieberman, 2016). Nevertheless, the number of existing infectious diseases continues to grow, posing new challenges to animals and humans. The density of population and easiness of travel make it easier for germs to spread, while pollution, drugs, and bad nutrition (among others) affect our immune systems negatively (see Kramer & Bressan, 2021).

Our immune system has developed amazing ways to protect us from foreign pathogens and parasites once we encounter them. Both the more general, innate immune system, which takes care of threats immediately after they appear, and the more specialized, adaptive immune system, which works in a

slower, long-term manner, are there to protect us from microbes. To better understand some of the research presented in this introduction it is good to be familiar with a couple of important immunity players. Cytokines are proteins produced by the cells of the immune system. They are responsible for communication between many different cells: immune systems cells (including the cells that produce them) but also glial cells, neurons, and others. They can have both a pro- and anti-inflammatory effect. Many of the cytokines are named interleukin with an identifying number (e.g., interleukin 6, IL-6, or interleukin 1, IL-1). Increased concentration of cytokines in the blood can suggest a heightened immune response to a pathogen threat. One of the jobs of the adaptive immune system is to produce antibodies – molecules that can recognize and neutralize a foreign particle (e.g. a pathogen) thus also rendering us immune to a given pathogen if we ever encounter it again (Abbas et al., 2020 was the source for my brief introduction to the immune system). Importantly for research on humans, the immune response can be studied without properly infecting the individual. One of the ways in which it can be done is by injecting lipopolysaccharide (LPS), which simulates the effects of bacterial infection without the actual bacteria entering the body. LPS stimulation induces a brief inflammatory response that returns to baseline levels between 6 to 24 hours after injection (depending on the inflammatory marker; (Lowry, 2005)

On a level visible to our naked eye, an attack of pathogens triggers disease-coping behaviors (sickness behaviors) such as fever, limited movements, food intake, and social interaction (Hart, 1988; Kent et al., 1992). These behaviors can be observed also after LPS stimulation. They benefit the effectiveness of the immune system, but they come at a cost. For humans, for example, avoiding contact with others means giving up on the benefits of social interactions or any potentially shared recourses (Sawada et al., 2018; Tybur et al., 2020). For animals, it often means decreased attention to predators and a higher risk of being attacked (Hart & Hart 2018).

Besides the tradeoff mentioned in the previous paragraph, multiple challenges to the immune system and repeated triggering of immune response can have a detrimental effect on the immune system functions (Segerstrom & Miller, 2004). Not surprisingly then, as fighting a disease after it had already reached our bodies might be too late (or too costly), we have also developed ways to protect the body from getting near potential sources of infection. These disease avoidance mechanisms have been lately called the behavioral immune system (BIS, Schaller & Park, 2011), to contrast it (for better or worse)[1] with the physiological immune system. Disease avoidance behaviors are present across species and involve grouping, grooming, avoiding foraging

[1] A discussion about the behavioral immune system terminology can be found in the General Discussion part of this thesis

near feces, using the healing power of saliva and plants, exclusion of sick conspecifics, not eating a conspecific carcass, etc. (Hart & Hart, 2018). Across species, animals showing signs of disease tend to be rejected or avoided (e.g. tadpoles, Goodall, 1986; and chimpanzees, Kiesecker et al., 1999). Although the disease threat is not unique to humans, the term BIS is used mostly when talking about humans.

The idea behind this distinction is that while the physiological immune system focuses on destroying pathogens after they enter the body using the arsenal of physiological reactions, BIS should take care of detecting and avoiding their sources through appropriate affective, cognitive, and behavioral reactions (Ackerman et al., 2018; Park et al., 2007). The two can have either complementary or compensatory relationship: a complementary relationship would mean that individuals with strong immune reactions would show a strong physical and behavioral response to threats, while a compensatory relationship would imply that if one system is weakened, the other would compensate by showing a stronger reaction (Ackerman et al., 2018).

The *behavioral immune system* concept is not universally accepted, and a critical perspective will be provided in the general discussion section. Throughout the thesis I will use the terms *disease avoidance*, *behavioral immune defenses*, and *BIS* interchangeably, always referring to the behaviors that avoid, limit and fight the disease threat.

There is some evidence for interactions between the physiological immune system and the behavioral defenses. Even though harmless themselves, pictures and descriptions of objects such as dirty toilets or infected individuals evoke disgust and can trigger a physiological reaction, namely increased body temperature (Stevenson et al., 2012), and increased pain sensitivity (Oaten et al., 2015). Interestingly, looking at illness-related pictures primes a stronger immune response (higher levels of IL-6, a pro-inflammatory cytokine) to an LPS challenge (Schaller, Miller, et al., 2010). In mice, we see that higher levels of the same proinflammatory cytokine (IL-6) result in the animal being more socially withdrawn (e.g. Hodes et al., 2014). Similarly, specimens whose antibody production is impaired due to genetic mutation devote less time to exploring conspecifics, as compared to healthy mice, yet they spend just as much time exploring new objects. Moreover, these differences in behavior disappear when the impairment disappears (Filiano et al., 2016).

The features of behavioral immune defense

Behavioral immune defense is thought to have several characteristics: a) it involves affective, cognitive, and behavioral reactions, b) it is both proactive and reactive c) it is biased, and d) it is functionally flexible (Ackerman et al., 2018; Miller & Maner, 2012; Schaller, 2011). It needs to navigate the general trade-off between benefits from engaging with other people (interpersonal

value, exchange of resources and information) and limiting the risk of contagion (Sawada et al., 2018; Tybur et al., 2020).

Proactive disease avoidance

As mentioned, disease avoidance is thought to have both proactive and reactive features, yet most research focuses on the reactive ones. The proactive role is aimed to deal with the pathogen threat in the long term through for example hygiene behaviors and routines, while reactive functions are activated in response to sensory cues (Ackerman et al., 2018).

Reactive disease avoidance: detecting and interpreting sensory cues

One of the main roles of behavioral immune defense is to recognize and learn about sensory cues that can signify a disease threat (Faulkner et al., 2004; Schaller, 2011). As humanity thrives (at least in terms of numbers), our disease avoidance strategies must be at least somewhat successful. Indeed, a recent study suggests that the ability to recognize subtle disease cues is universal and independent of culture (Arshamian et al., 2021). Sick people are often stigmatized and avoided while they are contagious (Schaller, 2006). Spoiled foods with signs of mold or suspicious smell are discarded. Interpreting a cue (correctly or not) as infectious causes a set of emotional, cognitive, and behavioral reactions (Schaller, 2006). The emotion evoked is disgust, on which more is written in the following sections. The ultimate behavioral reaction is avoidance (therefore the term disease- avoidance). The cognitive reaction potentially involves inference about disease-related traits (Schaller, 2006).

The biases in disease avoidance

The success of behavioral immune defense might be partially due to it being biased: we tend to overperceive, overgeneralize and overremember disease-relevant cues (Miller & Maner, 2012). Behavioral immune defense has to navigate between two possible errors: false positives (mislabeling a non-disease cue as threatening) and false negatives (mislabeling a disease cue as safe). Both errors have consequences: avoiding a safe object (or person) can make us miss on potentially nutritious food or a valuable social exchange, while approaching a source of disease might result in catching a serious illness, or at least one that requires a lot of energy and resources to combat it (Schaller & Park, 2011; Tybur & Lieberman, 2016). In case of disease avoidance, false positives seem to be less dangerous and therefore more common, resulting in exaggeration and overgeneralization of illness cues. From an error management theory perspective (Haselton & Nettle, 2006; Miller & Maner, 2012;

Nesse, 2005), such bias is actually functional, as it avoids the potentially more costly consequence. Both the physiological and behavioral immune defenses should thus show similar signs of biases when detecting threats, and indeed they do. One example from the physiological immune system is an allergic reaction. Allergies are basically an immune response triggered by non-threatening particles (Abbas et al., 2020).

As a result of this error preference, we are sensitive to superficial physical features and tend to perceive illness-resembling features more often than they actually appear in the environment (Faulkner et al., 2004; Miller & Maner, 2012). In fact, any deviation from the expected morphological features can be perceived as infectious (Kurzban & Leary, 2001; Schaller, 2006). Even features that we consciously know not to be contagious, such as birthmarks, disfiguration, or physical disability, can activate behavioral immune defenses and an avoidance reaction (Ackerman et al., 2009; Park et al., 2007; Schaller & Duncan, 2007). To sum up, pathogen detection is imperfect and it tends to err on the overly safe side.

Functional flexibility

When the threat is higher, attention to cues is heightened and responses can be more exaggerated (Schaller, 2011). Behavioral immune defense needs to be sensitive to changes in the costs-benefits trade-off of triggering an avoidance behavior, whether the tradeoff changes due to situational factors, for example, a ranging pandemic, or at an individual level e.g. when immune systems functioning is lowered e.g. during pregnancy or a chronic condition (Ackerman et al., 2018). Individuals who perceive themselves as more vulnerable to diseases tend to have stronger biases e.g. overgeneralize more about what cues are threatening (Faulkner et al., 2004; Inbar et al., 2012; Miller & Maner, 2012; Navarrete & Fessler, 2006; Park et al., 2007). On the other hand, people will still engage with others, even if there is a potential disease risk, if there is interpersonal value in the encounter (Tybur et al., 2020). For example, we are more likely to risk interacting with friends (vs. foes) and with strangers perceived as honest and agreeable (vs. dishonest and disagreeable).

Perceived vulnerability to disease

An attempt at tapping into the behavioral immune defense and individual differences in disease avoidance took the form of the Perceived vulnerability to disease scale (PVD, Duncan et al., 2009). The scale has two dimensions: germ aversion and perceived infectability. Germ aversion focuses on discomfort felt in contexts that carry a risk for pathogen transmission, while perceived infectability refers to one's perception of how easily one gets sick. However, most of the disease avoidance research focuses on measuring its key component – disgust.

Disgust and disgust sensitivity

Disgust is thought to be the anti-disease adaptation (Tybur et al., 2018). It is the main mechanism through which disease avoidance works. The way to look at individual differences in disease avoidance is also mostly done by looking at differences in individual levels of disgust sensitivity.

Disgust is a universal emotion linked to a defense mechanism that protects the body from contamination from potentially harmful substances (Curtis et al., 2004). It motivates the avoidance reaction toward other people, and objects such as food etc. (Rozin et al., 2008). Disgust has a characteristic facial expression: a wrinkled nose, pulled-down eyebrows, and a characteristic outline of the lips. These expressions are thought to minimize sensory exposure and limit the ways the pathogens can enter the body (Rozin et al., 2008). It is also accompanied by a specific physiological reaction, namely lowered blood pressure, lowered electrodermal skin response, and nausea (Rozin et al., 2008).

Neural correlates of disgust

Disgust experiences evoke patterns of brain activity that are common to other emotions, but also a specific pattern of activity unique to disgust. The unique activity is observed mostly in the insula, basal ganglia, and some parts of the prefrontal cortex (Husted et al., 2006; Rozin et al., 2008). The insula is a well-connected part of the cortex which is important for interoception (perception of signals coming from one's body) and body sensations, and emotional response to stimuli that can be distressing (Husted et al., 2006). Lesions to the insula and basal ganglia can result in impaired ability to recognize and experience disgust (Adolphs et al., 2003).

Measuring disgust

An early attempt at measuring disgust (and calling it disgust sensitivity) was done by Haidt and colleagues (1994), who created the Disgust scale (DS). The DS had eight (fairly arbitrary) domains: food, animals, body products, hygiene, body envelope violations, death, sex, and magic (yes, *magic*). DS suffered from several validity and reliability issues, which led Olatunji et al., (2007) to create a revised version of the scale, the Disgust scale – revised (DS-R). The DS-R has better psychometric properties and composes of three domains, established via factor analyses: core disgust, animal reminder, and contamination disgust. Through the elimination of items when creating the DS-R, items related to sexual and moral disgust were removed which left some researchers unsatisfied (Tybur & Karinen, 2018). Thus, Tybur et al. (2009) endeavored to create yet another disgust scale, the Three Domain Disgust Scale

(TDDS). As suggested by the name, the scale consists of three subscales relating to moral, sexual, and pathogen disgust, the latter resembling and correlating highly with the two older scales (DS, DS-R).

Sources of individual differences in disgust

There are several theoretical explanations as to what dictates individual differences in disgust sensitivity. Three of the most popular explanations have recently been reviewed and criticized (Tybur, et al, 2018). First, the idea that disgust sensitivity is an expression of broader emotionality or an aspect of neuroticism has not been supported by research: only weak correlations between the two were found when discarding disgust measure items that used neurotic-like language ("*I get upset/angry by…*", Tybur et al., 2018). Second, the idea that disgust sensitivity is shaped by learning (also referred to as modeling, mostly parental modeling) has not been supported by twin studies, which equally attributes disgust sensitivity to the heritability and unique environment (*not* shared by the twins). The shared environment seemed not relevant at all (Sherlock et al., 2016). That said, social learning definitely has some effect on interpreting what is disgusting and what is not, but it might be more situation-dependent (Schaller, 2006; Tybur et al., 2018). Lastly, the review looked at assumptions that disgust sensitivity is shaped by exposure to pathogens, a theory closely related to the parasite stress theory (Thornhill & Fincher, 2014b). The parasite stress theoretical framework builds on the fact that our planet is very varied in terms of regional parasite stress and pathogen prevalence (in other words: the potential disease threat). In the low latitudes, this stress is higher than in high latitudes. According to this theory, societies in regions of high parasite stress tend to be assortative societies, in which group members choose mating partners based on similarity of traits (more than a random mating pattern would predict; Thornhill & Fincher, 2014). Assortative societies are often linked to xenophobia, ethnocentrism, and other attitudes and behaviors aiming to limit contact with strangers and outgroups. This is thought to be a consequence of the outgroup being a higher pathogen threat in high parasite stress regions than in low parasite stress regions (Thornhill & Fincher, 2014a). The idea would be then, that pathogen prevalence contributes to individual differences in disgust sensitivity. However, the review by Tybur et al. (2018) concluded that there is weak evidence for these theories. For example, disgust sensitivity did not differ across nine regions of the world in a large (30000+) sample study. Thus, individuals located in regions with low and high disease rates showed similar levels of disgust sensitivity. The question of potential sources of individual differences in disgust sensitivity remains yet to be answered.

Disease avoidance and social bias

> "I started with the concept of *sonnimgut* shamanic ritual, which used to be held in response to outbreaks of smallpox. Smallpox, colloquially referred to as *sonnim* or 'guest', was regarded as a Western import"
>
> (Hwang Sok-yong, *The Prisoner*)

As mentioned before, false-positives bias and overgeneralization seem to be an integral feature of disease avoidance mechanisms/the behavioral immune system. One of the examples of this overgeneralization extends to foreigners and members of widely defined outgroups.

Outbreaks of diseases were blamed on the outgroups throughout history (Markel & Stern, 2002). On a semantic level, outgroups are often linked to the concepts of disease, and may be compared to animals that carry disease (rats, cockroaches, pests, etc.; Tipler & Ruscher, 2014). This is a part of the dehumanization process (Haslam, 2006).

Research shows that people are more concerned about illness-related cues on the faces of outgroup members than ingroup members (Bressan, 2021 reanalysis of van Leeuwen & Petersen, 2018). Faces appeared to look sicker, if they were less similar to the participants' own group. Unfamiliar faces with a rash were perceived as considerably sicker than familiar faces with the same rash. Other studies suggest that when disease threat is perceived as salient (either due to situational or individual factors), people tend to express more negative attitudes towards outgroups, ethnic and sexual minorities (Faulkner et al., 2004; Fessler et al., 2005; Inbar et al., 2012; Navarrete & Fessler, 2006), and prefer contact with familiar people (Schaller & Park, 2011). Behavioral immune defense, as indexed by disgust sensitivity or perceived vulnerability to disease has been linked to conservatism (Terrizzi et al., 2013). What are the tentative explanations for these biases?

From a historical perspective, events such as European colonialism caused epidemics among native populations (Callaway, 2017; Vågene et al., 2018) substantially contributing to the success of the invasion. For example, during the Spanish invasion of America, the native populations were killed in large numbers by smallpox and measles brought from Europe (Oldstone, 2010). Viruses interfered in war plans. Smallpox prevented a potential unification of

Canada and the United States of America (USA) by drastically reducing the colonial army on its way to retake Québec from the English and yellow fever hitting Napoleon's troops in Haiti contributed to his decision of selling Louisiana to the USA (examples come from Oldstone, 1998). Thus, outgroups and foreigners often brought with them the threat of unfamiliar diseases. When the ingroup and outgroup came from different ecologies, they were vulnerable to different pathogen threats (Thornhill & Fincher, 2014b). The geographical aspects of the disease threat posed by foreigners have been incorporated into the parasite stress theory.

As mentioned before, the evidence for the parasite stress theory is inconclusive, leading some researchers to discard it as a potential explanation for variability in disgust sensitivity alone (Tybur et al., 2018). In general, ideas about the link between disease avoidance and prejudice can be grouped into two theoretical threads of explanation*: outgroup avoidance account* and *traditional norms account* (terminology from Karinen et al., 2019). According to the *outgroup avoidance account,* humans build up resistance to pathogens that are present locally in their environment, and outgroup avoidance is thus a simple protective heuristic. This account incorporates also the Thornhill & Finch (2014) parasite stress theory.

The *traditional norms account* focuses on the role norms play in disease avoidance. Social norms serve a key protective role against disease, since they evolve, at least partially, in response to pathogen threats in the environment as a way to neutralize the threat. They affect food preparations (e.g. use of spices that counteract microbes, Sherman & Billing, 1999), and sanitary and hygiene practices (Schaller, 2011). Curtis, de Barra & Aunger (2011) highlight that pathogens are a problem not just for the individual, but also for the group as a whole and suggest that we have group responses to disease, taking the form of norms and manners. In line with this reasoning, whether a group is perceived as different in terms of such norms (and potentially unwilling to change) can influence attitudes towards this specific group. Interestingly, higher levels of disgust sensitivity are related to perceiving oneself as less similar – psychologically, not physically – to visually displayed social targets (Mentser & Nussinson, 2020).

Recent findings showed that negative attitudes towards immigrants were only positively correlated with disgust sensitivity if the immigrants were thought to not adhere to social norms (Karinen et al., 2019; see also van Leeuwen & Petersen, 2018; Bressan, 2021). Contrary to the outgroup avoidance account, the relationship between disgust sensitivity and anti-immigrant sentiments did not vary across conditions in which the participant was to have high (shaking hands) vs. low (riding the same bus) contact with the immigrant. Other results can be interpreted in favor of the norms account: disgust sensitivity is more strongly related to traditionalism (supporting traditions, which are also a form of norms), than it is to social dominance orientation (support for stratification and separation of social groups) across 30 nations (Tybur et

al., 2016). Norms related to disease avoidance, but not other norms, seem to be the most important for attitudes towards immigrants for individuals with high levels of disgust sensitivity. When immigrants were presented as willing to learn the local language, and adapt to the country's values related to democracy and equal rights, attitudes towards them were more positive than if they did not show these good intentions. However, participants with high levels of disgust sensitivity were not affected by these good intentions and continued to oppose immigration (Aarøe et al., 2017).

On the other hand, non-human species also show similar disease avoidance discriminations, and it is hard to imagine that animals have norms or traditions in mind (Kramer & Bressan, 2021). More research is needed to better understand the role of norms in disease avoidance.

Ingroups and outgroups revisited

Research presented in previous sections can be summarized with regard to the dynamics between the ingroup and outgroups. Whether it is due to having a different set of norms for health-relevant practices, bringing a different set of pathogens unknown in the ingroup etiology, or for yet another reason, outgroups can pose a disease threat. Disease cues coming from outgroup members are more salient than the same cues from the ingroup member. From this perspective, unless there are benefits to interaction with outgroups, the safe approach is to avoid them. This last statement brings to light another aspect that I have not yet discussed – we can simultaneously hold different attitudes towards outgroups in general (e.g., attitudes towards immigrants in general) and towards specific target groups (e.g., immigrants from a given country, or even more specific, towards one particular immigrant). It is important to keep this in mind. Faulkner et al (2004) showed that individuals with high levels of PVD were prejudiced against fictitious refugee groups coming from an unfamiliar location, but not toward more familiar immigrants. Similarly, Aarøe et al., (2017) showed that the origin of immigrants (Middle East vs. Eastern Europe) affected attitudes towards the immigrants in a USA sample. Attitudes were more negative toward immigrants from the Middle East, especially so among individuals with high disgust sensitivity.

Olfaction and odors

> "But there wouldn't be any smell. What a weird world. Ushikawa preferred a world where smells and pain still existed, even if the smells and pain were unendurable. Still, people like Ushikawa might become out-of-date relics."
>
> (Murakami Haruki, *1Q84*)

Many olfactory researchers start their story by making a point of olfaction being the disregarded or underappreciated sense. I, however, would like to start by saying that it is the most special sense of all (I might be a bit biased though). The chemical senses (taste and smell) are both rather special. Unlike the remaining senses, chemosensation results from an interaction between receptors and actual chemical molecules, without the help of other physical forces (e.g. light for vision, temperature for touch, etc.; Pickenhagen, 2017). Phylogenetically, taste and smell are the oldest of all senses, they appeared earlier in the evolution of life on earth (Hoover, 2010). Olfaction allowed the emerging life forms to find food, mate, and avoid threats posed by other life forms (Sarafoleanu et al., 2009). Moreover, the way in which the brain processes olfactory signals is unique, not to mention differences between olfaction and other senses in terms of attention, memory, and consciousness, to name just a few (e.g. Herz & Engen, 1996; Stevenson, 2009, 2012).

A brief introduction to the olfactory system

An odor is a sensation we feel as a result of odorants – chemical molecules – stimulating the olfactory system, in other words, it is the impression in the brain made by molecules recognized by olfactory receptors (Pickenhagen, 2017). The first step in olfactory processing is the sniff. Odorants – the volatile chemical molecules – inhaled through sniffing meet the receptors in the olfactory epithelium, located on the roof of the nasal cavity (Buck & Axel, 1991). Notice that the volatile molecules themselves actually enter our bodies. There are hundreds (350-400) different types of olfactory receptors, each receptor reacts to a range of odorants, and each odorant activates a range of receptors, although the combination of responding receptors is different for different

odorants (Malnic et al., 1999, 2004). From there, the signal travels to the olfactory bulb: every receptor in the mucosa is connected to the glomeruli in the olfactory bulb (OB, Ressler et al., 1993). Here the brain journey (described below based on Freiherr, 2017; and Olofsson & Freiherr, 2019) of the odorant signal begins. The OB is a part of the primary olfactory cortex. Its main function is to encode, organize and pass on the chemical information about the odorants. Unlike other senses, the odor signal does not pass through the thalamus on its way to cortical areas - it goes there straight from the olfactory bulb. The lateral olfactory tract leads encoded information from OB to several structures important for further processing of the smells, the piriform cortex for example (Lane et al., 2020). There, molecular features of the odorant are encoded, and a first object representation of the odor, its hedonics and category, is formed. Both the piriform cortex and the OB send the information further: to the entorhinal cortex, on its way to the hippocampus where important memory processes take place; and to the amygdala where the signal is processed in terms of emotional aspects. The hedonics of the odor are further coded in the orbitofrontal cortex (OFC), which is also important for the cognitive processing of the odor and creating a final odor percept. OFC is important for olfactory sensitivity and detection. The last structure I will mention as important for the olfactory signal journey is the insula. It receives information from the piriform cortex, the OFC, and the amygdala. Insula is important for avoidance behaviors and interception overall, and responds/regulates relevant responses to odors (for example a disgust response to unpleasant odors; Wicker et al., 2003). As you may remember, the insula was also a key structure for recognizing and processing of disgusting stimuli.

Odor proprieties

How do we react to odors? The main dimensions that emerge when perceiving odors are valence (pleasantness) and edibility (Zarzo, 2008). Even if we cannot instantly identify the source of the odor, we can clearly perceive whether we find it pleasant or not and if it is ok to eat the source. If the smell is unpleasant, we probably do not want to approach the source of it. Another reaction we often talk about in reference to odors is arousal: smells can either excite us or calm us down. For example, the smell of lavender has a calming effect and even has a positive effect on the quality of sleep (Goel et al., 2005), while the smell of peppermint has an invigorating effect (Goel & Lao, 2006). Importantly though, the effect of odors, and the perception of odor characteristics is highly dependent on the smeller. There are great interindividual differences in how we react to smells (Seubert et al., 2017). Thus, it is not given that every person would find lavender calming, or even pleasant. Additionally, the intensity of odor contributes to whether it is thought of as pleasant or unpleasant (e.g., Distel et al., 1999; Doty, 1975). At the same time, certain smells

tend to be perceived in a similar way overall. Recent studies show this is true for children in various countries (Oleszkiewicz et al., 2022), and adults in various countries and cultures (Arshamian et al., 2022). Smells can elicit emotions. Four dimensions of emotions felt in response to odors were found to be common in different cultures. The first of this domain was disgust, followed by happiness, sensuality, and energy-related feelings (Ferdenzi et al., 2011)

Whatever the effect of an odor may be, we get used to smells (habituate) and no longer notice them after some time. The time it takes to habituate to the smell depends both on the smell and the smeller (Cain, 1970; Dalton et al., 2002).

The role of olfaction in disease avoidance

Wrinkling the nose is one of the core features of disgust reaction (e.g. Rozin, Haidt & McCauley, 2008). It serves a clear purpose, namely to limit the way in for potential airborne pathogens (Susskind et al., 2008). In fact avoiding microbial environmental hazards has been proposed as one of the main functions of olfaction – the sense of smell uniquely picks up microbial threats before they reach our body (Stevenson, 2010). In rodents, olfaction is thought to be most important for recognizing and avoiding infected conspecifics (Kavaliers et al., 2020). Even more, olfactory cues can stimulate or suppress the response from the immune system (Mei et al., 2000; Ramı´rez-Amaya & Bermudez-Rattoni, 1999). Thus, olfaction can be thought of as a fairly early warning system (Stafford, 2017). Interestingly, one study using an IAT with olfaction-related words (*whiff*, *aroma*, *smell*, *nose*, *scent*) and disease or health-related words, showed that the concept of odor was more closely related to the concept of disease than healthiness (Bulsing et al., 2008).

Olfaction and disgust

In a seminal study, Wicker et al. (2003) showed that disgusting odors and disgusted faces activate the same brain area (anterior insula), suggesting that similar brain circuits might process both unpleasant odors and seeing someone expressing disgust. In fact, olfaction and disgust share several points in their brain processing pathways, mostly in the insula, the OFC, and the amygdala (Soudry et al., 2011; Zald & Pardo, 1997).

Across cultures, olfactory cues related to the lack of cleanliness of other people elicit disgust (Curtis & Biran, 2001). In fact, there might be a relationship between disgust sensitivity and olfactory abilities. Disgust sensitivity was positively related to self-reported olfactory abilities (Kelley & Crowell, 2018). Olfactory sensitivity, measured by a threshold test that reflects the ability to detect low concentrations of odors, might also be related to disgust sensitivity (Chan et al., 2020; Croy et al., 2017; Schienle & Schöpf, 2017). However, the

results are inconsistent and seem to potentially depend on gender. Other studies showed a relationship between olfaction and sexual disgust, but not pathogen disgust (Prokosch et al., 2021)

The role of olfaction in navigating the social world

Olfaction, and body odors in particular, are useful when navigating the social world. Body odors, and their chemical profiles, contain information about the state (e.g. feeling fear or being sick) and trait (e.g. gender) characteristic of the individual (de Groot et al., 2017). Just by smelling body odors, people can make above-chance inferences about personality aspects such as extraversion and neuroticism (Sorokowska et al., 2012). Moreover, people born with anosmia (inability to smell) report increased social insecurity and problems in social relationships with other people. These problems were related to being unable to perceive own body odor, and the body odor of the other person (Croy et al., 2012). Body odors are important for kin recognition (e.g. Schäfer et al., 2020) and romantic relationships (Mahmut & Croy, 2019). These studies are great examples of how olfaction and social interactions are linked, and that this is especially true for body odors. Let us talk more about body odors!

Body odors

Bodily odors are specifically important for pathogen avoidance and disgust. They are universal elicitors of disgust across different cultures (Curtis & Biran, 2001; Schleidt et al., 1988).

On a physiological level, the human body emits hundreds of volatile organic compounds (VOCs) which reflect the metabolic condition of an individual (Shirasu & Touhara, 2011). In a seminal paper, entitled accurately 'The scent of disease', Shirasu & Touhara, (2011) describe smell profiles of bodily excretions such as sweat, urine, and blood in health and disease. Importantly, the VOCs are influenced by infectious diseases: the body smells characteristically for many diseases. For example, the breath of a person suffering from pneumonia will have a foul quality, while the overall body odor of a person with typhoid fever has a musty quality to it, almost like baked bread. Body odors of men infected with gonorrhea were perceived as less pleasant and with more putrid quality compared to healthy body odors (Moshkin et al., 2012). Thus, body odors carry information about the state of health. Moreover, one study showed that humans are able to accurately judge other people's healthiness (or sickness) levels based on their body odor cues only: sweat collected from people whose immune systems have been temporality activated by injection of lipopolysaccharide (LPS, an endotoxin) smelled more intense, less pleasant and less healthy than sweat coming from healthy individuals (Olsson

et al., 2014). Another study using LPS stimulation, although unable to replicate the perceptual differences between healthy and sick body odor, showed an increased brain activation response to sick body odors in olfactory areas such as OFC and the piriform cortex (Regenbogen et al., 2017). People showing olfactory signs of illness were also less liked in a study by Sarolidou et al. (2020).

A further indication of the importance of body odors in disease communication lies in the connection between body odors and major histocompatibility complex (MHC) genes. MHC encodes peptide display molecules (MHC class I and class II molecules) which are crucial in one type of immune response – they show (display) information about microbes present in the body to the cells of the immune system, the first step necessary to trigger a response when needed (Abbas et al., 2020). MHC affects the odor quality of urine, and possibly other body odors (e.g., breath Aksenov et al., 2012). An individual carries only a certain amount of all possible MHC variations. Diversity in the MHC allows for defense against a wider range of foreign substances, while similarity of MHC is crucial when doing transplants (Abbas et al., 2020). Thus, meeting a partner with a different set of MHC might be beneficial. Research has suggested that the similarity of MHC smells unpleasant (Wedekind et al., 1995) and less attractive (Havlíček et al., 2020). However, other research shows that it has no influence on mate choice (Croy et al., 2020).

To sum up, body odors are linked to the immune system, their quality communicates information about the health status of the individual, and they are universally considered disgusting. It is important to note, however, that this summary pertains mostly to neurotypical adults. Perception of body odors and odors in general might be different for children (e.g., Schmidt & Beauchamp, 1988) or adults with, for example, autism spectrum disorder (e.g., Legiša et al., 2013).

Body odor disgust and social attitudes

Based on what I have presented so far, I hope to have conveyed the message that the sense of smell is important in disease avoidance, and that body odors seem to be cues of particular significance. Disgust reaction to body odors should be one of the main mechanisms involved in behavioral immune defense. However, in the four scales used in research on disease avoidance (DS, DS-R, TDDS, and PVD), very little attention is given to olfactory elicitors of disgust, with the number of olfactory-related items ranging between 5 and 16%. Recently, a new disgust scale has been created, which focuses solely on body odors: the Body odor disgust sensitivity scale (BODS, Liuzza et al., 2016a). The scale includes 12 items that relate to six body odors: upper body sweat, feet, breath, feces, gas, and urine. Each body odor appears in an internal (coming from one's own body) and external (coming from a stranger) source. Importantly, BODS focuses on pure and universal sensory disgust triggers, remaining free from social and moral judgments (even if norms regarding body odors exist). BODS does not require participants to ask about behaviors, or to judge them as right or wrong, just how disgusted they would be by certain smells. The BODS scale has been validated in the context of perceptual reactions to an actual body odor, namely armpit sweat (Liuzza et al., 2017). Importantly, higher levels of BODS were related to a higher perceived disgust of the odor, but not its intensity.

The BODS scale has two subscales: the internal (odor source is one's own body) and external (odor source is a stranger's body). The two subscales are highly correlated ($r = 0.67$) and both are associated with disease avoidance traits (Liuzza et al., 2016b). Nevertheless, they might be related to different aspects of behavioral immune defense: detecting disease cues from odors emitted by other people, and avoiding these people can help prevent catching a disease, while monitoring one's own body status via odors can help trigger relevant disease-coping behaviors (sickness behaviors) that channel the energy appropriately and maximize the efficiency of the immune system (Hart, 1988; Kent et al., 1992). Interestingly, a recent study showed that over 90% of participants reported smelling themselves, which suggests that own body odor is an important and frequently accessed signal (Perl et al., 2020). If people are smelling themselves often, then maybe reactions to internal sources of odors deserve more attention in disease avoidance and other contexts. Addi-

tionally, reaction to own smell is potentially less normative and culture-dependent, as compared to reactions to external sources of body odors. Thus, the internal and external subscales of BODS might provide complementary yet different information.

Relevance of BODS for the behavioral immune defense

The BODS scale was created based on the theoretical importance of body odors and disgust. It was also created following a psychometric approach to scale construction and validation. Across several studies, Liuzza and colleagues (2017) aimed to place BODS on the map of existing measures and relevant concepts. BODS is correlated with PVD ($r = 0.38$), more so than PVD and the DS-R contamination subscale ($r = 0.21$) or PVD and the pathogen subscale of TDDS ($r = 0.21$). BODS correlated positively with other olfactory assessment scales: the Chemical sensitivity scale (CSS, Nordin et al., 2004), the Olfactory Orientation Scale (OO, Arshamian et al., 2011), and self-reported smell ability. Moreover, the relationship between BODS and the other disease avoidance relevant measures remained even when accounting for these olfactory measures. These results show that BODS may be a valuable tool when investigating disease avoidance

Relevance of BODS for social attitudes

The first attempt to investigate if BODS is indeed relevant for social attitudes focused on a possible link with authoritarianism (measured by RWA). Authoritarianism can be viewed as a form of avoidance ("preserving existing cultural norms, traditions, and old-fashioned values" e.g. Hainmueller and Hiscox, 2010)", and thus should be related to body odor disgust, just as it is related to overall disgust (Tybur et al., 2016). Indeed, higher levels of BODS are related to more authoritarian attitudes, even when taking into account other disgust measures, namely TDDS (pathogen subscale) and DS-R (Liuzza et al., 2018). This relationship translated to preferences in a real-life situation of the presidential elections in the US in 2016: higher levels of BODS were related to stronger support for Donald Trump, but not Hilary Clinton. The relationship between support for Trump and BODS was fully explained by individuals' authoritarian views (RWA scores). To place BODS within the dual-process framework, the authors looked also at the relationship between BODS and social dominance orientation and endorsement of social inequality. BODS was not related to SDO, only related (positively) to RWA. This is in line with the dual-process framework and strengthens the assumption that perceiving

the world as a dangerous (and pathogen-rich) place is the shared ground between disgust sensitivity and authoritarianism (Duckitt, 2001; Liuzza et al., 2018).

Relevance of BODS for prejudice

There are ample theoretical grounds for hypothesizing that body odor disgust sensitivity will be related to prejudice. Moreover, there is already data showing that BODS is related to some forms of social bias, such as RWA. However, the relationship between prejudice and BODS, and the role of olfaction in prejudice need further investigation. Is BODS related to explicit declaration of bias? Is it related to potentially more subtle, implicit attitudes? Is it related to overall attitudes towards others as well as attitudes towards specific targets/groups? Can we identify individual and group-level processes that explain this relationship? Can we manipulate attitudes using odors? In this thesis, I describe my journey to organize and advance the knowledge about olfaction and prejudice.

Gathering the theory outlined in this introduction

I integrate the theories presented in this introduction and map the assumed causal relationship between the important concepts in a form of a causal graph – a directed acyclical graph (DAG). DAGs are graphical representations of causal relationships between variables. A DAG has nodes corresponding to concepts (variables) and arrows which show the existence of assumed causal relationships and their directions. The word *acyclical* refers to the fact that causality goes only one way (the cause is not caused by a variable it causes; McElreath, 2020). DAGs allow us to see which variables we need to collect and adjust for in order to avoid biasing the model (based on the assumed causal relationships (Textor et al., 2017). Figure 1 gathers all the concepts mentioned in this introduction (disease avoidance immune system, norms, prejudice, etc.) and shows what causal relationships I assume between them based on existing data and theories.

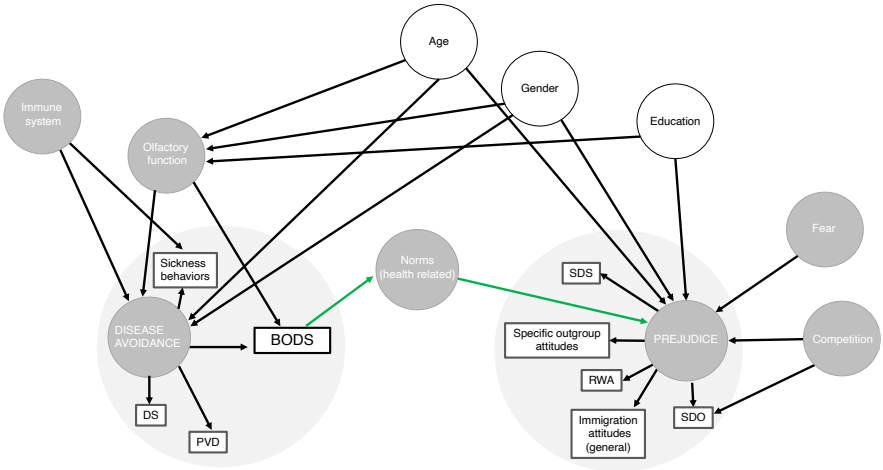

Figure 1 A directed acyclical graph (DAG) depicting the hypothesized theory relevant for this thesis. Circles represent latent variables (concepts), rectangular shapes - observable variables that we use to approximate the latent concepts. White circles represent factors that need to be adjusted for to avoid bias in estimating a causal relationship between BODS and Prejudice. Big, light gray circles encompass measures we can use to tap into the main concepts (Disease avoidance or Prejudice). Arrows represent causal paths and their direction. The green arrows highlight the relationship between the variable of interest in this thesis (BODS) and prejudice. BODS- Body odor disgust sensitivity; DS – Disgust sensitivity; PVD – Perceived vulnerability to disease; SDS – Social distance scale; SDO – social dominance orientation; RWA – Right-wing authoritarianism.

Aims of the thesis

The general aim of this thesis was to investigate the connection between olfaction, (body) odor disgust, and social attitudes from the perspective of disease avoidance. The thesis aimed to answer these specific questions:

1. Is body odor disgust sensitivity (BODS) related to explicit (Studies I and III) and implicit prejudice (Study II)?
2. Are there other individual characteristics and differences in attitudes that can help explain why BODS is associated with prejudice? (Study I, II, and III)
3. Can disease-relevant olfactory cues enhance negative attitudes towards outgroups? Is this effect stronger among high BODS levels individuals? (Study II)
4. How generalizable is the relationship between BODS and prejudice: will it replicate across different cultures and countries? (Study III)
5. How are BODS levels related to odor perception and what is it that high body odor disgust sensitive individuals are sensitive to? (Study IV)

Overall, this thesis tries to examine how body odor disgust sensitivity can inform our knowledge about behavioral immune defenses and their relationship with social attitudes.

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Methods

Replications, open science, and preregistrations

Recent years have witnessed an increased awareness of several issues in scientific research that have serious consequences on how much confidence we should have in existing research findings. A series of efforts by researchers in the fields of psychology, as well as other fields, have shown that only about 47% of findings from top journals could be replicated, and that the effect sizes of replications were in general about half as big (Open Science Collaboration, 2015). While some perceive this as a crisis and others as the beginning of a renaissance era, it is undoubtedly a phenomenon that cannot be ignored. The Open Science Collaboration, and other initiatives resulted in a call to increase the openness of research practices and materials and formed a demand for attempts to replicate the existing findings, highlighting that a single study is not enough to have confidence in its effects (e.g. Nelson et al., 2018; Pashler & Harris, 2012; Rosseel, 2012; Shrout & Rodgers, 2018).

In my research, I tried to follow the guidelines for reproducible research outlined in the literature cited above. Data, analysis code, and materials used in this thesis are all available online at the Open Science Framework repository (OSF, osf.io/exsfj). Study I, II, and III were preregistered – the hypothesis and analysis plan were defined before running the analysis, and any exploratory ventures or deviations from the preregistered approach are clearly stated in the corresponding manuscripts. Moreover, Study III is an attempt to replicate my own finding on different samples. Study IV gathers data from multiple experiments to get a more reliable overview of the relationship investigated.

Statistical approach

Throughout the thesis, I tried to focus as much as possible on parameter estimation rather than a pure hypothesis testing approach. Although this might be a matter of preference, asking solely the question of *is there a relationship?* is less interesting and meaningful to me than focusing on *what the relationship is*. Whenever possible, I used Bayesian statistics, to be able to evaluate evidence both in favor and against my hypotheses. This can be done using Bayes factors. Bayes factor (BF) is a ratio comparing the likelihood of the data under the null and alternative hypotheses, it can give information about both (see,

for example, Jarosz & Wiley, 2014). To distinguish between the two, BF_{10} represents evidence in favor of the alternative hypothesis (versus the null) while BF_{01} represents the opposite: evidence in favor of the null (versus the alternative hypothesis).

However, when modeling large datasets of self-reported measures, I used Structural Equation modeling (in a frequentist form) as it has several benefits. To name a few: it estimates parameters from variances and covariances, it allows the use of single item data, without the need for averaging and it shifts the focus from variables to the *concepts* behind them (Hoyle, 2011). It is particularly relevant when the research question involves relationships between several variables, which is often the case with questionnaire data. In my personal experience, it makes you think more about what it is that you try to measure and how the concepts can be causally related (even if you are not testing the causality). Although there are Bayesian equivalents of SEM, to the best of my knowledge, there is no clear consensus about how to perform it yet.

Ethics approval

All research covered in this thesis was done in accordance with the Declaration of Helsinki and was additionally vetted by the local committee (Etikprövningsmyndigheten, EPN) when applicable (relevant EPN decision: Dnr 2020-04690, Dnr 2018/1169-31/5).

Body odor disgust sensitivity scale

BODS is a 12-item scale: items refer to six types of body odors (feces, upper body sweat, feet, urine, gas, and breath) appearing both in an internal (e.g., "*You are alone at home and notice that your feet smell strongly*") and external (e.g. "*You are sitting next to a stranger and notice that their feet smell strongly*") contexts. Participants are asked to rate the extent to which each scenario elicited disgust on a Likert type of scale ranging from 1 (*not disgusting at all*) to 5 (*extremely disgusting*). Individual scores are usually computed by averaging responses on all items. Additionally, a separate estimate of the internal and external BODS can be calculated by averaging items corresponding to the two subscales. As this scale is a key measure in this thesis, I present it below.

Table 1 The Body odor disgust sensitivity scale. Odd items (white background) constitute the internal subscale: even items (grey background) constitute the external subscale

How disgusting would you find each of the following experiences? Before answering each question, take the time to imagine the smell being described. Many of the scenarios have only small differences between them, so please read carefully!
1. You are alone at home and notice that the t-shirt you are wearing smells strongly from your own sweat.
2. You are standing next to a stranger and notice that the t-shirt they are wearing smells strongly from their sweat.
3. You are alone at home and notice that your feet smell strongly.
4. You are sitting next to a stranger and notice that their feet smell strongly.
5. You are alone at home and notice that your breath smells strongly.
6. You are chatting with a stranger and notice that their breath smells strongly.
7. While alone at home, you use the bathroom. Afterwards, you notice that the room smells strongly of your feces.
8. You use the bathroom after a stranger and notice that the room smells strongly of their feces.
9. You are alone at home and pass gas. It is silent but smells strongly.
10. You are sitting next to a stranger and they pass gas. It is silent but smells strongly.
11. While alone at home, you use the bathroom. Afterwards, you notice that the room smells strongly of your urine.
12. You use the bathroom after a stranger and notice that the room smells strongly of their urine.

Online survey studies (Study I and III)

Study I and III were online survey studies. As Study III was a replication and extension of Study I, both studies shared similar measures. All measures were self-reported and explicit.

Drashneeans

We adapted a scenario used by Faulkner and colleagues (2004). The scenario introduces a fictitious group of immigrants from Drashnee (Drashne in Study II[2]), that seek refuge in the participant's country. No information is given

[2] The name was change to Drashne (single 'e') in Study III to adapt it better to the European origin of the group

about the group except their origin (Central Africa in Study I, either Eastern Africa or Eastern Europe in Study III).

> "Imagine the following scenario: There is a country in [Central Africa], which for the purposes of this study we will refer to as Dhrashnee, that has been experiencing a great deal of civil unrest in recent years. As a result of these conditions, many people from this country are trying to leave. A large number of these refugees are seeking to immigrate to your country".

After reading the text above, participants were asked questions that were used to measure the perceived (dis)similarity of the fictitious group and attitudes towards them.

Perceived dissimilarity

We asked participants how they perceived the fictitious outgroup. Specifically, we asked how similar (or dissimilar) they perceive the Drasheeans in terms of (1) food, (2) hygiene, and (3) sanitary practices. The answers were given on a 10-point scale ranging from 1- *Not at all similar* to 10 -*Highly similar.* The answers on these items were then reverse-scored so that high values represented high levels of perceived dissimilarity.

Prejudice

To measure attitudes towards the fictitious outgroup, we asked three questions related to (1) participants' overall attitudes towards Drashneeans, (2) how much they agree that Drashneeans could bring health-related problems, and (3) criminality into the country if they were allowed to immigrate. The answers were given on a 10-point scale (ranging from *strongly disagree* to *strongly agree*. Additionally, we used a feeling thermometer – a simple and common, one-item way to get an evaluation of overall attitudes towards a group (Esses et al., 1993). The feeling thermometer was a visual analog scale (VAS) with a sliding scale ranging from 0 to 100. High numbers on the scale indicate favorable attitudes towards Drashneeans, 50 indicates a neutral attitude, and the low numbers indicate more unfavorable attitudes. Answers to the three questions were combined with the answer on the feeling thermometer to form an individual index of prejudice. This was done after reverse scoring some of the items so that a higher score indicated more negative attitudes towards the fictitious outgroup. To deal with the difference in scales between these items, we either standardized all responses (Study I) or scaled the thermometer responses by 10 to bring it on a 1-10 scale (Study III) before taking an average of the four items.

Other questionnaires

Besides questions about attitudes towards the Drashneeans, both online studies included the BODS scale and a measure of general attitudes towards immigration. Each study included additional questionnaires that are not part of this thesis but can be accessed on the OSF page of the projects.

General attitudes towards immigration

To get an idea about participants' attitudes towards immigration in general, we used six questions from Faulkner et al. (2004). These questions assessed participants' opinions about immigrants moving to their country and a) introducing new skills and practices to the existing culture and economy b) integrating into the participants' personal life (e.g., by marrying into their family). Participants gave answers on a scale from 1 – (*Strongly disagree*) to 7 (*Strongly agree*), with higher scores indicating opposition to immigration. Answers to some items (e.g. "*My country's immigration policies are too strict*") were reverse coded so that higher values reflected negative attitudes towards immigration or opposition to immigration. Individual scores were calculated by computing the mean of answers of all items (after reverse-scoring the inverted items).

Experimental studies (Study II and IV)

Study II included a mixture of explicit and implicit measures of prejudice. Study IV focused on perceptual ratings of olfactory stimuli. The two studies shared some methodology, common for olfactory research.

Olfactory stimuli

Doing smelly research requires additional preparations. The experimental room needs to be properly ventilated ensuring that no smell lingers longer than intended. The stimuli itself is often a concentrated odorous substance diluted in mineral oil. There are several ways of delivering olfactory stimuli. The diluted substance can be placed in a jar and participants are asked to hold the open jar next to their nose and smell the content (Study IV). Alternatively, if the smell is to be present for a longer time, a drop of the solution can be put on a cotton pad, the pad then placed in tube-shaped cotton band tied under the participant's nose (Study II, Study IV). If time precision is of crucial interest, one can use an olfactometer – a machine that pumps puffs of odorants at specific time points and for a specific duration (Study IV).

Odor ratings

A common practice when using odor stimuli is to collect information about how participants perceive the odors, at least in terms of intensity and valence. This is done to ensure that stimuli are matched (e.g., one odor is not extensively more intense than another) and serve the intended purpose (i.e. odors chosen for their pleasantness are rated as pleasant, and odors meant to be disgusting are perceived as unpleasant). All experimental studies in this thesis included intensity and valence ratings. Study IV is devoted to studying these ratings.

Explicit measures of prejudice

Social distance scale

The social distance scale (SDS, Bogardus, 1993) is a common way to get a sense of general attitudes towards the outgroup. We used a modified version (Müller et al., 2014) of the original SDS. Participants read four scenarios ("*Please imagine that this person lives in your neighborhood*") followed by a description of a person who is a high school student and engages in a religious community in their free time. This person could be either male or female and either Swedish or Romani. Participants had to rate how they would feel if such person (a) was their closest neighbor, (b) took care of their parents, (c) married into their family. Ratings were provided on a four-point scale, from (1) *very positive* to (4) *very negative*. Individual SDS scores were computed as a mean of answers for all items, with higher values representing more negative attitudes.

Right-Wing Authoritarianism scale

To measure right-wing authoritarianism (RWA), we used a validated version of the original RWA scale with 15 items that did not refer to specific minority populations and were thus reflecting authoritarianism, rather than prejudice against a specific group (Zakrisson, 2005). Participants read each statement and responded on a seven-point scale ranging from 1 (*totally disagree)* to 7 (*totally agree*). Items on the scale (e.g., "*The 'old-fashioned ways' and 'old-fashioned values' still show the best way to live.*") were related to traditionalism, punitiveness, and conservatism. Individual RWA scores were computed by averaging the answers for all items, after reversing the score of the inverted items. Higher values represented more authoritarian views.

Social dominance orientation scale

To measure social dominance orientation (SDO), we used a 16-item version of the original SDO, which focuses on tolerance for inequality among social groups (Pratto et al., 1994). Participants read each statement them (e.g. "Some groups of people are simply inferior to other groups.") and responded how

they feel about on a 1 (*very negative*) to 7 (*very positive*) Likert-type scale. Individual SDO score was computed as the mean of all answers, after reversing the score of the inverted items. Higher values represented more social dominance.

Implicit measures of prejudice

Implicit Association Test

The Implicit Association Test (IAT, Greenwald et al., 1998) is a categorization task. Our IAT included words and pictures: the words had to be categorized as *positive* or *negative* and the pictures as representing either the ingroup or the outgroup culture (8 stimuli per category). The pictures were chosen based on a pilot study. They were of neutral valence and covered eight areas: man, woman, children, family, housing, newspaper, flag, and folklore dress. For words, we used a standard set of the IAT valence-words. Participants were requested to respond (categorize) as quickly and accurately as possible to the stimuli that appeared on the monitor. The entire procedure consisted of five blocks: 1 (positive vs. negative) and 2 (ingroup vs. outgroup) were single categorization blocks that helped participants to familiarize themselves with the task and learn which stimuli belong to which category. Blocks 3–5 were combined categorization tasks in which participants had to press the same keys to categorize either outgroup-related pictures or negative words vs. ingroup-related or positive words (*stereotype congruent block*), or ingroup or negative words vs. outgroup or positive words (*stereotype incongruent block*). Block 4 served the purpose of changing from incongruent to congruent (or vice versa). Each block consisted of 32 trials. The stimuli were presented in random order within each block. The association strength was determined by computing the standardized difference between the response times in the incongruent vs. congruent block. Data from these blocks was used to compute a difference score (D score), following Greenwald et al. (2003) with an error penalty method.

Implicit Association Test – a disease version

We used a second, disease/health-related, version of the IAT, in which we used words associated with disease, e.g. “disease,” “health,” “rotten,” “fresh,” etc. The task was otherwise the same, with the exception that participants had to classify words as health vs. illness-related, rather than positive vs. negative.

Overview of the studies

Study I

Zakrzewska, M. Z., Olofsson, J. K., Lindholm, T., Blomkvist, A., & Liuzza, M. T. (2019). Body odor disgust sensitivity is associated with prejudice towards a fictive group of immigrants. *Physiology & Behavior*, *201*, 221–227. https://doi.org/10.1016/j.physbeh.2019.01.006

Aim

This study aimed to test if body odor disgust sensitivity is related to prejudice (negative attitudes) and to see what non-olfactory characteristics might explain this relationship. Specifically, I wanted to see if more negative attitudes towards a fictitious outgroup are related to higher levels of BODS and if this relationship can be explained by a) how this specific outgroup is perceived in terms of norms similarity (target-specific prejudice) and b) general attitudes towards immigration.

Background

Building on results from Faulkner et al. (2004), I wanted to see if BODS levels are related to attitudes towards an unfamiliar fictitious group, about which the only available information is their origin (Central Africa). If BODS is an index of disease avoidance, we should see such a relationship. Following the *traditional norms account* of the connection between disease avoidance (and BODS) and prejudice, BODS might be related to an individual's opinion about whether an outgroup's norms are similar or different from their own group's norms, and these opinions should relate to attitudes towards the outgroup. Extending this reasoning, although the attitude towards any specific outgroup can be largely influenced by one's general disposition towards outgroups (in this case: immigrants), perception of this particular outgroup's norms should have an additional contribution to attitudes towards the group.

Method

I used Amazon Mechanical Turk (MTurk) through a Qualtrics web interface (Qualtrics, Provo, UT) to collect data. The sample was based on a power analysis. Final sample size consisted of 805 participants (444 females; mean age = 37.8, SD = 11.6). Participants did a self-paced online survey in which they were introduced to the Drashneeans scenario and responded to questions measuring perceived dissimilarity of the Drashneeans and prejudice towards them. Additionally, they filled in the BODS questionnaire and responded to questions about their general attitudes towards immigration. The individual scores on all questionnaires were standardized before the analysis. The sample size, hypotheses, materials, and analysis plan were preregistered on OSF (https://osf.io/fsbna/)

Analysis

Before testing our hypotheses, I ran a confirmatory factor analysis for all scales to ensure that we meet our preregistered criteria in terms of internal consistency and that the assumed unidimensionality of each scale provides a good fit to our data. Next, I performed confirmatory analyses on individual average scores from each questionnaire using Bayesian modeling and Bayes Factors. To further confirm the results, I used SEM on item-level data. All models included demographic variables known to be related to prejudice, namely gender, age, and education level.

For the SEM analysis, the hypothesized partial mediation model included a direct effect of BODS on prejudice and two mediating paths for the BODS-prejudice relationship: via a) perceived dissimilarity and b) general attitudes towards immigration. As alternative models, I had a complete mediation model, and two other, simpler models (e.g., an additive model in which each variable had an independent effect on prejudice). I report standardized estimates and corresponding 95% posterior credibility intervals (PCI).

Results

BODS levels were positively related to negative attitudes towards Drashnee refugees (0.19 [0.13, 0.24], $BF_{10} > 1000$). Individuals who scored higher on BODS had also more negative attitudes toward the outgroup. This relationship was partially explained by both specific and general attitudes towards the group (Figure 2). Namely, participants who perceived the group as different in fundamental norms relevant to health and disease (relating to food, hygiene, and sanitary practices) were also more prejudiced against the outgroup (0.87 [0.82–0.93], $BF_{10} > 1000$). Additionally, an overall opposition towards immigration in general was related to more prejudice towards the outgroup, although the estimate for this effect was close to zero and the evidence was inconclusive (0.08 [0.01–0.15], $BF_{10} = 1.54$).

This pattern of results was confirmed by SEM analysis. The SEM analysis provided additional information showing that our hypothesized model outperformed other alternative models. The partial mediation model of the BODS – prejudice relationship (with two mediation paths: via perceived dissimilarity and via general attitudes towards immigration) was better than a complete mediation model and two other models.

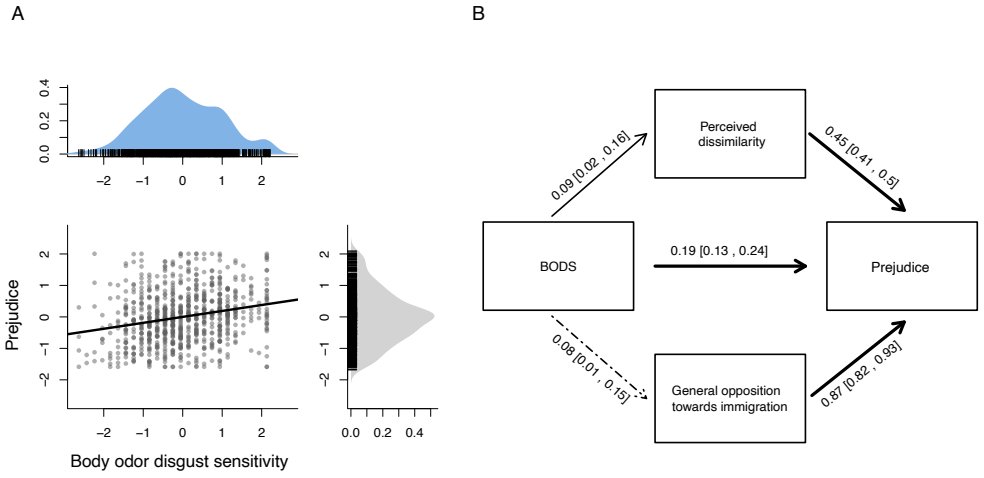

Figure 2 (A) Relationship between body odor disgust sensitivity (BODS) and negative attitudes towards the fictive outgroup (Prejudice). The distributions of both variables are depicted above (BODS) and to the right (Prejudice) of the scatterplot. The density of the data is additionally illustrated by the intensity of the color of each data point; (B) Summary of the results from multiple regression models with regard to preregistered hypotheses. Evidence for the existence of a relationship is marked by the thickness of the arrows with 3 steps: BF > 1000 (thick solid arrow), BF > 3 (solid arrow), and BF < 3 (two-dashed arrow). Coefficients and 95% PCIs are noted next to the corresponding arrows.

Conclusions

Consistent with disease avoidance theories, I found that body odor disgust sensitivity is related to negative attitudes towards an outgroup. This relationship was partially mediated by how similar the outgroup was perceived in terms of health and disease-relevant norms (and possibly general attitudes towards immigrants), supporting the traditional norms account of prejudice. Self-reported olfactory assessments may be well suited to assess potential sensory roots of outgroup prejudice.

Study II

Zakrzewska, M. Z., Liuzza, M. T., Lindholm, T., Blomkvist, A., Larsson, M., & Olofsson, J. K. (2020). An Overprotective Nose? Implicit Bias Is Positively Related to Individual Differences in Body Odor Disgust Sensitivity. *Frontiers in Psychology*, *11*, 301. https://doi.org/10.3389/fpsyg.2020.00301

Aim

This study aimed to investigate if BODS is related to implicit and explicit prejudice. Additionally, I wanted to confirm how BODS fits into the dual-process framework of prejudice. I also wanted to test if disease-relevant olfactory and word cues can enhance negative attitudes towards outgroups and if this effect would be stronger among high BODS levels individuals.

Background

In Study I, I found that BODS is related to explicit prejudice, both on a general level and in response to a specific (although fictitious) target group. The dual-process framework (Duckitt, 2001) provides an organized map of how different factors contribute to prejudice. It is important to try to incorporate new findings (such as the BODS-prejudice relationship) into existing frameworks. In this study, I gathered several explicit measures of prejudice to see whether BODS is selectively related to some forms of prejudice and conservatism, following the existing theories, or if it is generally related to various forms of negative attitudes towards others. While SDS and RWA can be thought of as forms of social conservatism, SDO relates more to economic than social conservatism (Duckitt, 2006; Duriez et al., 2005; Jost et al., 2009). The picture of the BODS-prejudice relationship would not be complete without investigating it from a more implicit angle. I thus included an IAT task in this study. Previous studies used IAT with disease and health-related words to activate the behavioral immune defenses (e.g., Faulkner et al., 2004). For this reason, I used two versions of the IAT: a normal IAT and a disease-related version of the IAT. Additionally, if odor disgust is important for attitudes towards others, we should try to manipulate these attitudes using odors. Odor cues have been previously used in experimental settings to successfully influence the perception of emotional stimuli (e.g. Seubert et al., 2010; Syrjänen et al., 2018), and in priming paradigms (e.g. Kastner et al., 2015; Olofsson et al., 2014).

Method

We recruited participants according to a sequential Bayes factor design (Schönbrodt & Wagenmakers, 2018) with the minimum sample size defined via a null hypothesis significance testing a priori power analysis. The final

sample consisted of 35 participants (25 women; mean age = 28.5, SD = 6.3). Participants first completed a set of questionnaires on a computer screen. They filled in the BODS, RWA, SDO, and SDS along with demographics. Next, they performed the IAT tasks with odors placed under their nose. The hypothesis, materials, and analysis plan were preregistered on OSF (https://osf.io/6jkp2)

Odor stimuli

I used two different odors: an unpleasant and sweat-like odor (valeric acid), and a pleasant and soap-like odor (lilac). In previous research, valeric acid has been used as human feet sweat-like odor (Anderson et al., 2003; Syrjänen et al., 2018). Both odors were diluted with an odorless mineral oil solution (Propylene glycol, 1.2-propanediol 99%, Sigma- Aldrich) in order to reach what equals a moderate intensity. Based on our previous psychophysical investigations, a 30% concentration corresponds to moderate intensity for both odors (Syrjänen et al., 2018). Participants were exposed to odors via cotton pads placed in tube-shaped cotton bands, tied under their noses – a method that has proved efficient in previous studies (e.g., Syrjänen et al., 2018). Additionally, I also used clean cotton pads to create a no-odor condition. Before and after performing the task, participants were asked to rate the intensity and hedonic valence of the odors. The ratings were made on a seven-step, Likert-type scale, ranging from 1 – *not detectable* to 7 –*extremely intense* (intensity), and from 1 – *extremely unpleasant* to 7 – *extremely pleasant* (valence).

IAT with odors

I used a regular and a disease version of the IAT (Figure 3). I used pictures relating either to Swedish culture or to a stigmatized minority outgroup in Sweden, namely the Romani people. The two versions were administered in a pseudo-random order, counterbalanced across participants. Participants performed both versions of the task three times, each time with a different odor placed under their nose (the sweat-like unpleasant odor, the soap-like pleasant odor, or a clean cotton pad). The odor conditions were manipulated within participants. Each odor was kept under the participant's nose throughout the duration of one IAT task repetition.

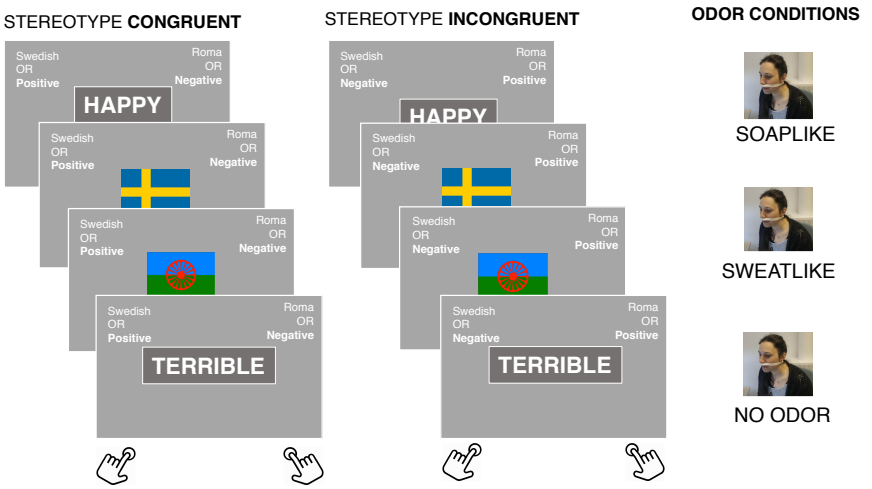

Figure 3 An example of trials in the normal IAT, in both congruent and incongruent blocks. The disease IAT was identical, with the exception that I used health and sickness-related words. Participants were instructed to classify the words and pictures as quickly as possible. IATs were presented in pairs: each pair consisted of both IATs (disease and normal) and was repeated three times: with a soap-like odor, a sweat-like odor, and a neural odorless cotton pad. The order of odor conditions was randomized between participants.

Analysis

I used Bayesian modeling and hypothesis testing through Bayes factors to analyze the IAT data. Each hypothesis was formed as a model and then tested against a corresponding null model. If it was better than the null model, I sampled from the posterior distributions of the model with 10000 iterations to obtain the estimates of the effects, and be able to infer the strength and direction of the observed effects. I report raw estimates with corresponding 95% PCI. To look at the relationships between BODS and other scales (SDO, RWA, and SDS), I first standardized the scales (including BODS) in order to be able to interpret the results with regard to previous studies. Thus, I report standardized estimates for the relationship between BODS and SDS, RWA and SDO, with corresponding 95% PCI.

Results

I found a small-to-medium size negative bias toward the outgroup in our sample (mean D score = 0.40 [0.30, 0.49). BODS levels were positively related to negative bias towards the outgroup (0.17 [0.09, 0.28], BF_{10} = 315], Figure 4A). However, the odor exposure did not influence negative bias (BF_{01} = 15), and this (lack of) effect was the same for all levels of BODS (no interaction between BODS and odor exposure, BF_{01} = 106). Similarly, the version of the IAT (disease or regular) did not have any effect on the IAT scores (BF_{01} = 21).

The estimates for effects of odors and IAT version were all close to 0 (ranging from -0.03 to 0.03, all PCIs including 0).

In terms of explicit measures, BODS was related to measures of social, but not economic conservatism. Namely, I found a positive relationship between BODS and SDS (0.38 [0.07, 0.71], BF_{10} = 7, Figure 4B1), but there was no relationship between BODS and SDO (0.005 [−0.31, 0.31], BF_{01} = 3, Figure 4B2). There was no clear relationship between BODS and RWA (0.09 [−0.21, 0.4], BF_{01} = 2.6, Figure 4B3) yet the evidence for the null was inconclusive. As an exploratory analysis, I used the results from this study to update our beliefs on the BODS-RWA relationship coefficient from a previous study (Liuzza et al., 2018). With this new data, the new 95% PCI [0.13, 0.32] still did not include 0, and the BF_{10} > 1000 suggested there is evidence to believe that BODS and RWA are, overall, related (Figure 4B4). I did the same updating procedure for the BODS-SDO relationship: the new 95% PCI [−0.11 0.07] included 0 with a BF_{10} < 1, suggesting no relationship between BODS and SDO.

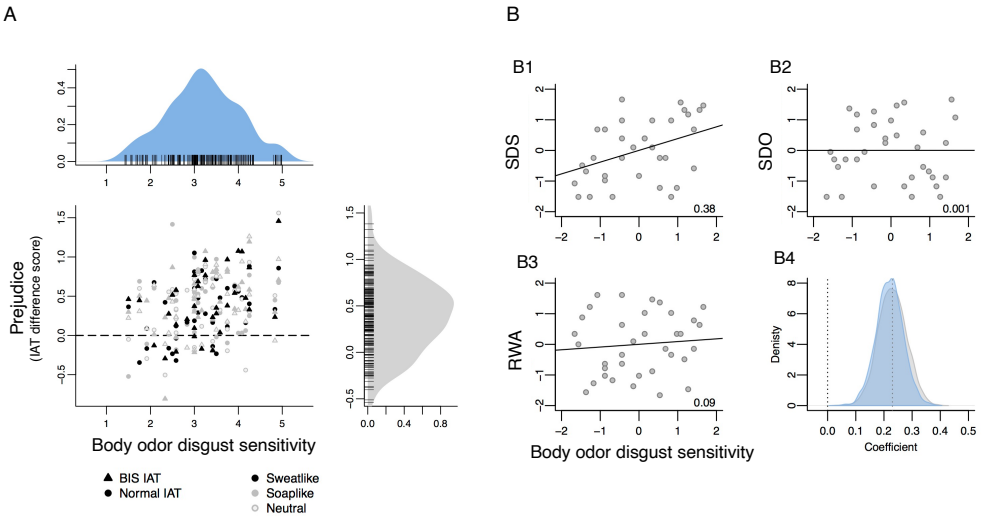

Figure 4 (A) Body odor disgust sensitivity (BODS) is positively related to implicit prejudice. Positive IAT difference scores indicate bias against the outgroup, while negative values indicate bias against the ingroup. No bias (0) is marked by the dashed line. The upper and right panels depict the density distribution of BODS and IAT difference score respectively; (B) Relationship between BODS and social distance scale (SDS, B1), social dominace orientation (SDO, B2) and right-wing authoritarianism (RWA, B3). All variables were ranked and standardized. Numbers in the lower right corner of each plot are the regression coefficients. Blue distribution on (B4) is the posterior distribution of the estimate for BODS – RWA coefficient after using data from this study to update our beliefs on results from Liuzza et al. (2018), represented as gray distribution (the prior). Dotted lines represent 0 (no relationship) and 0.23 – the lowest coefficient from Liuzza et al. (2018)

Conclusions

I found further evidence that body odor disgust, a potent sensory disease avoidance function, is related to prejudice, both using explicit and implicit measures. These findings corroborate the hypothesis that individual differences in how sensitive one is to disease cues, and how prone one is to avoid them, can make one prefer behaviors and express attitudes that limit contact with the outgroup. However, I did not manage to manipulate the implicit bias by using the olfactory cues nor by using disease-related word cues. These results show that more research is necessary to understand the exact role of olfaction in shaping (or at least: influencing) attitudes.

Study III

Zakrzewska, M. Z., Challma, S., Lindholm, T., Olofsson, J. K. & Liuzza, M. T., (*submitted*). Body odor disgust sensitivity is associated with xenophobia: Evidence from 9 countries across 5 continents.

Aim

The aim of this study was to replicate findings from Study 1 concerning the relationship between BODS and explicit prejudice, and the role of norms in this relationship. Moreover, I wanted to see if this relationship is generalizable across different countries and cultures. Additionally, I introduced another fictitious refugee group from Eastern Europe, to better understand the role of perceived cultural similarity in the BODS-prejudice relationship. I changed the origin of the African group from Study I (originally coming from Central Africa) to Eastern Africa for equivalence. I wanted to see if attitudes towards the two outgroups would be the same and if levels of BODS would yield different effects in the two group origin conditions.

Background

In Studies I and II, I found that BODS is related to various forms of prejudice towards outgroups. Although this in itself is very interesting, recent publications indicate the importance of replicating scientific studies and gathering evidence, rather than basing our knowledge on singular findings (Open Science Collaboration, 2015). I thus wanted to replicate these findings and see if the relationship between BODS and prejudice is similar in different samples. If BODS is indeed a manifestation of disease avoidance mechanisms, rooted in evolutionary processes, the observed pattern of relationships should be similar in other samples across the globe. A universal pattern of results would

highly benefit the disease avoidance theory of prejudice, while stark differences between countries could possibly undermine them.

Method

I collected the data using Qualtrics survey software (Qualtrics, Provo, UT). The data was collected in two waves: first in Sweden and Italy during the first wave of COVID-19 pandemics (April 2020), second in Canada, Chile, Hong Kong, Kenya, Nigeria, Mexico, New Zealand, and the United Kingdom in a later pandemic wave (December 2020). The sample size in each country was based on recommendations to get reliable estimates in SEM analysis (Schönbrodt & Perugini, 2013, Kline, 2011). Participants completed a self-paced survey, which was translated into five languages (Swedish, Italian, English, Spanish, and Traditional Chinese). The survey consisted of all the measures used in Study I: the Drashean scenario, perceived dissimilarity, prejudice, general attitudes towards immigration, and the BODS scale. To extend the scope of the study, I included another, control group of fictitious immigrants, coming from Europe. Participants were randomly assigned to one of the two conditions (Drashnean origin either *Eastern Africa* or *Eastern Europe*, half/half in each country). This data was collected as a part of a bigger study: we also collected information about all participants' attitudes on issues related to the COVID-19 pandemic, their political preferences (first wave only), and other ideological measures (second wave only). All measures were pre-registered and can be found, along with relevant hypotheses at OSF. At the end of the survey, there was an attention check.

Final sample size consisted of 6836 (3289 females; mean age = 42, SD = 14.7) from 9 countries. The hypothesis, materials, and analysis plan were pre-registered on OSF (wave 1: https://osf.io/ycwb3/, wave 2: https://osf.io/p72m6/).

Analysis

I analyzed data using SEM analysis. Data from all countries (except Mexico) was combined based on measurement invariance requirements stated in pre-registration. Data from Mexico was excluded as the outcome measure (prejudice) worked differently in this sample, and measurement invariance could not be obtained while keeping this data. I conducted the analysis in two steps: first, I modeled the data according to our hypothesized model, which assumed that there is a relationship between BODS and prejudice and that it is partially mediated by perceived dissimilarity and general attitudes towards immigration. I compared this model against seven alternative models (three of them used also in Study I). To decide which model was best I looked at a) fit indices (change in TLI and CFI > 0.01) b) BIC (Bayesian information criterion) and AIC (Akaike information criterion), where smaller values suggest a better model, and c) $\chi 2$ difference test and its significance.

Next, I used the model which came out best in this comparison to investigate differences between attitudes towards the two Drashee groups. As an exploratory analysis, I looked at how the total relationship between BODS and prejudice looks in each of the nine countries. All models included demographic variables known to be related to prejudice, namely gender, age, and education level. For all SEM modeling, I used 1000 bootstrap iterations and a maximum likelihood (ML) estimator. I report raw estimates with corresponding 95% confidence intervals.

Results

I replicated the findings from Study I: levels of BODS were positively related to negative attitudes towards outgroups. As in Study I, this relationship was partially mediated by how the group was perceived in terms of disease–related norms, and one's general attitudes towards immigration (Figure 5A). The partial mediation model outperformed all alternative models according to our specified criteria. The total positive effect of BODS was 0.37 [0.32, 0.43] including the mediation path via perceived dissimilarity (0.16 [0.14, 0.18]), the mediation path via general opposition to immigration (0.16 [0.12, 0.19]) and a direct effect (0.06 [0.02, 0.1]).

Although the two Drashne origin groups differed in perceived dissimilarity attitudes towards them were similar (Figure 5C). Eastern African Drashneans were perceived as more dissimilar than the Eastern European Drashneans (EA: 6.99 [6.92, 7.06], EE: 6.44 [6.37, 6.51], with a difference of 0.55, [0.45, 0.64]). Additionally, the relationship between BODS and the two mediators (perceived dissimilarity and general attitudes towards immigration), and the relationship between the two mediators and prejudice were all similar in the two groups. Modeling them as different did not improve the model fit according to our specified criteria.

Conclusions

This study used a large sample to extend previous findings of a positive relationship between body odor disgust sensitivity and explicit prejudice (Study I, Zakrzewska et al., 2019) across countries and continents. Of particular interest was to understand whether or not body odor disgust is linked to negative attitudes to refugees because of the perceived dissimilarity of the refugees. I found that this was the case and that our findings generalized well across several countries. This result further supports the traditional norms account of prejudice. Understanding the link between behavioral immune defenses and

prejudice may be critical for understanding the psychology of intergroup processes.

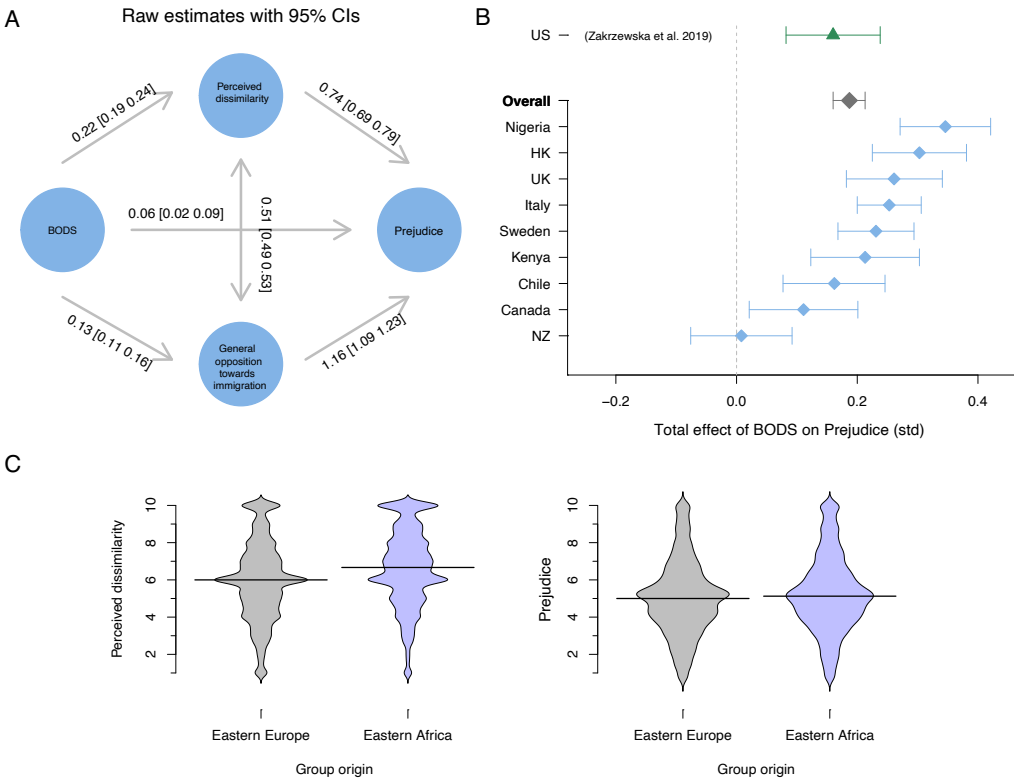

Figure 5 (A) estimates from the best model (partial mediation), with corresponding 95% CIs. Latent variables are marked with circles. (B) Total effect of BODS on Prejudice in each country. Standardized estimates of total effect of BODS on Prejudice (including the two mediation paths via perceived dissimilarity and general attitudes towards immigration) with corresponding 95% CIs. We also show the estimates for all countries (from the partial mediation model A in the main analysis) and the estimate from the original study on a US sample (Zakrzewska et al., 2019). NZ - New Zealand, HK- Hongkong, UK - United Kingdom. (C) Overall perceived dissimilarity (left) and Xenophobic attitudes (right) towards the fictitious immigrant groups coming from Eastern Europe (gray) or Eastern Africa (blue). The horizontal black lines mark median values, and the width of each plot indicates distributions of scores.

Study IV

Zakrzewska, M. Z., Liuzza, M. T., & Olofsson, J. K. (*submitted*). Body odor disgust sensitivity (BODS) is related to extreme odor valence.

Aim

The aim of this study was to learn more about how self-reported body odor disgust sensitivity relates to the perception of real odors and to investigate what is it that high body odor disgust sensitive individuals are sensitive to.

Background

Despite the vast number of studies about how disease avoidance and disgust sensitivity are related to social or personality variables, not much is known about how this self-reported sensitivity relates to disgusting stimuli. The few exceptions in the visual domain show a predicted pattern: higher disgust sensitivity was positively related to disgust ratings of disgusting images (Ammann et al., 2018; Haberkamp et al., 2017). In the olfactory domain, there are studies looking into the relationship between olfactory and disgust sensitivities, but up to my knowledge, only two studies look at how disgust sensitivity relates to the perception of odors. One study has been previously mentioned and found that BODS levels were positively related to ratings of disgust, but not intensity, of human sweat odor (Liuzza et al. 2017). Another study found that higher disgust sensitivity was related to lower pleasantness ratings for an unpleasant, feces-like smell, but not to the perception of the pleasantness of several other odors; nor was it related to the perception of the intensity of any of the smells (Croy et al., 2014). Neither study used pleasant odors that could be cues for hygiene and health. In this study, I hypothesized several scenarios of how BODS could be related to the perception of odors, each scenario contributing differently to the knowledge about disease avoidance. I also wanted to look deeper into the two subscales of BODS – internal and external – and their role in predicting the perception of health and disease-related odor cues.

Method

I combined data from four experiments previously run in the lab. The inclusion criteria were simple: the experiments had to use both pleasant and unpleasant odors, collect perceptual ratings of these odors in at least two aspects (intensity and valence), and use the BODS scale. The final dataset included 190 individuals. Table 2 shows information about the experiments included in the study. Each study used unpleasant odors which resembled body odors, and pleasant odors that often are used in soap or other hygiene products.

Analysis

I analyzed the data using Bayesian modeling and parameter estimations. Ratings were standardized within each experiment. In the first step, I wanted to know how (if) BODS levels are related to the perception of odor valence and intensity. I modeled the two outcomes separately and used model comparison to see if BODS predicts the ratings beyond the odor category and if the two interact. Model comparison was based on the difference in information criteria (widely applicable information criterion[3], WAIC; difference denoted as ΔWAIC) and the standard error of the difference (ΔSE). For a model to be considered better, it had to have a lower WAIC value than the alternative model(s), and this difference had to be at least twice as big as the ΔSE.

In the second step, I wanted to investigate if the overall BODS score or one of its two subscales has the best predictive value for the perceptual ratings. In both steps all models allowed individual intercepts for overall ratings for each participant (random effect of participants' ID). Additionally, all models included gender, as it has been shown to affect both disgust sensitivity and olfactory abilities. I report standardized mean posterior estimates from the best models with a corresponding 94%[4] HPDI.

[3] Also known as the Watanabe–Akaike information criterion

[4] Why 94%? Why 95%? There is nothing magical or special about 95% intervals and they often (wrongly) imply a connection to the 0.05 alpha level (see McElreath, 2016, p. 56).

*Table 2 Descriptive statistics and information about smell and ratings used in Study IV. EXP – experiment; N – number of participants; F – number of female participants; Age – mean age (standard deviation). Italics indicate unpleasant smells; bold indicates smells and ratings present in all four experiments. * Borg CR-100 scale (Borg & Borg, 2002). ** data used here comes from the initial rating task, not ratings within the main task*

	N (F)	**Age**	**Odors**	**Odor characteristics**	**Smell delivery**	**Ratings collected**	**Trials per odor**	**Rating scale(s)**	**Relevant publication**
EXP 1	53 (29)	25.8 (5.8)	**Lilac** ***Valeric acid***	soap sweat	cotton pad with a drop of odor solution placed under the nose	**Pleasantness** **Intensity**	3	-10 to 10 1 to 120*	Syrjänen et al. (2018)**
EXP 2	35 (25)	28.5 (6.3)	**Lilac** ***Valeric acid***	soap sweat	cotton pad with a drop of odor solution placed under the nose	**Pleasantness** **Intensity**	2	1 to 7	Zakrzewska et al. (2020)
EXP 3	22 (15)	28 (6.2)	**Lilac** Lily of the valley Peppermint ***Valeric acid*** *Scatole* *Butyric Acid*	soap soap, perfume fresh breath sweat feces vomit	a jar containing odor solution	**Pleasantness** **Intensity** Familiarity	3	0 to 100	
EXP 4	80 (40)	29.2 (8.3)	**Lilac** Lemon ***Valeric acid*** *2-picoline*	soap fresh sweat breath compound	olfactometer	**Pleasantness** **Intensity** Disgust	2	-100 to 100 1 to 120* 1 to 120*	

Valence

Model comparison indicated an interaction between odor category and BODS: the interaction model was better than the additive model, and models including only odor category or only BODS (all ΔWAIC >= 2*ΔSE). In this best (interaction) model, unpleasant smells were rated as less pleasant than pleasant smells (-0.7 [-0.87 -0.49], Figure 6A). Individuals with higher BODS levels rated odors as more strongly valanced: unpleasant smells were rated as more unpleasant, but pleasant smells were rated as more pleasant (Figure 6C-D). The second step of the analysis revealed that external BODS was the best at predicting valence ratings.

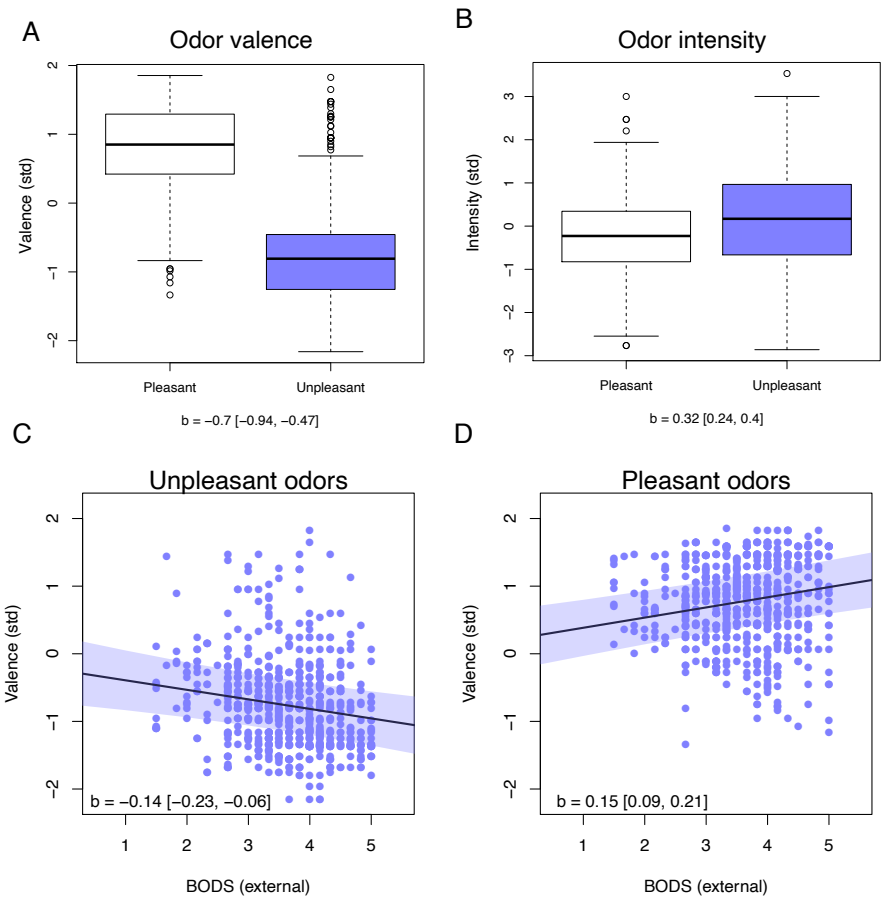

Figure 6 Valence and intensity ratings. Relationship between BODS and valence ratings for unpleasant (A) and pleasant odors (B). Intensity ratings (C) for pleasant (white) and unlpeasant (blue odors). Shaded areas and numbers in square brackets represent 94% HPDI for the slope. Black lines on the boxplots show median values.

Intensity

A simple, odor category only model was the best when looking at WAIC (all $\Delta WAIC < 2*\Delta SE$). In this model, unpleasant smells were perceived as more intense by 1/3 of standard deviation (0.32 [0.24, 0.4], Figure 6B). As BODS was not clearly related to intensity ratings, I did not proceed to the next step of our analysis (looking at different aspects of BODS) and thus concluded the investigation of intensity ratings at this stage.

Conclusions

I found that self-reported disgust sensitivity to body odors is related to the perception of odors, namely odor valence, in a way that suggests that BODS is relevant for both *avoidance* and *approach* reactions to odor cues. In the light of these results, not only do high BODS people perceive the unpleasantness of odors as a potential disease signal, but also perceive the pleasantness of an odor as a safety cue. This work is a step further in understanding the mechanisms olfactory disgust plays in disease avoidance, however, much more work is needed to make strong conclusions about said mechanisms.

General discussion

In my research, I used both experimental and survey methods to look into the relationship between olfaction and prejudice. Across four studies, I tried to meet five aims which I will discuss in detail on the following pages. First, let's recap the main findings of this thesis.

1. Body odor disgust sensitivity is positively related to both explicit prejudice against a fictitious outgroup and implicit prejudice towards a minority group.
2. The relationship between BODS and prejudice can be at least partially explained by both general (general attitudes towards immigration) and specific (perceived dissimilarity in terms of health/disease-relevant norms) factors. BODS is related to social but not economic conservatism.
3. Disease-related olfactory and word cues did not influence either prejudice towards an outgroup or the relationship between BODS and prejudice.
4. The relationship between BODS and prejudice is quite robust across countries and cultures.
5. BODS is related to the perception of odor valence. For individuals with higher levels of BODS, pleasant smells are perceived as more pleasant, and unpleasant smells are perceived as more unpleasant.

Aims revisited

(1) Is body odor disgust sensitivity related to explicit and implicit prejudice?

In my studies, I found that with increasing body odor disgust sensitivity, explicitly stated attitudes towards a fictitious refugee group are becoming more negative (Study I and III). Similarly, when looking at IAT scores, which are thought to reflect both a bias in favor of the ingroup and bias against the outgroup, we can see a positive relationship between BODS and implicit bias:

higher BODS relates to more prejudiced attitudes (Study II). Should we conclude that BODS is related to prejudice then? There are a couple of aspects to consider here. First, is the effect similar across the studies, and is it of a meaningful size? In all three studies, the relationship I find is of similar magnitude (Figure 6).

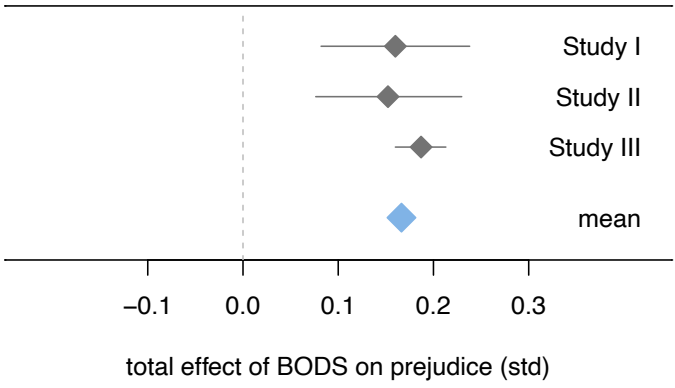

Figure 7 Standardized coefficients (and a 95% precision interval) for the relationship between BODS and prejudice in Studies I, II, and III. The blue diamond shows a mean of all three effects.

The effect is not large, but would we expect it to be large? Although there are a lot of theoretical support for a link between disgust, olfaction, and prejudice, the theory does not imply that chemosensation is the deciding factor in shaping attitudes. It would be unreasonable to assume that disease avoidance mechanisms are fully responsible for how we react to other people. There are other factors – education, attitudes of parents and friends, personality and so on that may likely contribute to bias more than disease avoidance. The point of this thesis, however, was to show that our biases can at least *partially* be traced back to these primitive disease avoidance functions. In fact, many important effects in psychology are 'small' and the notion of what is *meaningful* should be interpreted based on the context (Funder & Ozer, 2019). To me, the fact that the relationship between prejudice and chemosensation was found is meaningful. It highlights that prejudice is based on common, natural processes. It helps to look at prejudice from a bigger picture perspective, showing that there might still be factors we have not included in the state-of-the-art theories.

Another aspect to consider when answering this question is related to the tools I used to investigate the topic of prejudice. I show that BODS is related to several of the most commonly used measures of prejudice. However, there is a debate about how good these measures are at tapping into prejudice, especially with regard to the IAT. Nevertheless, these are still some of the best

tools available, and in my opinion, they represent negative attitudes towards widely defined outgroups, and after all, that is what I set out to investigate.

(2) Are there other individual characteristics and differences in attitudes that can help explain why BODS is associated with prejudice? (Study I, II, and III)

Another aim of this thesis was to try to find further explanations of the relationship between BODS and prejudice. We looked into economic and social conservatism, the importance of health-related norms, the relevance of target group-specific factors as well as general anti-outgroup attitudes. In Studies I and II, I found that both how we perceive the specific outgroup, and what we feel about outgroups in general can explain to a large degree the link between odor disgust sensitivity and prejudice. In other words, individuals easily disgusted by body odors perceived this specific outgroup as different in terms of norms related to food, hygiene, and sanitation and thus were less positive towards them. Similarly, the negativity was partially explained by a more general opposition towards immigrants. Importantly, the fact that BODS is related to the perception of the outgroup with regards to norms suggests that the BODS-prejudice relationship is driven by something more than some general negativity, an attitude of being against and unhappy about objects and people.

Although the remaining, direct effect of BODS levels on prejudice is very small (Study I, Study III), it suggests that there might be more factors that explain this relationship. General negativity might be one of them. Future studies will hopefully identify the missing pieces of this puzzle.

I further confirmed the selectivity of BODS, as opposed to it being a part of negative attitudes towards everything, in Study II. Individuals high in BODS were more socially conservative, but not economically conservative. This is in line with the dual processing framework (Duckitt, 2001), where prejudice can be based either on perceiving the world as a dangerous place, which is the basis of RWA, or a competitive jungle, which is the basis of SDO. The feeling of disgust is more related to the perception of the world as a dangerous place and authoritarian attitudes. Both serve as a form of avoidance and distancing. In contrast, the other perspective on the world, the competitive jungle, motivates social dominance, aggressive competition, and economic conservatism.

Can we use what I've learned about disgust sensitivity to body odors to inform anti-prejudice actions? Can we, for example, use smells to boost or dampen bias?

(3) Can disease-relevant olfactory cues enhance negative attitudes towards outgroups? Is this effect stronger among high BODS levels individuals? (Study II)

Background odors proved to have no effect on bias measured by the IAT. How do we consolidate this result with the supposed link between olfactory disgust and social attitudes? Several important factors need to be discussed here. First, there might be no effect to be found: the relationship between BODS and prejudice might not be so easily influenced by short term manipulations and temporary circumstances. Next, I would like to discuss the potential consequences of using background odors, rather than a cue-target pairs paradigm. It is possible that having the smell in the background for the duration of an entire IAT task resulted in habituation to the smell, and suppression of its effect (Smeets & Dijksterhuis, 2014), although studies done previously in our lab did not show a strong habituation effect using a similar design (e.g. Syrjänen et al., 2018). Nevertheless, a cue-target paradigm, where short, odor cues are paired with a target stimulus (as they are in a priming task) might serve better when trying to influence attitudes toward a specific target group. Research shows that congruency effects (for semantic and emotional aspects of stimuli) can be observed on a single trial level through olfactory priming (e.g. Kastner et al., 2015; Olofsson et al., 2014).

Another aspect I would like to discuss here is what we can actually learn from the IAT. What does the IAT measure? As mentioned in the introduction there are several views on this matter. One of them highlights that it is dependent on how, and how often, concepts are paired in a given culture. If it is mostly showing culturally developed associations, then it is highly unlikely we would be able to influence them by such a small manipulation as introducing an odor.

These shortcomings of the IAT were known to me before running the study. However, it was a task that seemed a promising way of investigating the effect of odors on bias. In fact, it is incredibly hard to find a task that would allow combining odor manipulation and bias measurement. One of the difficulties posed by such paradigms is that they require clearly valenced stimuli (e.g., words) while odor perception is highly individual. Even if most people perceive certain smells (e.g., valeric acid) as unpleasant and others (e.g., lilac) as pleasant, the degree to which they do so varies a lot. Indeed, some people might perceive either smell as completely neutral. Although not included in this thesis, I have made two other experimental attempts at finding the optimal prejudice measuring task with the use of odors. I briefly describe the obstacles I met and conclusions for future studies in the *Future directions* section of this discussion.

Lastly, although the idea of being able to manipulate attitudes using odors might be attractive, would it really be a good thing? It might be for the better that it is not so simple. Although it would have had great potential applications

in decreasing bias, it might as well be used to serve the opposite, undesired goal – to increase bias.

(4) How generalizable is the relationship between BODS and prejudice: will it replicate across different cultures and countries?

In Study III, I found that the positive relationship between BODS and explicit prejudice is similar across nine countries on all continents. I also replicated the findings concerning the importance of outgroup norms in prejudice. These results strengthen the assumption that the relationship between disease avoidance and attitudes towards outgroups is universal, based possibly on evolutionary adaptations, and thus should be present overall, not only in Western society. The sample has included countries representing various cultures and geographical locations and could thus support the idea of generalizability of the BODS – prejudice relationship. Nevertheless, one needs to keep in mind that the samples, although representative of each country's population in terms of gender, age, and education might not be representative in other aspects. Only a subset of the populations in question has access and time to fill in online questionnaires.

There is another question related to generalizability that my thesis has not answered. In my research, I focused on the majority ingroup perspective. It would be interesting to see if the same prejudice is observed when looking from the perspective of minority groups, which would usually be used as outgroups in such studies. For example, would Romani participants sow the opposite bias in the IAT task from Study II, and would it be related to levels of BODS? Alternatively, would attitudes towards inhabitants of the country be related to BODS and perceived similarity of norms from the perspective of newly arriving refugees? To truly talk about the *generalizability* of the relationship between disease and prejudice, these different perspectives need to be addressed.

(5) How are BODS levels related to perception and what is it that high body odor disgust sensitive individuals are sensitive to?

Study IV provided insight into how individual differences in BODS translate to the perception of odor valence and intensity in an experimental setting. Individuals who perceive themselves as easily disgusted by body odors perceived odor valences more strongly overall: pleasant stimuli were rated as more pleasant, and unpleasant stimuli as more unpleasant. The intensity of the odor however was perceived similarly by participants with all levels of BODS. Interestingly, Olsson et al. (2014) show that when rating sick vs healthy human sweat samples, both pleasantness, and intensity are relevant, even if the differences in pleasantness were maybe slightly greater *(Cohens d* for intensity = 0.21 vs d = 0.26 for pleasantness). This finding is in line with findings

by Liuzza et al. (2017), where BODS levels were related to how disgusting participants found human sweat odor to be, but not to how intense the odor was. Taken together, these results suggest that disgust sensitivity to body odors is related more to qualitative aspects of the smell signal (pleasantness, disgustingness) than the strength of the signal itself. This differentiates people with high levels of BODS from those who have high chemical sensitivity or intolerance. These individuals, unlike high BODS individuals, rate odors as more intense, but similarly pleasant (compared to controls; Cornell Karnekull et al., 2011). Importantly, our results suggest that disgust sensitivity's function may not only be to promote avoidance behaviors (by responding more negatively to potentially threatening stimuli) but also to initiate approach behaviors (by perceiving pleasant and potentially health-related stimuli more positively).

It is interesting to consider these results from a signal detection theory (SDT) perspective: in the light of SDT, individual disgust sensitivity should depend on two parameters: how sensitive they are to detecting a disgusting odor (i.e., the detection threshold, referred to as *d*') and what is their *criterion* to call an odor disgusting. Our perceptual rating results suggest that people with higher BODS levels are more likely to have a lower criterion i.e., less is needed for them to judge an odor as unpleasant or pleasant, rather than then suggesting that they detect the odor more easily. Indeed, a couple of studies did not find a relationship between disgust sensitivity and olfactory thresholds, however the results were inconsistent (Chan et al., 2020; Croy et al., 2017; Schienle & Schöpf, 2017). Our reasoning is in line with recent results about visual disgust. Namely, when studying how a disgusting image can cause the attention blink effect, researchers showed that while the effect itself was not related to individual differences in disgust sensitivity, the valence ratings of the image causing it to appear were (Perone et al., 2021). However, a limitation of our study is that we do not test the threshold of detecting an odor directly, thus our conclusions with regard to lower criterion vs. lower threshold are preliminary and should be tested directly in a future study.

Strengths and limitations

I would like to briefly mention the strengths of the thesis. First, this thesis is a combination of experimental and survey data, hopefully allowing for a better overview of the topic. I applied the most appropriate (to my knowledge) statistical approach to data analysis. Whenever possible, I used Bayesian statistics which allowed me to make inferences for both the alternative and null hypotheses. I always provide estimates with an interval to allow the reader to get an idea of *what* the effect is (not only that there *is* an effect), and what is the predicted range for this effect. Whenever the sample size allowed for it, I

modeled the questionnaire data using SEM, taking the necessary steps to ensure the scales have the desired factor structure and reliability. Three out of four studies were preregistered and I was transparent about the *a priori* hypotheses and planned vs. exploratory analysis. All materials, data, and scripts used, created, or collected as part of this thesis are available online.

Another strength of this thesis is that I focus on the receiver of body odors, rather than the person who emits them. In chemosignalling literature, responses to body odors are usually studied in terms of the characteristics of the body odor producer (donor). The interest lies mainly if what information about the donor can be extracted from the smell, with regard to the person's age, reproductive status, emotional state, healthiness, etc. (Pause, 2017). In my thesis, I shift the focus from the donor to the receiver and ask what the reaction to odors says about them, rather than about the person who emits the odor. This adds a social context to body odor perception.

This thesis is not free from limitations and shortcomings. I would like to start by talking about the ever-present (in psychological research) elephant in the room: causality. Although the theory outlined by me assumes a causal, directional relationship between individual differences in disease avoidance (as illustrated by body odor disgust sensitivity) and prejudice, the studies in the thesis do not allow for causal conclusions. Unfortunately, as I am interested in what is a trait, rather than a temporary state characteristic of an individual, it is not easy to have a pure experiment allowing for causal inferences. I hope this can be tackled in future research (for example in twin studies). For now, I have to really on the logic behind the theory. Throughout the thesis, I have tried to refrain from saying that odor disgust *shapes* attitudes, even though that is what the theory assumes. Although I can make no claims on the causal relationship between BODS and prejudice, I can address the aspect of the *directionality* of any possible causal effect underlying the relationship. It seems unlikely that attitudes towards outgroups could affect how we react to odors, especially if the source of the odors is one's own body.

Another limitation of the thesis is that although talking about *body odor* disgust, I have not used actual body odors in my studies. However, one of the reasons for creating the BODS scale is the be able to tap into odor disgust without having to use real body odors, which are difficult to collect and manage, and chemically very complex and variable (Havlíček et al., 2017). Valeric acid, used in Study I and IV, is in fact present in body odor, especially in disease (Pandey & Kim, 2011; Shirasu & Touhara, 2011). It has been widely used as a sweat-like odor in other studies (e.g. Anderson et al., 2003; Jacob et al., 2003). Interestingly, a recent study showed that isovaleric acid (very similar to valeric acid) was perceived as unpleasant by adults in both Western, Non-western and even hunter gathers communities in various climates and locations on the globe (Arshamian et al., 2022).

Methodological and theoretical considerations

In the following pages, I present in more detail a couple of theoretical and methodological considerations I find important for the research in the field.

A person-oriented versus the variable-oriented approach

This thesis, like all prejudice literature I am familiar with, suffers from one drawback: I look at correlations and relationships, focusing on variables, not *people* and what they are characterized by. Maybe there is a better approach to tackle the subject? Instead of looking at how BODS relates to prejudice, we should maybe find prejudiced individuals, and see whether they are indeed highly sensitive to body odors. This approach to psychology has been suggested already a long time ago (Bergman & Trost, 2006) yet has not been widely applied, at least not in the field of prejudice and bias. Such studies are potentially harder to conduct – researchers need to find participants with certain features (e.g., high bias) rather than gathering *N* of individuals and see how the distribution of their individual scores on one feature relate to the other feature.

Future studies should try to follow this approach: find people that are prejudiced and see if they are mostly high in BODS. How would the hypothesis that BODS is related to prejudice fair in that light? Although not able to provide a clear answer without a new study, I can share a bit of insight using data collected during my PhD. As part of data collection for Study III, we also asked participants in Sweden (and Italy) about their sympathies towards existing political parties and who they would vote for if they were to vote right now. Thus, we have access to a subset of participants that showed the will to vote for a right-wing party, known for its anti-immigration policies and attitudes - the Swedish Democrats (Sverigedemokraterna). Among those who chose Swedish democrats, almost 30% scored between 4 and 5 on the BODS scale, so in the top bin of the scale. For comparison, only 12% of supporters of the left-wing party (Vänsterpartiet), and only 9% of participants who chose the Liberal party (Liberalerna) could be placed in the same bin. When looking at external BODS, which might be even more relevant here, the percentage of Swedish Democrats supporters in the 4 to 5 BODS score bin is as high as 53%. For comparison, 27% of Vänsterpartiet supporters placed in the same bin. Are these percentages enough to support the claim that prejudiced people tend to also be higher in BODS? I believe more research is needed to address such questions.

Should we talk about a *behavioral immune system*?

While doing my research, the following question kept coming back to me: do we have a behavioral immune system, as defined by the field in contrast to the

physiological immune system? One of the reactions of the immune system is what we call asset of sickness behaviors, for example, loss of appetite and lower food intake, fatigue, lethargy and decreased movements, loss of interest in the usual activity, lowered social exploration, etc. (Hart, 1988; Kent et al., 1992). Some of these sickness behaviors, as the reader might instantly realize, are in fact *behaviors*. For this reason, it might be confusing to keep referring to two separate systems, the BIS, and the 'actual' immune system. Some researchers might even argue that what is conceptualized as the *behavioral immune system* is nothing other than sickness-preventing and sickness behaviors. Interestingly, the immune system is full of individual differences, beyond those including purely physiological reactions. Recent work shows how heterogenous is the reaction to an immune threat, in terms of the presence, onset, duration, and intensity of various sickness behaviors (Lasselin, 2021). An important future line of research should focus on combing the knowledge about individual differences in the physiological and psychological aspects of immune reactions, shifting away from the potentially unnatural distinction between physiological and behavioral immune systems. This is one of the reasons why I have hesitated to use the *behavioral immune system* term in this thesis, instead going for broader (in my opinion) terms such as disease avoidance or behavioral immune defenses, which also do not misleadingly suggest a separation from the biological immune system.

Relevant forms of prejudice

Although the link between disease avoidance and prejudice has been investigated in the context of attitudes towards various groups, such as ethnic (e.g., Faulkner et al., 2004) and sexual (Inbar et al., 2012) minorities, obese people (Park et al., 2007), and individuals with morphological defects (Ackerman et al., 2009), this thesis focuses solely on attitudes towards ethnic outgroups. Thus, the conclusions based on research presented here should be treated with caution when thinking of attitudes towards members of groups formed on other than ethnic bases. There are theoretical implications for believing that disease avoidance and disgust sensitivity might be related to attitudes towards other groups, yet one can imagine that it might not always have as strong relevance. For example, would disgust sensitivity be related to attitudes towards supporters of a sports team, or music band, different to that of person's favorite? More research is needed.

Ethical considerations

In my research, I use harmless, but really unpleasant odors. Although the perception of pleasantness is very individual, I guarantee that most people do

find these smells very unpleasant. For this reason, it is important to plan experiments using such stimuli really well and make sure we do not make participants go through the trouble of smelling these unpleasant odors in vain. It is also very important to be clear from the start about the quality of the odors, and if possible, allow participants to get a sample of what is to come before they fully begin the task, giving them an option to opt-out of the study if the smells are too much.

Another ethical consideration I have whenever talking to less scientific audiences is the importance of highlighting the fact that just because prejudice has evolutionary origins, and potentially biological (chemosensory) correlates, it does not mean we have no control over our attitudes, or that discrimination is justified. These are some common misconceptions that should not be propagated.

Finally, I would like to mention a fairly new aspect of research ethics – open science. Sharing scripts, materials, and data is a time investment that pays off to the research community, rather than to individual researchers but maybe we should consider it our obligation. I did my best to make my thesis science open science. Lastly, although opinions might vary about the importance of preregistrations, I found that each of them allowed me to have a more thought-through idea about what I want to investigate, and a deeper understanding of what statistical tools should be best fitted for the research question in focus.

Future directions

After four years of researching body odor disgust and social attitudes, there are many new research questions that I find important, that I think should be investigated in the future. I have already outlined some of my ideas when revisiting the aims of my thesis. This section contains additional thoughts on body odor disgust-related research.

Making the best use of the BODS scale

The body odor disgust sensitivity scale is a fairly quick and informative (as I hope I showed in this thesis) tool. There are at least a few directions in which I did not have time to jump during the time of my PhD but that I think could yield interesting results. The two subscales of BODS, pertaining to reactions to internal and external sources of odors, although highly correlated seem to be potentially tapping into different aspects of odor sensitivity, disgust, and disease avoidance. As shown in Study IV, the external subscale was best at predicting perceptual ratings (pleasantness) of experimental odor stimuli. The external scale can reflect how we react to odors coming from outside, high

level of BODS making the stimuli more 'loaded' - either more pleasant or unpleasant, depending on the nature of the smell. The internal scale, however, can potentially reflect self-monitoring processes and tuning into the interoceptive cues about the state of our own body. Individuals with high internal BODS sensitivity might, in my own opinion, be the ones who turn most often to avoidance behaviors and potentially show higher levels of prejudice. It is a speculation on my part, yet it could be examined in future studies.

A very interesting line of research would be to combine what we know and hypothesize about behavioral disease avoidance with behavioral response to actual infection, and sickness behaviors. If (body odor) disgust sensitivity is really a manifestation of an individual behavioral immune defenses, it should be related to sickness behaviors. There is great, and until recently rather understudied, interindividual variability in sickness behaviors (Lasselin, 2021), and I wonder if disgust sensitivity could explain some of it. As far as I know, there is no research about disgust and sickness behaviors. One can speculate whether higher disgust sensitivity would be linked to more pronounced (a complementary relationship between behavioral and physiological immune responses) or less pronounced (a compensatory relationship) sickness behaviors. An interesting initiative has been undertaken recently to study a similar topic and showed that pathogen disgust sensitivity was negatively related to infection markers in people living in high-pathogen risk locations (Cepon-Robins et al., 2021).

Another line of research using BODS could try to reduce the scale even further – as mentioned in the manuscripts for Study I and III, some of the items tend to be very highly correlated, and possibly an even shorter scale would yield just as good approximation of individual levels of disgust sensitivity to odors. In fact, in Study I, I show results based on a shorter version of BODS, where we removed one of two pairs of items related to sweat (armpit sweat and foot sweat). In Study III, we decided to solve the correlation issue differently and retain all items. Similarly, one could choose to do an item-level analysis. It would be especially interesting from a cultural perspective to see if all the six body odors are causing similar disgust reactions or if the reactions to some of the odors are culture or location-based.

Using BODS vs. other disgust scales in a prejudice context

The BODS scale might seem like a niche tool, and in many ways, it is one. Nevertheless, I would argue that when interested in studying disease avoidance, researchers should think properly about what they want to look into, and choose the appropriate tool (which might actually turn out to be BODS). When should you choose BODS, and when not? BODS scale is a short, easily understandable tool that has shown good psychometric proprieties across several studies. This is an important aspect, not always appreciated in disease avoidance research. In this matter, BODS can already offer more than the older

disgust scales. It is fairly free from moral, social, and cultural-related judgments making it a great tool for looking at the purer, pathogen-related disgust, possibly even more so than the pathogen subscale of TDDS. Additionally, it allows for looking at disgust from two perspectives, focusing on signals from own vs another person's body. If this is of importance to your research question, BODS might be the best choice. However, if the moral or sexual disgust is relevant to the theory under investigation, BODS is not the scale you need. To conclude – we should always be aware of the proprieties of the tools we want to use.

Finding the best paradigm to look at odors and bias

In the scope of my thesis, I ventured into two other projects (not included in this thesis) that tried to find the perfect odor-bias paradigm, yet failed. One task I tried using was a modified evaluative priming paradigm with odor cues and minority vs. majority group faces as targets. The obstacle I faced was that for evaluative priming to work, participants need to a) categorize targets into valanced categories (for example pleasant or unpleasant) and b) get feedback on their answers. This is not easily done when one wants to use ingroup and outgroup pictures – we cannot ask participants to categorize the faces of people as pleasant or unpleasant and arbitrary give them feedback about which face belongs to which category. To circumvent this problem, I tried to have a different categorization task: the faces expressed either disgust or happiness, and participants needed to categorize faces as being disgusted or not. This solved the problem of providing feedback, yet it introduced another level of congruency: an odor–emotion congruency. Trials with disgusted faces paired with a disgusting odor were emotionally congruent, similar to happy faces paired with a pleasant odor. Trials with disgusting face paired with pleasant odor, and trials with happy face paired with disgusting odor were emotionally incongruent. On top of that, we had the odor-group congruency: trials consisting of an outgroup face and disgusting smell, and trials with ingroup face and pleasant smell, can be considered stereotype congruent, if there are stereotypical affective associations between odor valence and group in the minds of the participants. This congruency was hypothesized based on the disease avoidance related theories as well as our observed association between prejudice and body odor disgust sensitivity. While there was evidence of emotional congruency (between facial expression and odor), there was no evidence of congruency effects related to group. It is unclear whether the reason is that there is truly no effect, or if the emotional congruency effect overshadowed other congruency effects. Data collected for purposes of trying this paradigm has been used in Study IV (or a subset of the data pertaining to perceptual odor ratings). Nevertheless, this project, as well as Study II, allowed me to have an understanding of how to go about finding the perfect paradigm and gave me a much better idea of what this paradigm should look like.

The affective and semantic mechanisms of disease avoidance and prejudice

The course of my PhD has been affected by the outbreak of COVID-19 pandemics. For very disease-avoidance-related reasons, I was unable to realize one of my aims, which was to investigate whether the relationship between BODS and prejudice relies more on the affective, or semantic connotations between members of an outgroup and potential pathogen threat. It has been previously proposed that behavioral immune defense relies on both semantic and affective activations. For instance, there is a semantic overlap between concepts of disease and foreigners that is visible in xenophobic propaganda (Suedfeld & Schaller, 2002). Moreover, PVD is predictive of implicit cognitive associations linking foreign groups to danger, but not to unpleasant concepts in general (Faulkner et al., 2004). In fact, Faulkner and colleagues (2004) suggest that mere cue learning and perception by itself is not sufficient to cause behavioral avoidance. They suggest that humans evolved mechanisms through which perception of an illness-related cue triggers a specific *affective reaction* which in turn activates cognitive representations through which the perceptual object is linked to *semantic concepts* pertaining to disease. All this together motivates avoidant behavioral reactions.

With the help of an odor priming paradigm (into the development of which I put a lot of time and effort, as described in previous paragraphs) and electroencephalography, one could try to answer the question of whether semantic or affective components drive the congruency between the concepts of outgroups and disease (and also between the concept of ingroup and health). Neuroimaging techniques, specifically electroencephalography (EEG) and event-related potentials (ERP) come with great aid when evaluating whether priming effects rely more on a semantic or affective (evaluative) congruence (Herring, Taylor, White & Crites, 2011). While semantic priming derives from a similarity between the meaning of a prime and target, evaluative priming occurs when the prime-target associations are based on valence rather than meaning. The semantic priming effects are reflected by the so-called N400 component, a negative peak visible from 250 to 600 ms after target presentation, peaking around 400ms over centro-parietal sites (Kutas & Federmeier, 2011). Evaluative priming effects have been related to the late positive potential (LPP, also known as the P3, P300, and late positive component), an ongoing positive activity peaking approximately 600 ms after target presentation (Cacioppo et al., 2008). Thus, N400 can serve as a neural index of how strongly our semantic representations of a social group are congruent or incongruent with a pathogen cue. LPP on the other hand can reflect the affective congruency between disease-related cues and an outgroup. Effects in one (or both) ERP components would give us further insight into what drives prejudice.

Looking at the outgroup perspective

This thesis, as well as most research in the field, focuses on the perspective of the majority outgroup on the minority ingroup, the majority group often being predominantly white, Western societies. It is important to have the other side of the story as well: how are the majority groups perceived by the minority group members? Can we find similar social biases there? What are the attitudes of immigrants towards the native inhabitants of the country they migrate to? Not only is the research often lacking this perspective, but research on prejudice is also mostly focused specifically on Western societies. Moreover, both research and media perspective can often be biased when talking about prejudices: for example, incidents of xenophobia in the developed world are called "acts of xenophobia" while almost the same incidents in the developing world are called "ethnic conflicts" (Rannou, 2017). The same research concluded that while called differently, xenophobia takes a similar form, no matter where it happens and it is highly determined by the perception of threat and the anti-immigrant attitudes and the rhetoric of the elites. More studies need to be done from this complementary perspective, looking at attitudes towards outgroups in both developed and developing world. In the context of BODS, it would be valuable to look at how the relationship between BODS and prejudice looks not only in different regions, but also for different combination of ingroup and outgroup (for example having refugees perspective as the ingroup perspective).

Concluding remarks

The work presented in this thesis is a step towards learning about prejudice and all the different aspects of biology (of the living being, human or animal) and society (groups of living beings) that can potentially contribute to it. It also teaches us something about behaviors that aim to help our immune defense and health, and their potentially unexpected consequences. In four studies, I found that how easily one gets disgusted by body odors is reliably related to negative attitudes towards others, in a small, yet meaningful way. Although this relationship may be surprising at a first glance, it has a solid theoretical foundation in multidisciplinary research on disease avoidance. The fight between more complicated living forms (like us humans), and pathogens continues, and we should continue to try to understand how to use the physiological and behavioral machinery we have at our disposal efficiently, yet without unnecessarily hurting other human beings, and preventing the group conflicts that our dispositions may result in.

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